

# Chlorine and Building Materials

A Global Inventory of Production Technologies, Markets, and Pollution

*Phase 1: Africa, The Americas, and Europe*



**BY HEALTHY BUILDING NETWORK  
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*Phase 1: Africa, The Americas,  
and Europe*



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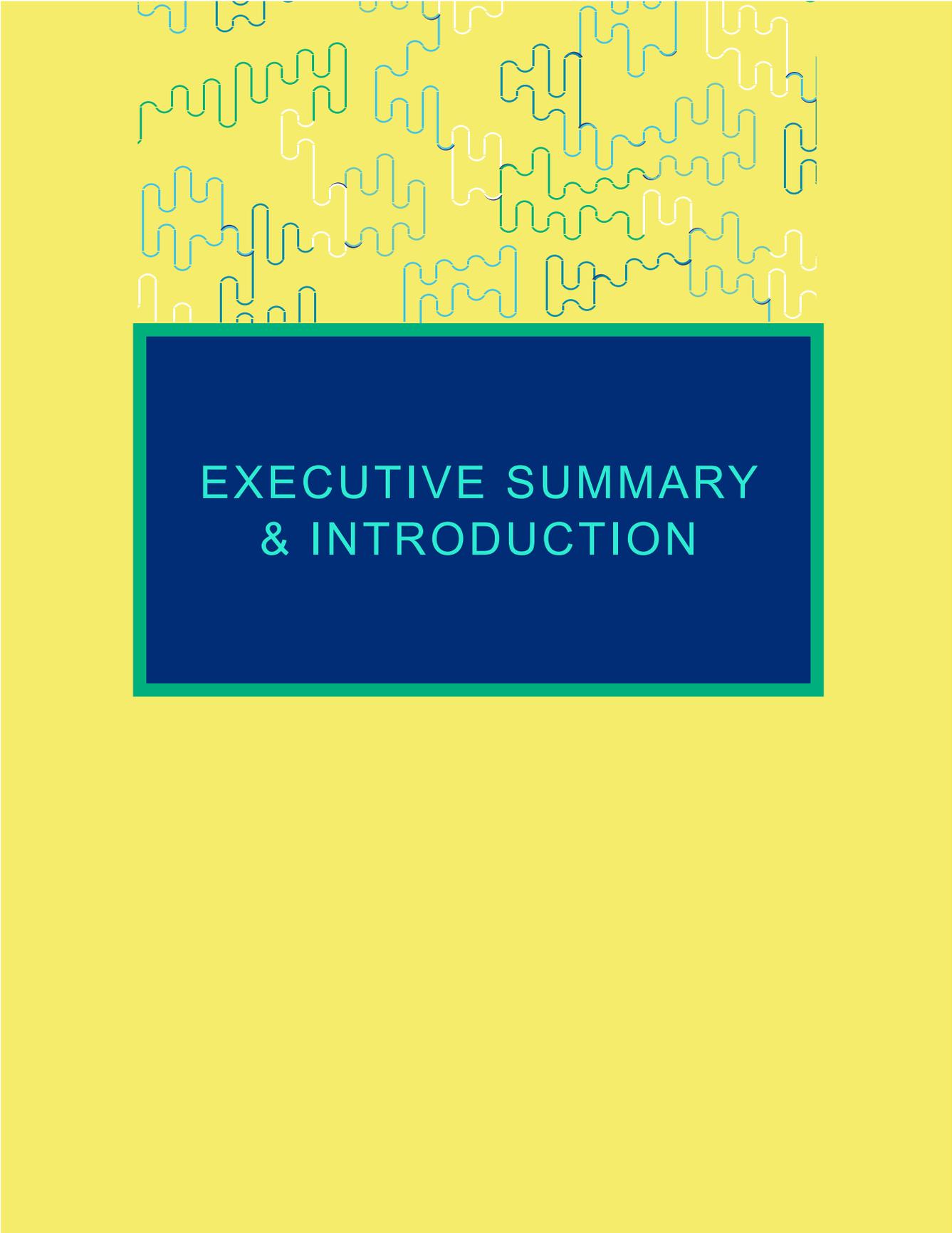
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EXECUTIVE SUMMARY  
& INTRODUCTION

## Executive Summary

There is extensive interest in the building industry in the manufacture and use of chlorine, the key ingredient in the polyvinyl chloride (PVC) supply chain. A necessary first step in reducing the environmental health impacts of chlorine in the supply chain of PVC and other chlorine-based products is to create a public global inventory of chlorine and vinyl chloride monomer (VCM) producers, and associated documented pollution. This report, Phase 1 of HBN's global inventory, covers the 86 largest chlor-alkali plants and 56 largest PVC plants in the Western Hemisphere, Africa, and Europe. It analyzes chlorine markets with an emphasis on the PVC supply chain, chlorine production technologies, and pollution associated with the production of chlorine and chlorine-based products.

### Chlorine & Chlorine-Based Products: Inherent Environmental Health Challenges

Chlorine, PVC and all chlorine-based products leave a unique chemical footprint in three fundamental ways.

1. **Chlorine is inherently highly toxic.** Chlorine-based products are made from chlorine gas (the same gas used in chemical weapons). While familiar uses of chlorine such as bleach and water purification solutions account for less than 10% of chlorine use, over 90% of chlorine is used in downstream product manufacturing.
2. **Chlorine production uses and releases mercury, asbestos, or other highly toxic pollutants.** Chlorine gas is created in an energy-intensive industrial process that splits brine (salty or brackish water from oceans or underground sources) into equal parts chlorine gas and caustic soda. Four technologies are currently used in this process. The two oldest types of technology rely upon asbestos or mercury, which are then released into the environment. Newer technologies use a teflon-like coating of per- and poly-fluoroalkyl substances (PFAS). As concern about the environmental health impacts of PFAS grows, more research is needed to understand the environmental health impacts of these plants.
3. **Combining chlorine with carbon-based materials creates environmental health impacts that are difficult if not impossible to solve.** The production of PVC and other chlorine-based products involves combining chlorine gas with carbon-based substances. This creates strong chemical bonds that resist breakdown in natural systems, causing intractable pollution problems. Many of society's most familiar chemical problems, bans, and phase-outs involve chlorine-based products. These include but are not limited to: chemicals that destroy the earth's protective ozone layer (such as CFCs); long-lived highly toxic compounds such as Agent Orange, dioxins, polychlorinated biphenyls (PCBs); and highly toxic solvents such as methylene chloride.

### Chlorine Markets: Driven by the Building Industry

Market data indicate that, as many industrial uses of chlorine decline due to environmental health concerns, market deselection, and stricter regulations, the market share of chlorine used in PVC and certain other products has increased. Today, most of the chlorine produced in the world is used to make four plastics: PVC, epoxies, polycarbonate, and polyurethane.

PVC contains nearly 60% chlorine by weight, and most PVC is manufactured for use in building products. Indeed, chlorine and building industry analysts agree that because building trends drive PVC demand, and PVC demand drives chlorine production, it can fairly be said that the building-products industry drives chlorine production levels and its attendant environmental and human health impacts.

The US is the world's leading supplier of chlorinated feedstocks for the production of PVC. An estimated 54% of US chlorine is used to make PVC worldwide. This chlorine flows through an intricate global supply chain in the form of VCM, ethylene dichloride (EDC), and PVC resins. However, the US is losing value-added PVC product manufacturing jobs, as this production has been steadily moving offshore, especially to China. Currently, more US-made chlorine is used to make finished products abroad than in the US.

## Chlorine Production Technologies

There are four industrial processes that can be used to create chlorine gas. The oldest technologies use either mercury or asbestos. The two newer technologies (introduced in the 1970s) use diaphragms or membranes coated with per- and polyfluoroalkyl substances (PFAS).

Most chlorine produced in Europe and Africa comes from PFAS-coated membrane technology. The main chlor-alkali producers in Africa do not use mercury cells or asbestos diaphragms. In Europe, exemptions to regulations that otherwise prohibit asbestos and mercury-based technologies allow the largest chlor-alkali plant to continue to use asbestos, and at least five other locations will continue using mercury into the foreseeable future.

Approximately 45% of chlorine production capacity in the Americas, including 8 of the 12 largest plants in operation, use asbestos diaphragms. Seven of these 8 are located on the US Gulf Coast. The other is in Brazil, which is phasing out asbestos mining. The US plants have relied upon Brazilian asbestos and soon will depend upon asbestos mined in Russia.

## Chlorine-Based Pollution

While all petroleum-based products are associated with industrial pollution, the introduction of chlorine and chlorine-based substances adds an additional pollution burden that is uniquely associated with chlorine.

This begins with the manufacturing of the chlorine itself. Over 400 tons of chlorine gas are released per year by chlor-alkali facilities in the US and Canada. Asbestos and mercury releases are well documented from the plants employing those antiquated technologies, which pollute the environment and poison people throughout the life cycle, from mining, to distribution, to use, and finally, to recycling or disposal operations. The more modern technologies employ machinery coated with per- and polyfluoroalkyl substances (PFAS). PFAS are highly toxic and long-lived chemicals that are coming under increasing scrutiny. The Harvard School of Public Health has issued warnings about these “forever chemicals” as used in consumer products such as Teflon, and as stain- and water-repellents on carpeting and upholstery. Because PFAS are not regulated at the point of use at chlorine manufacturing plants, there are no reported PFAS emissions or waste. However, PFAS have been detected in the effluent from the main US manufacturer of membranes used in chlorine plants.

The use of chlorine for PVC production creates additional burdens, generating organochlorine waste and byproducts. These chemicals are not broken down by natural systems, and typically last for generations in the environment. Many of them also build up in the ecosystem, including fish, wildlife, and humans, and are toxic at low doses. In addition to polluting the local environment near the facilities that release them, these chemicals can also be transported around the globe. One of them, carbon tetrachloride, is an ozone-depleting chemical and potent global-warming gas.

Additionally, PVC plastic production plays a role in the growing concern about microplastic ocean pollution through the factory discharge of PVC resins, in the form of small plastic pellets, into waterways.

## Moving Forward

While environmentalists, building owners, architects and designers, and building-product manufacturers differ in their opinions on the avoidance of PVC, there is widespread and growing support for the elimination of mercury and asbestos from the supply chain of PVC and other chlorine-based products. A public global inventory of chlorine and VCM producers, and associated documented pollution, is a necessary first step for taking action.

HBN is providing this report, and accompanying online materials, spreadsheets, and map, as full open-access content. This data can help manufacturers to avoid chemicals derived from toxic technologies, scientists to fill gaps in understanding on the material flow of pollutants like PFAS and carbon tetrachloride, and communities to connect with others who, like them, face daily pollution from the chlorine and PVC industry.

*When we know better, we can do better.*

## About HBN

Healthy Building Network (HBN) envisions a future in which all people and the planet thrive when the environment is free of hazardous chemicals. HBN's mission is to advance human and environmental health by improving hazardous chemical transparency and inspiring product innovation. As a non-profit organization, our work broadly benefits the public, especially children and the most marginalized communities, who suffer disproportionate health impacts from exposures to toxic chemicals.

Since 2000, HBN has defined the leading edge of healthy building practices that increase transparency in the building-products industry, reduce human exposures to hazardous chemicals, and create market incentives for healthier innovations in manufacturing. We are a team of researchers, engineers, scientists, building experts, and educators, and pursue our mission on three fronts:

- 1) Research and Policy — uncovering cutting-edge information about healthier products and health impacts,
- 2) Data Tools — producing innovative software platforms that ensure product transparency and that catalog chemical hazards, and
- 3) Education and Capacity Building — fostering others' capabilities to make informed decisions.

We work to reduce toxic-chemical use, minimize hazards, and eliminate exposure, especially to those chemicals of concern deemed unnecessary or which fail to improve product performance. We promote the development of affordable green chemistry solutions that support a healthy, successful, circular economy.

## About HBN Subscription Research

Healthy Building Network prides itself on independent and unbiased research. Our partners and stakeholders rank our independence and impartiality as a key value proposition in their decision to work with us. Our analysis of chemical hazards, industry trends, supply chains, and market structures, and the health, social, and environmental impacts of product manufacture is widely respected for its depth and rigor.

HBN has launched a "crowd-funded" research model to allow several interested parties to jointly participate in funding support for select research projects. HBN develops the goals, carries out the research, and publishes the results. Subscribers receive research updates and have pre-publication access to research findings.

*Eligibility:* There are no restrictions on the types of organizations eligible to apply for the subscription research services. HBN reserves the right to accept or decline subscribers on a case-by-case basis. Subscription rates and limits, if any, are determined project by project, at the sole discretion of HBN.

*Transparency:* The names of all subscribers will be listed in research products to which their subscription fees contributed.

## Introduction

This report is the first of its kind: a globe-trotting, plant-by-plant accounting of the production, use, and releases of chlorine, a key feedstock for a wide range of chemicals and consumer products.

Most chlorine plants have been in operation for several decades; a few even date to the 1890s. While their production of chlorine has been a constant, how that chlorine is made, who owns the plant, and how that chlorine is being used, changes constantly.

Many chlorinated products have vanished from commerce. Many organochlorine pesticides, leaded gasoline additives, chlorofluorocarbons -- products that fueled the proliferation of chlorine production after the Second World War -- have been banished from the marketplace.

Demand from manufacturers of building and construction products now drives the production of chlorine. Chlorine is the key ingredient of polyvinyl chloride (PVC) used in pipes, siding, flooring, roofing membranes, and more. It is also an essential feedstock for epoxies used in adhesives and flooring topcoats, and for polyurethane used in insulation and flooring. The production of these three plastics -- PVC, epoxies, and polyurethane -- consumes most of the world's chlorine.

This Healthy Building Network report establishes basic facts concerning chlorine production: Who is producing chlorine? Where? How much? And with which technologies? What plans exist to stop using mercury or asbestos to make chlorine? What products use the chlorine made in each plant? What harm has been caused by each chemical plant's operation?

Plant by plant, this report examines the technologies, capacities, histories, and futures of chlor-alkali production in the Americas, Africa, and Europe. It includes details about the largest 86 chlor-alkali and 56 PVC plants. (The second phase of this project will inventory the industry in Asia.)

The Findings section synthesizes key data from the Inventory into actionable information. This report also includes a Glossary of Notes that explains key phrases and concepts. In addition to this report's long-form Inventory, and detailed Appendices, essential data is also available in companion online resources, including the HBN Chlor-Alkali Inventory Maps and the HBN Chlor-Alkali Inventory Spreadsheets. The maps and spreadsheets are available in the Reports section of the Healthy Building Network website ([www.healthybuilding.net](http://www.healthybuilding.net)).

*Chlorine and Building Materials: A Global Inventory of Production Technologies, Markets, and Pollution* is a prerequisite to understanding the origins and life-cycle impacts of high-volume building materials such as polyvinyl chloride, polyurethane, and epoxies.

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## Methodology

This report uses many hundreds of sources spanning over a century to establish facts and draw conclusions; for each, we provide full citations including links where available. Sources include annual corporate reports, technical literature, trade databases, industry news and press releases, reports, directories, news articles, and government and chemical industry archives.

While we rely upon the latest primary information for the vast majority of data, some data are our own *estimates* based on these sources and other data points, such as proximity of plant locations and chemical conversion factors. For some countries and companies, contemporaneous public plant-capacity information is limited outside of expensive commercial databases. Historical data are used for baseline information about plant technologies and capacities when recent sources are unavailable.

Information is derived from resources on hand or available online during the time this report was researched (August 2017 to May 2018).

Where the term “tons” appears, it refers to metric tons, into which most reported weights have been converted for consistency. See Glossary of Notes for further details.

There are smaller chlor-alkali plants in operation than those detailed in this report. Also, many plants have closed, especially in recent years. Companion online spreadsheets to this report include lists of these smaller or shuttered chlor-alkali plants.

This report is a first attempt at establishing a baseline understanding of the global chlorine industry. *Chlorine and Building Materials: A Global Inventory of Production Technologies, Markets, and Pollution* is not an insider’s view of the industry, but rather an outsider’s accounting of the industry as revealed by its own data. Healthy Building Network welcomes updates or clarifying information from readers.

Please send feedback by e-mail to [research@healthybuilding.net](mailto:research@healthybuilding.net).



THE FINDINGS

## Findings

This report is Phase 1 of a global inventory of chemical plants that produce chlorine. It is intended to establish a full and open-access accounting of the technologies used to make chlorine and of the pollution caused by the production of chlorine and of major products derived from chlorine. Phase 1 provides these details for the 86 largest chlor-alkali plants in North and South America, Africa, and Europe. Phase 2 of this project - Asia - will complete the global inventory.

Key findings are summarized below, then discussed in further detail by section (chlorine markets, production technologies, and pollutants). Additional data, including references and raw data, are found elsewhere in this report, and in companion online spreadsheets and maps.

## Key Findings

### CHLORINE MARKETS

- **The majority of US chlorine production feeds PVC production, the bulk of which is used in building products.**
  - The US is the world's leading supplier of chlorinated feedstocks for the production of polyvinyl chloride (PVC) plastics. **An estimated 54% of the chlorine produced in the US is used to make PVC resins domestically and abroad.**
  - The most significant current consumers of chlorine are building- and construction-product manufacturers, which consume 70% of PVC resins in the US and Canada, with additional chlorine going to polyurethane- and epoxy-building product production.
- **More chlorine made in the US is used in finished PVC products manufactured overseas than in PVC products made in the US.**
  - Overseas consumers, especially manufacturers of PVC products used in building and construction, have replaced lost US domestic demand. **The chlorine contained in exported PVC resins, and in its essential feedstocks - ethylene dichloride (EDC) and vinyl chloride monomer (VCM) - often returns to the US in finished products.**
  - **HBN estimates that 32% of US-made chlorine goes into PVC manufacturing overseas, which is a greater share than what is consumed in domestic finished goods (20%). Of this 32%, 12% of US-made chlorine is exported in the form of EDC, 6% as VCM, and 14% as PVC resin.** We estimate that another 2% of chlorine is treated or released as pollution from chlorine, EDC, VCM, and PVC plants in the US.
  - **US-made PVC feedstocks return to the US in the form of finished building materials.** At an almost synchronous rate with shipments of PVC resin *from the US* to China, PVC flooring and wall covering shipments *from China* to the US reached record levels in 2017. Most vinyl flooring sold in the US is now made in China.
- **The geography and ownership of chlorine production is becoming concentrated.**
  - The **US Gulf Coast is one of the world's lowest-cost regions** for chlor-alkali production of chlorine and its derivatives. Other export-oriented producers are scattered across the planet, from Vancouver to Peru to Egypt; but no place approaches the global scale of production found in the Gulf Coast. The US exports 27% of the world's globally traded VCM, EDC, and PVC resins, according to HBN's analysis of trade data. From 2013 to 2016, the US exported on average 5.1 million tons of these chemicals and resins. This is more than the combined total of the next three largest exporters: Germany (1.8 million tons); Taiwan (1.4 million tons), and Japan (1.3 million tons).
  - Chlorine-plant ownership changes frequently. Mergers, acquisitions, and closures lead to consolidation. **Three companies** (Olin, Occidental Petroleum, and Westlake Chemical) **own an estimated 70% of chlorine-production capacity in the Americas.**

- We estimate that corporations headquartered in other countries -- Formosa (Taiwan), Shin-Etsu (Japan), Mexichem (Mexico), and Saint-Gobain (France) -- own an estimated 58% of the PVC-production capacity in the US. **Formosa and Shin-Etsu own 4 of the 7 largest PVC plants in the United States.** Formosa ships Gulf Coast chlorine products to its plants in Asia for further processing. Mexichem ships US-made VCM to its PVC factories in Mexico and Colombia, which are two of the 10 largest in the Americas (North and South America). St. Gobain's Certaineed subsidiary operates a relatively small plant in Lake Charles, Louisiana.
- Asian and North American companies have also been gaining PVC -production shares in Europe and Africa. Mexichem, Shin-Etsu, Wanhua (China) and Westlake (USA), combined, own over one-third of PVC capacity in Europe.

## PRODUCTION TECHNOLOGIES

Chlorine is produced in an energy-intensive industrial process known as the chlor-alkali process. The chlor-alkali process starts with brine, which is water with a high concentration of salt (sodium chloride), typically seawater or brackish water from underground sources. A powerful electrolytic reaction splits the sodium chloride in the brine into chlorine gas and sodium, and then reacts the sodium with water to form sodium hydroxide (the "alkali" part of the term, "chlor-alkali"). Sodium hydroxide is also commonly known as caustic soda. The end result is that brine is converted into caustic soda and chlorine gas at a 1.1 to 1 ratio. Four kinds of technologies are used to produce these two commodities.

In the mercury cell process, a shallow film of liquid mercury forms the negative cathode. As the mercury flows from one side of the cell to the other, sodium amalgamates (combines) with the mercury. Chlorine gathers at the cell's positive anode (where the electrical current enters the chamber). The sodium amalgam flows in to another cell, where it reacts with water and creates caustic soda and hydrogen gas.

The other three technologies are variations of barriers that divide the electrolytic cell into two compartments. Chlorine gas remains on one side of the barrier, while allowing sodium ions to pass through to the other side. There are two categories of barriers: membranes and diaphragms. Membranes are coated with per- and polyfluoroalkyl substances (PFAS). Diaphragms are coated with asbestos or PFAS, or sometimes a blend of both. PFAS-coated diaphragms are called synthetic diaphragms. For further background on these techniques, see Glossary of Notes.

Thirty-two of the 86 chlor-alkali plants listed in this report, as of May 2018, still use mercury cells and/or asbestos diaphragms: 16 plants use asbestos diaphragms, 14 use mercury cells, and 2 use both mercury and asbestos.

### In the Americas (North and South America):

- **Mercury cell and asbestos diaphragm technologies are still in widespread use in the Americas.**
  - Fifteen plants still use asbestos diaphragms, which, we estimate, provide **41% of chlor-alkali capacity** (6.8 million out of 16.6 million tons). **These include 8 of the 12 largest plants in operation.**
  - **Another 8 plants (4% of capacity) use mercury cells.**
  - Membrane (48%) and synthetic, non-asbestos, diaphragms (7%) account for the balance of production in the Americas.
  - Olin and Occidental, the two largest chlorine producers in the Americas, mostly use asbestos diaphragms. An estimated 75% of Occidental's chlorine is produced via asbestos diaphragm cell. **Combined, Olin and Occidental own an estimated 83% of asbestos diaphragm chlorine capacity in North and South America.**
  - Seventeen chlor-alkali plants in the Americas use exclusively membrane or synthetic (non-asbestos) diaphragm technology to produce chlorine. Their combined capacity is an estimated 6.6 million metric tons of chlorine, or about 40% of the hemisphere's total capacity.

- Eight plants in North and South America, with an estimated one-third of production capacity, use a mixture of old technology (asbestos diaphragm or mercury cell) and newer (membrane or synthetic diaphragm).

### In the US:

- **Asbestos diaphragm technology is used in 11 chlor-alkali plants in the US (including 7 of the 12 largest plants), and accounts for 45% of the country's chlorine-production capacity.**
- **Asbestos diaphragm technology plants supply 7 of 16 US PVC resin plants (including 3 of the 5 largest plants).**
- As of May 2018, there have been no announced plans to close any of the surviving asbestos diaphragm plants in the US.
- **Continued use of asbestos in the US is likely to become dependent on a mine in Russia.** In recent years, US chlor-alkali plants have depended upon asbestos imports from Brazil. Asbestos mining ceased in the US in 2002 and Canada in 2011. **US chlor-alkali plants** run by Olin, Occidental, and Westlake **consumed all of the asbestos imported into the country in 2017.** They imported an average of 480 tons of asbestos from Brazil each year between 2014 and 2017. These shipments came from Eternit, which announced in December 2017 that it was halting mining asbestos mining due to a Supreme Court ruling in favor of a national asbestos ban. After some legal maneuvering, Eternit restarted export-oriented mining in 2018. When Brazil forces an end to asbestos mining, Russia will be the last supplier left. Ural-asbest of Russia sent at least three shipments of asbestos to Louisiana since 2014, including one in April 2018.
- As of May 2018, Westlake Chemical has not announced any plan to close its mercury cell plant in Proctor, West Virginia. (The other surviving mercury cell plant in the US, Ashta Chemical in Ohio, plans to convert to membrane technology by 2019.)

### In Europe:

- The use of asbestos diaphragms is less common in Europe than in the Americas. In Western Europe, there is just **one plant that uses asbestos**, but it is **the largest chlor-alkali plant in all of Europe: Dow's complex in Stade, Germany.** This plant can produce up to 1,030,000 tons of chlorine per year via asbestos diaphragm. Dow stockpiled enough asbestos to supply operations through 2025. Since 2006, the European Commission has exempted the plant from a ban. The only other chlorine producers in Europe that use asbestos are two small plants in Russia.
- In the European Union, a mandatory phase-out prodded most mercury cell plants to convert to membrane technology or close entirely. However, two German chlor-alkali plants (**BASF in Ludwigshafen and Evonik in Lülldorf**) **will continue using mercury indefinitely** under an exemption. BASF has the second highest production capacity by mercury cell (170,000 tons) in Europe. The 182,000-ton-chlorine-capacity HaloPolymer plant in Kirovo-Chepetsk, Russia, is the largest mercury cell plant in Europe. Mercury cell production is also ongoing in Hungary, in two plants in Belgium, and in two other plants in Russia.
- As of May 2018, no plans have been announced to close the remaining mercury cell plants in Germany or Russia.

### In Africa:

- **No major chlorine producers in Africa use mercury cell or asbestos diaphragm technology.**

## POLLUTION

HBN examined national pollutant-registries data in Canada and the US and other available data from Europe for chlor-alkali plants detailed in this Inventory, as well as for VCM, EDC, and PVC plants that are associated with them. We gathered available data on releases of three materials used in chlor-alkali production operations (asbestos, mercury, and PFAS). We also reviewed data for releases of chlorinated substances which have significant health or environmental impacts, including carbon tetrachloride, chlorine, chloroform, dioxins, ethylene dichloride (EDC, also called 1,2-dichloroethane), hexachlorobutadiene (HCBd), hydrochloric acid, polychlorinated biphenyls (PCBs), and vinyl chloride monomer (VCM).

### Findings by type of pollution include:

- **Asbestos: Chlor-alkali cells using asbestos diaphragms release asbestos into the air and landfills.**
  - In pollution reports filed from 2012 to 2016, three plants in Louisiana and one in Texas reported releasing asbestos out of stacks into the air.
  - Current asbestos demand suggests that the industry generates about 300 tons of asbestos waste per year in the US.
  - In a plant in Poland, concentrations of asbestos in the workspace air routinely exceeded up to 30 times the occupational exposure limits.
  - Asbestos that is not released during production is usually landfilled at the end of service life, which can last anywhere from 6 months to 10 years.
- **Mercury: Mercury cell plants in Ohio and West Virginia release mercury into air, water, and landfills.**
  - Since 1987, these two plants have released over 23.8 metric tons of mercury into the air. The Westlake Chemicals plant in West Virginia released mercury into the air at a rate of 0.74 grams-per-ton capacity from 2012-2016.
  - The Sodium chlor-alkali plant in West Virginia has released at least 715 kilograms (kg) into the Ohio River since 1987. The Ashtabula plant has released over 26 kg of mercury into water.
  - Most mercury waste is landfilled, mostly in the small rural town of Emelle, Alabama.
- **PFAS: Releases of per- and polyfluoroalkyl substances (PFAS), the primary alternatives to mercury and asbestos cells in chlor-alkali plants worldwide, are unregulated and undocumented.** These substances belong to a class of chemicals called “forever chemicals,” which are toxic at low doses and persist in the environment. They are a subject of widening concern to public-health and environmental officials.
  - PFAS chemicals are not regulated at the chlorine manufacturing plant. There is no public record of testing by the US EPA or state environmental agencies for PFAS compounds in the wastewater from chlor-alkali plants that use membrane or synthetic diaphragm technology. To the extent that PFAS compounds are released over time for any reason, they are unregulated and not tested for in air or water discharges.
  - In late 2017, the EPA detected two PFAS compounds in the Cape Fear River in North Carolina, and traced them to the production of Nafion membranes by Chemours in Fayetteville, North Carolina. Nafion membrane cells are the industry standard replacement for asbestos and mercury cells. The North Carolina Department of Environmental Quality said it “demanded that Chemours stop the release of Nafion byproducts,” and added, “little information is known about the potential health effects... of the Nafion byproducts.”
  - European researchers documented PFAS depletion from use in membrane technology between 4 and 6.7 grams per ton of chlorine capacity.

- Applying these rates to combined annual chlor-alkali production capacities reveals a substantial potential mass of membrane resins: between 30.7 and 51.5 tons for Europe, 2.4 to 4.1 tons for Africa, and 31.9 to 53.4 tons for the Americas.
- **Chlorinated pollution:** Releases of chlorine and chlorinated compounds (including carbon tetrachloride, dioxin, EDC, hydrochloric acid, and VCM) vary significantly among facilities. However, we also found distinct trends within release data.
  - Release rates of chlorinated pollutants, overall, do not appear to correlate with any particular technology used to produce the chlorine in these plants.
  - **Most chlorinated pollution is associated with the production of EDC, VCM, and PVC resins, not chlorine alone.**
  - The highest rates in the US come from plants that produce VCM. Most of the highest emission plants are owned by Westlake. The Calvert City, Kentucky, plant owned by Westlake reported the highest rates of EDC and VCM releases. The Formosa plant in Point Comfort, Texas, released carbon tetrachloride and chloroform at rates (per chlorine throughput capacity) higher than any other place in the US.
  - Plants that produce mainly chlorine generally release less chlorinated pollution, although there are exceptions such as Westlake's Natrium chlorine plant, which led the industry in hydrochloric acid releases.
  - In the European Union, toxic release data reporting is incomplete. Data for chlorinated pollutants is most robust for two chemicals, EDC and VCM. EDC releases correlate with EDC production. VCM releases correlate strongly with VCM and PVC production.
  - In other places covered by this report -- Ukraine, Russia, Africa, and Latin America -- there is no routine public reporting of estimated releases of organochlorine pollutants.
- **Chlorine: Chlor-alkali plants routinely release chlorine gas into the air.**
  - Our analysis of US and Canadian pollution reports found a median rate of 2.3 kg of chlorine released as waste gas per 1,000 tons of chlorine throughout.
  - Several plants released chlorine at much higher rates. The Westlake plant in Calvert City, Kentucky, and the Occidental Chemical plant in Wichita, Kansas, released chlorine into the air at rates over 150 kg per 1,000 tons of chlorine throughput capacity between 2012 and 2016.
  - As a whole, the industry reported releasing over 661 tons of chlorine into the air per year in the US and Canada.
  - European data on chlorine releases is incomplete.

### Organochlorine pollutants include:

- **Carbon Tetrachloride: Chlor-alkali plants release significant amounts of carbon tetrachloride, a toxicant, global-warming gas and destroyer of Earth's ozone layer.** It is a largely unintentional by-product of chlor-alkali production.
  - Five of the 10 leading point sources of carbon tetrachloride pollution in the US were chemical complexes with chlor-alkali plants.
  - Some plants' releases of carbon tetrachloride are increasing because they are using it as a feedstock for a new generation of blowing agents.
  - Releases of carbon tetrachloride worldwide are much higher than industry experts predicted in the 1990s, when a global treaty regulating ozone depleting substances exempted the use of this chemical as a feedstock.
  - Scientists are finding that much more carbon tetrachloride may go unreported, and that releases from chlor-alkali plants may be extending the damage to our stratosphere.

- No European chlorine plant has reported carbon tetrachloride releases; however, scientists predict that these plants may be releasing as much as 0.4 kg of this chemical per ton of chlorine produced.
- Using this rate of 0.4 kg-per-ton of chlorine produced, plants in Europe (11,069,000 tons of estimated chlorine capacity), the Americas (16,634,000 tons), and Africa (728,000 tons) have the capacity to release over 11,000 tons of carbon tetrachloride.
- **Dioxins and PCBs: The highest releases of dioxins and polychlorinated biphenyls (PCBs) came from plants that produce EDC and/or VCM.** Reported rates of release for these highly potent chlorinated pollutants vary greatly between plants.
  - The 4 highest release rates were reported from facilities that produce VCM. Chemical plants that include VCM units account for over 90% of the chlorine industry's dioxin releases.
  - The 5 plants that reported PCB releases produce VCM; 97% of the industry's releases came from Olin in Freeport, Texas, and Occidental in La Porte, Texas.
  - European data on dioxin and PCB releases is minimal.
- **Vinyl Chloride Monomer (VCM):** Vinyl chloride monomer (VCM), a carcinogen and gene mutagen, is released primarily during the production of PVC resins. The Australian and European PVC industries have established voluntary standards for residual VCM in PVC resins and VCM release rates from production. The Vinyl Institute trade association in the US has not implemented similar quality controls for production.
  - **Several plants in the US release VCM at rates well over voluntary industry standards established in Europe and Australia.**
  - Nine PVC plants in the US reported releasing more than 30 grams of VCM per ton of PVC (the Australian industry association's limit for suspension PVC resins).
  - Four PVC plants in the US reported releasing over 100 grams of VCM per ton of PVC (the European industry association's limit for suspension PVC resins).
  - Three PVC plants in the US (but none in the EU) reported releasing over 1,000 grams (1 kg) of VCM per ton of PVC (which is the European and Australian limit for emulsion PVC resins.) These were Formosa in Point Comfort, Texas, and Westlake in Calvert City, Kentucky, and in Plaquemine, Louisiana.
  - In Europe, 34 PVC, VCM, and EDC factories reported releasing VCM from 2012 to 2016.
  - Seventeen plants in Europe reported releasing more than 30 grams of VCM per ton of PVC (the Australian industry association's limit for suspension PVC resins).
  - Seven of these 17 plants reported releasing over 100 grams of VCM per ton of PVC (the European industry association's limit for suspension PVC resins). Kem One's PVC plant in Saint Auban, France, reported the highest rate: 601 grams of VCM per ton of chlorine.
  - Residual amounts of VCM are present in PVC resin. PVC drinking-water pipe, particularly imported pipe, sometimes exceeds industry standards for maximum residual VCM.
- **Some PVC manufacturing plants release dust and pellets into surrounding communities and waterways.** These PVC microplastics threaten human health and contaminate aquatic ecosystem health.

## Summary Tables

### Chlor-Alkali in the Americas: Chlorine Capacity and Production Technology, by Owner

TABLE 1 . CHLORINE PRODUCTION CAPACITY AND TECHNOLOGY IN THE AMERICAS

COMPANY	NO. OF PLANTS	CAPACITIES (1,000 TONS PER YEAR, ESTIMATED)					OVERALL CAPACITY SHARE	ASBESTOS & MERCURY SHARE OF PRODUCTION
		ASBESTOS	MERCURY	MEMBRANE	SYNTHETIC DIAPHRAGM	TOTAL		
Olin	7	3026		2521		5547	33.3%	55%
Occidental	9	2682		683	220	3585	21.6%	75%
Westlake	6	426	100	1675	377	2578	15.5%	20%
Shin-Etsu	1			1055		1055	6.3%	0%
Formosa	1			910		910	5.5%	0%
Unipar Carbocloro	3		270	255	148	673	4.0%	40%
Braskem	2		70		409	479	2.9%	15%
DowDuPont	1	415				415	2.5%	100%
Covestro	1			363		363	2.2%	0%
Mexichem	2	300				300	1.8%	100%
Chemtrade	1			231		231	1.4%	0%
Cydsa	3		98	99		197	1.2%	50%
Quimpac	2		76	58		134	0.8%	57%
Pequiven	1			120		120	0.7%	0%
Ashta	1		47			47	0.3%	100%
<b>TOTAL</b>		<b>6849</b>	<b>661</b>	<b>7970</b>	<b>1154</b>	<b>16634</b>	<b>100.0%</b>	<b>45%</b>
% of whole		41%	4%	48%	7%			
No. of Plants	41	15	8	24	5			

Healthy Building Network analysis, 2018.

Some plants employ multiple types of technology.

TABLE 2 . 15 LARGEST CHLORINE PRODUCERS, WESTERN HEMISPHERE

RANK	INVENTORY CODE	COMPANY - LOCATION	CHLORINE CAPACITY (*)	TECHNOLOGIES	CHLORINE MARKETS
1	AMUSA16	Olin - Freeport, Texas	3,030,000	Asbestos Diaphragm+ Membrane	Captive epoxies; VCM sales to PVC producers.
2	AMUSA22	Westlake - Lake Charles, Louisiana	1,270,000	Membrane+Synthetic Diaphragm	VCM sales to PVC producers.
3	AMUSA19	Shintech - Plaquemine, Louisiana	1,055,000	Membrane	Captive PVC.
4	AMUSA18	Olin - Plaquemine, Louisiana	971,000	Asbestos Diaphragm	Isocyanates, epoxies, chlorinated organics.
5	AMUSA03	Formosa Plastics - Point Comfort, Texas	910,000	Membrane	Captive PVC Resins exported worldwide.
6	AMUSA14	Olin - McIntosh, Alabama	685,000	Asbestos Diaphragm+ Membrane	Offsite PVC.
7	AMUSA10	Occidental - Taft (Hahnville), Louisiana	655,000	Asbestos Diaphragm+ Membrane	Offsite PVC.
8	AMUSA07	Occidental - Ingleside, Texas	570,000	Asbestos Diaphragm	VCM to Mexichem plants in US, Mexico and Colombia.
9	AMUSA06	Occidental - La Porte, Texas	525,000	Asbestos Diaphragm	VCM to nearby PVC plant.
10	AMUSA08	Occidental - Geismar, Louisiana	438,000	Membrane+Synthetic Diaphragm	PVC, Blowing Agents, Isocyanates.
11	AMUSA20	Westlake - Plaquemine, Louisiana	426,000	Asbestos Diaphragm	Captive PVC.
12	AMBRA05	Dow - Aratu, Brazil	415,000	Asbestos Diaphragm	Propylene dichloride exported for use in Dow isocyanates plant in Freeport, Texas.
13	AMBRA01	Braskem - Maceió, Brazil	409,000	Synthetic Diaphragm	Captive PVC.
14	AMUSA02	Covestro - Baytown, Texas	363,000	Membrane	Captive isocyanates.
15	AMBRA03	Unipar Carbocloro - Cubatão, Brazil	355,000	Mercury+Synthetic Diaphragm+Membrane	Nearby PVC plant.

(\*) Estimated metric tons per year.

TABLE 3 . CHLORINE PRODUCTION CAPACITY AND TECHNOLOGY IN AFRICA

COMPANY	CAPACITIES (1,000 TONS PER YEAR, ESTIMATED)					OVERALL CAPACITY SHARE	ASBESTOS & MERCURY SHARE OF PRODUCTION
	ASBESTOS	MERCURY	MEMBRANE	SYNTHETIC DIAPHRAGM	TOTAL		
Sanmar Holdings			250		250	34%	0%
Sasol			20	112	132	18%	0%
Egyptian Petrochemicals			109		109	15%	0%
SynChem			101		101	14%	0%
Misr Chemical			68		68	9%	0%
Ynna Holding			68		68	9%	0%
<b>TOTAL</b>	<b>0</b>	<b>0</b>	<b>616</b>	<b>112</b>	<b>728</b>		<b>0%</b>
% of whole	0%	0%	85%	15%			
No. of Plants	0	0	6	1			

Healthy Building Network analysis, 2018.

Some plants employ multiple types of technology.

TABLE 4 . CHLORINE PRODUCERS, AFRICA

RANK	INVENTORY CODE	COMPANY - LOCATION	CHLORINE CAPACITY (*)	TECHNOLOGIES	CHLORINE MARKETS
1	AFEGY03	TCI Sanmar - Port Said, Egypt	250,000	Membrane	PVC production on-site and in Tamil Nadu, India.
2	AFSAF02	Sasol - Midland, South Africa	112,000	Synthetic Diaphragm +Membrane	On-site PVC, global market.
3	AFEGY02	Egyptian Petrochemicals Company - Alexandria, Egypt	109,000	Membrane	On-site PVC.
4	AFSAF01	SynChem (NCP Chlorchem) - Chloorkop, South Africa	101,000	Membrane	Drinking water purification; Mining; Pulp and Paper; Chemicals.
5 (tie)	AFEGY01	Misr Chemical Industries - Alexandria, Egypt	68,000	Membrane	Drinking water purification.
5 (tie)	AFMOR01	Ynna Holding (SNEP) - Mohammedia, Morocco	68,000	Membrane	PVC production on-site.

(\*) Estimated metric tons per year.

TABLE 5 . CHLORINE PRODUCTION CAPACITY AND TECHNOLOGY IN EUROPE

COMPANY	NO. OF PLANTS	CAPACITIES (1,000 TONS PER YEAR, ESTIMATED)					OVERALL CAPACITY SHARE	ASBESTOS & MERCURY SHARE OF PRODUCTION
		ASBESTOS	MERCURY	MEMBRANE	SYNTHETIC DIAPHRAGM	TOTAL		
DowDuPont	2	1030		800		1830	17.2%	56%
Ineos	7		110	1194	110	1414	13.3%	8%
Covestro	4			1360		1360	12.8%	0%
AkzoNobel	4			1008		1008	9.5%	0%
International Chemical Investors Group	2		90	705		795	7.5%	11%
Kem One	2			325	378	703	6.6%	0%
Westlake	2			430		430	4.0%	0%
BASF	1		170	215		385	3.6%	44%
Wanhua Industrial Group	1		131	192		323	3.0%	41%
Mexichem	1			265		265	2.5%	0%
Nikochem	1	95	125			220	2.1%	100%
JSC Bashkirskaya Khimiya	1	84	134			218	2.0%	100%
PKN Orlen	1			214		214	2.0%	0%
Sibur and Solvay (RusVinyl JV)	1			205		205	1.9%	0%
JSC HaloPolymer	1		182			182	1.7%	100%
Xedrian Holding	1			180		180	1.7%	0%
PTT Global Chemical and Perstorp Group (Vencorex JV)	1				171	171	1.6%	0%
PCC Rokita	1			150		150	1.4%	0%
Evonik	1		137			137	1.3%	100%
Renova Group	1			135		135	1.3%	0%
Ercros Industria	1			120		120	1.1%	0%
Oltchim S.A.	1			105		105	1.0%	0%
EuroChem Group	1			91		91	0.9%	0%
<b>TOTAL</b>		<b>1209</b>	<b>1079</b>	<b>7694</b>	<b>659</b>	<b>10641</b>		<b>22%</b>
% of whole		11%	10%	72%	6%			
No. of Plants	39	3	8	34	4			

Healthy Building Network analysis, as of May 2018.  
Some plants employ multiple types of technology.

TABLE 6 . 15 LARGEST CHLORINE PRODUCERS IN EUROPE

RANK	INVENTORY CODE	COMPANY LOCATION	CHLORINE CAPACITY (*)	TECHNOLOGIES	CHLORINE MARKETS
1	EURDE09	Dow - Stade	1,585,000	Asbestos Diaphragm+ Membrane	Captive EDC, polycarbonates, chlorinated polyethylene, epoxies, other chlorinated organics.
2	EURNE01	AkzoNobel - Botlek	637,000	Membrane	Co-located with Shin-Etsu VCM plant which supports PVC production in Pernis, Netherlands, and Estarreja, Spain. Also supplies chlorine to other chemical plants (isocyanates, epoxies, chlorinated pesticides) in the Pernis-Botlek-Europoort chemical complex, one of the largest in the world.
3	EURDE05	Covestro - Dormagen	480,000	Membrane	Captive isocyanates.
4	EURBE02	Inovyn - Lillo and Zandvliet (Antwerp)	458,000	Mercury+Membrane(**)	EDC, likely polyurethane, epoxy, and polycarbonate.
5	EURUK01	Ineos/Vynova - Runcorn	430,000	Membrane	Supplies EDC to Vynova's VCM and PVC (370,000- tons) plant in Wilhelmshaven, Germany.
6	EURDE06	Covestro - Leverkusen	390,000	Membrane	Captive isocyanates; chemical plants in shared complex.
7	EURDE03	BASF - Ludwigshafen	385,000	Mercury+Membrane	Captive alcoholates and isocyanates.
8	EURBE03	Vynova - Tessenderlo	365,000	Mercury+Membrane (**)	Supplies VCM to Vynova PVC plants in Mazingarbe, France, and Beek Geleen, Netherlands. Also linked to other chemical plants in complex.
9	EURFR03	Kem One - Lavéra	363,000	Synthetic Diaphragm+ Membrane	Supplies VCM to nearby Kem One Balan (Ain) PVC plant.
10	EURFR01	Inovyn - Tavaux	360,000	Membrane	Captive PVC. Also is merchant seller of EDC and VCM.
11	EURFR02	Kem One - Fos-sur-Mer	340,000	Synthetic Diaphragm+ Membrane	Supplies VCM to Kem One PVC plants in Bouches-du-Rhone and Saint-Fons. Some chlorine sold as disinfectant.
12	EURHU01	BorsodChem	323,000	Mercury+Membrane	Captive PVC and isocyanates.
13 (tie)	EURDE07	Covestro - Uerdingen	280,000	Membrane	Captive isocyanates and polycarbonate.
13 (tie)	EURNO01	Inovyn - Rafnes	280,000	Membrane	Supplies VCM to Invoyn (Ineos) PVC plant in Herøya (Porsgrunn).
15	EURDE12	Vestolit - Marl	265,000	Membrane	Captive PVC.

(\*) Estimated metric tons per year.

(\*\*) Mercury phase-out planned in 2018.

## FINDINGS: CHLORINE MARKETS

“As restrictions on the use of chlorine run their course in pulp bleaching and chlorofluorocarbons, the growth trend in polyvinyl chloride (PVC) and its intermediates, ethylene dichloride (EDC) and vinyl chloride monomer (VCM), will dictate the fortunes of chlorine.”

- Report of the Electrolytic Industries for the Year 1995.<sup>1</sup>

Chlorine production in North America and Europe is in long-term decline.

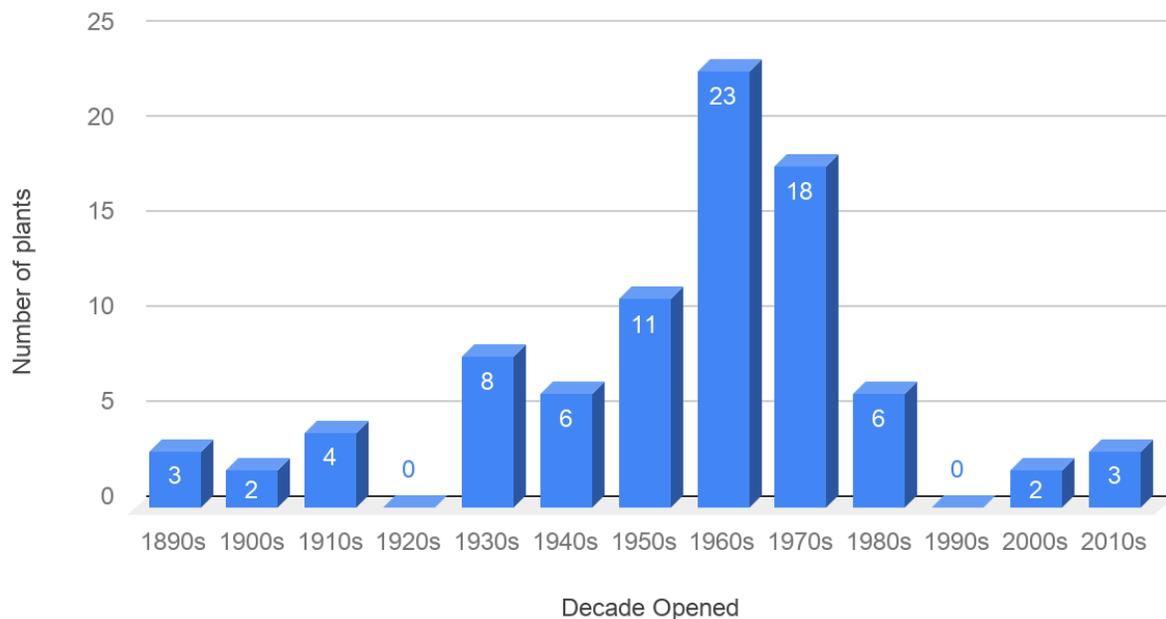
In the US, production peaked in the year 2000 (at over 12.7 million metric tons, according to the Chlorine Institute).<sup>2</sup> In 2016, the industry produced 11.1 million tons of chlorine, a decline of 12.5% from 2000.

In Europe, peak production reached 10.7 million tons. In 2016, according to Euro Chlor, Europe produced 9.5 million tons of chlorine, down 11.6% from 2007.<sup>3</sup> Production was expected to drop by another 1.5 million tons by 2018, as many mercury cell plants closed rather than convert to different technology.<sup>4</sup>

Stasis and decline in the chlorine industry are reflected in the median year that the complexes in this report began operations: 1963. Only 5 out of the 86 production sites in this report opened within the last three decades, the same number as were built before 1910. Seventy-five of the 86 plants were opened before 1980, when membrane and synthetic diaphragm technology began to replace mercury and asbestos diaphragms.

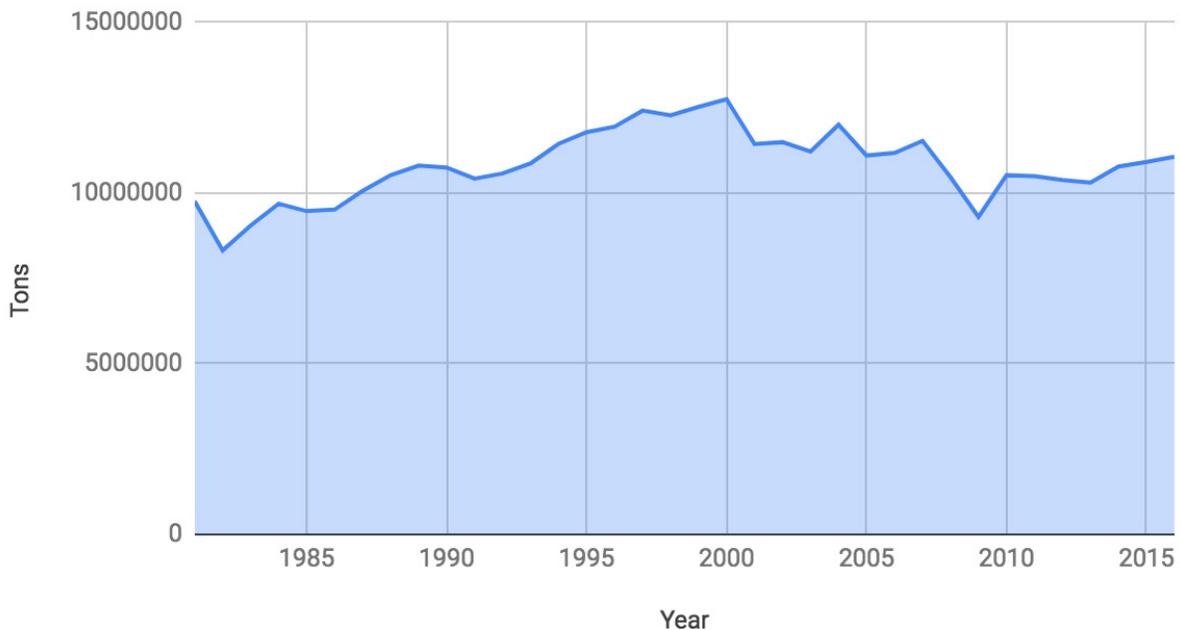
In the last 35 years (since 1983), only one new chlor-alkali plant in Europe exceeds a 100,000-ton capacity: RusVinyl, a joint venture of Solvay and Solvin, which Russian president Vladimir Putin inaugurated in 2014.

### Chlorine Plants Operating in Africa, The Americas & Europe



HBN graphic, based on chlorine plants listed in this report.

## US Chlorine Production



HBN Graph based on Chlorine Institute *Pamphlet 10*

Many chlor-alkali plants have closed in recent years. Many used mercury cells. Others produced chlorine in service of products that were disfavored or outlawed. Declining production coincided with a succession of regulations and marketplace deselections of products that are high consumers of chlorine. The chemical industry no longer makes chemicals like ethyl chloride (an anti-knock additive used in leaded gasoline), chlorofluorocarbons (refrigerants and blowing agents that destroy Earth's protective stratospheric ozone layer), and most chlorinated pesticides. Many chlorinated flame retardants and solvents have been banned or deselected in the marketplace.

The paper industry is another rapidly fading customer. In 1994, the pulp and paper industry consumed an estimated 9% (about 1 million out of 11.4 million tons) of chlorine produced in the US. "Concerns over chlorine's potential to form toxic chlorinated organics has had a negative effect on the use of chlorine in this industry," noted an EPA study in 2000. "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."<sup>5</sup> By 2010, the pulp and paper industry consumed just 1% (about 110,000 out of the roughly 11 million tons) of chlorine made in North America.<sup>6</sup>

"Environmental regulations affecting chlorine end-use markets have reduced the demand for chlorine and help explain the exit of selected chlorine plants," explained the 2010 EPA study. The pulp and paper industry has shifted from using chlorine to bleach pulp, and the Montreal Protocol phased out CFCs and other chemicals that attack Earth's protective ozone layer. "Chlorine plants that were co-located with pulp and paper mills and plants affected by the Montreal Protocol were more likely to shutdown (11 to 15% higher than the average chlorine plant)."<sup>7</sup>

As noted by the IHS Markit in 2015,<sup>8</sup> "The chlorine industry, including the production, sale and consumption of derivatives such as hydrochloric acid and anhydrous hydrogen chloride, has been under pressure as a result of evidence that several chlorine-containing products are harmful to the environment, to workers and to the general public."

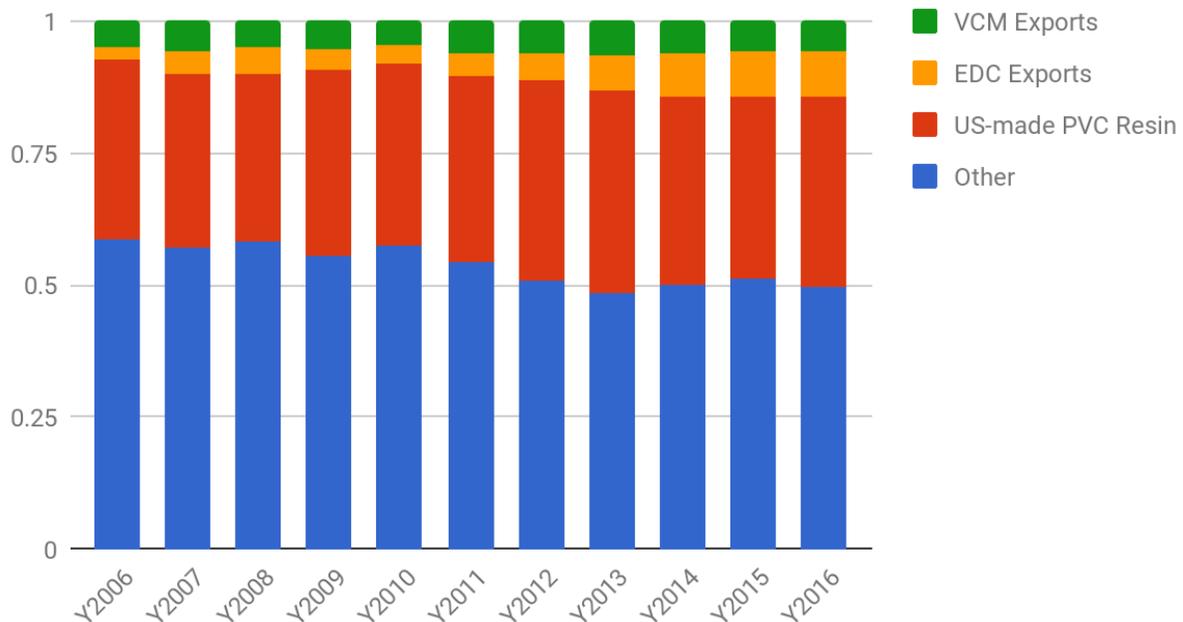
As other industries stop using chlorine, the shares of chlorine used to produce plastics -- mainly PVC, polyurethane, polycarbonate, and epoxy -- have risen.

## Chlorine and PVC

Chlorine is used in the manufacturing of PVC and its feedstocks ethylene dichloride (EDC) and vinyl chloride monomer (VCM). The reaction of ethylene with chlorine creates ethylene dichloride (EDC). Cracking units turn EDC into vinyl chloride monomer (VCM). Vinyl chloride monomer, when polymerized, forms PVC.

PVC resin production and feedstock exports consume about half of the chlorine made in the US.

### US-Made Chlorine Destinations



HBN Stacked Bar Chart based on Chlorine Institute *Pamphlet 10*, American Chemistry Council Resin Review, International Trade Commission DataWeb (HTS numbers 390410, 390421 and 390422)

### PVC resin production in the Americas

Between 2012 and 2016, US chemical plants produced on average around 10.7 million metric tons of chlorine annually, according to the Chlorine Institute.<sup>9</sup> HBN estimates that over 54% of this chlorine is consumed or released in the production of PVC resins and in PVC's feedstocks. An increasing share of feedstocks and PVC resins is shipped overseas. Plants in the Gulf Coast are the world's leading sources of EDC, VCM, and PVC resins.

Three companies, Olin, Occidental, and Westlake Chemicals, control roughly 70% of all chlorine production capacity in the Americas.

Much of the capacity of Occidental and Westlake is oriented towards making PVC, usually in the same location.<sup>10</sup> Combined, the two companies hold 50% of the PVC production capacity in the US and Canada.

Olin, we estimate, holds a third of the region's chlorine capacity, more than any other company in the Americas. It does not make PVC; however, it produces chlorine, EDC, and VCM used by other companies to produce PVC resins and isocyanates. Olin also uses chlorine for on-site epoxy adhesive production.

Shin-Etsu (through its US subsidiary Shintech) consumes a considerable proportion of Olin's chlorine to make PVC. The Shintech PVC factory in Freeport, Texas, is next to a chlor-alkali plant owned by Olin. The Olin plant has the capacity to produce over 3 million tons of chlorine per year, more than the combined capacity of the next two largest plants, combined. Shintech in Freeport can produce up to 1.45 million metric tons of PVC per year, far more than the second largest plant in the hemisphere.

Overseas demand for EDC, VCM, and PVC resins is sustaining US chlorine production. Formosa exports PVC resins from the Gulf Coast to customers around the world. Olin says it is the planet's leading EDC supplier for PVC production.<sup>11</sup> A substantial proportion of these PVC feedstocks return to the US in the form of building materials and other consumer products.

A review of the chlor-alkali industry in 1995 foretold the increasing flow of US-made chlorine into the global PVC supply chain. According to the "Report of the Electrolytic Industries for the Year 1995":

The shift in demand patterns is influencing decisions about where to locate chlorine production. Since EDC and VCM are relatively easily moved, logistics become an expense rather than a barrier, leaving the cost of production as the criterion.... Larger plants, fewer producers, fewer production sites, and a greater percentage of production on the Gulf Coast will be the trends in the chlor-alkali industry. Chlor-alkali production units in the Pacific Northwest and the Southeast have been closing as the pulp and paper markets are decreasing. Gulf Coast production capacity will grow because of attractive power rates, abundant salt reserves, and the ease with which EDC and VCM can be exported to growing Asian markets.<sup>12</sup>

Producers today consider the Gulf Coast to be the least expensive place in the world to manufacture chlorine, and products derived from it, including EDC, VCM, isocyanates, and epoxies. Raw materials for these products (brine, fossil fuels, water) abound. According to our findings, plants on the US Gulf Coast today account for nearly three-quarters of the chlorine produced in all of North and South America.

Fracking and the resultant flood of inexpensive natural gas into the Gulf region have accelerated those predicted trends. Ethylene accounts for over half the cost of PVC manufacturing. Cheap natural gas has led global PVC producers to invest billions of dollars in ethane crackers in Louisiana and Texas.

Industry analysts describe PVC feedstock exports from the Gulf as "a channel of moving cheap energy in the form of chlorine and ethylene."<sup>13</sup>

Most PVC products exported from Latin America contain chlorine that originated in the US Gulf Coast. Mexichem has a joint venture with Occidental in Ingleside, Texas, to produce VCM for export to its Cartagena, Colombia, and Altamira, Mexico, facilities. The Altamira and Cartagena PVC plants rank among the nine largest in the Americas. Mexico and Columbia rank 12th and 14th in PVC net exports, globally.<sup>14</sup>

Producers of PVC finished goods in Asia consume substantial proportions of EDC and PVC resins made in the US. China and South Korea are the top two destinations for EDC made in the US. China is also the leading destination of US-produced PVC resins.

Most PVC resins are used in building and construction products, such as pipes, siding, windows, roofing, and flooring. According to American Chemistry Council data, between 2012 and 2016, building and construction products contained 70% of the PVC resins consumed in the US and Canada.<sup>15</sup>

**"Construction activity dominates chlorine demand," industry analysts from IHS-Markit stated in December 2017.** This demand includes PVC used in infrastructure and residential applications, and isocyanates used in polyurethane building products and furnishings.<sup>16</sup>

Exported PVC feedstocks may return to the US in the form of finished PVC goods, including building materials. Most PVC interior finishes now sold in the US are made overseas, mainly in China. For example: The US flooring industry consumed 248 million pounds of PVC resins in 2003, according to the ACC. This dropped to 62 million pounds by 2007, and only slightly recovered, to 71 million pounds, by 2016.<sup>17</sup> In 2017, about 85% of all PVC floor, wall, and ceiling coverings entering the US came from China. Net US imports of these products from China rose from 11 million square meters in 1996 to 231 million square meters in 2017. Cumulatively, from 1996 to 2017, the US imported 15.2 billion square feet of PVC floor, wall, and ceiling coverings from China.<sup>18</sup> This is enough material to wrap a 115-foot-wide vinyl floor across Earth's equator, or lay a 0.2-mile-wide strip from San Diego to Boston.

Smaller export-oriented, merchant chlor-alkali plants operate elsewhere in the Americas. From North Vancouver to Peru, these operations export liquid chlorine gas and caustic soda, by rail, river barge, and ocean freighter, to

disparate consumers around the Americas and beyond. Merchant-plant chlorine is available on the spot market, and may become feedstock for PVC, isocyanate, or epoxy when established chlorine suppliers go off-line due to maintenance, accidents, or hurricanes.

These and other market relationships are detailed in this report's Inventory and accompanying online spreadsheet.

### PVC resin production in Africa

Four of the six largest chlor-alkali plants in Africa produce PVC resins or feedstocks; two (Sasol in Midland, South Africa, and Egyptian Petrochemical in Alexandria, Egypt) are vertically integrated facilities, meaning they produce everything from chlorine to PVC resin. Manufacturers in Africa (including pipe, cabling, profile, and shoe companies) consume most of these products.

Overall, African plants have the capacity to produce an estimated 645,000 tons of PVC.

Some of the industry in Africa is export-oriented. Sasol sells PVC resins worldwide. Egypt ranked as the world's twenty-fifth leading source of PVC resins from 2013-2016. The Indian company, Sanmar Holdings, owns a 250,000-ton-per-year chlorine plant in Port Said, Egypt, which produces VCM and ships it to Sanmar's PVC plant across the Indian Ocean, to Tamil Nadu, India.

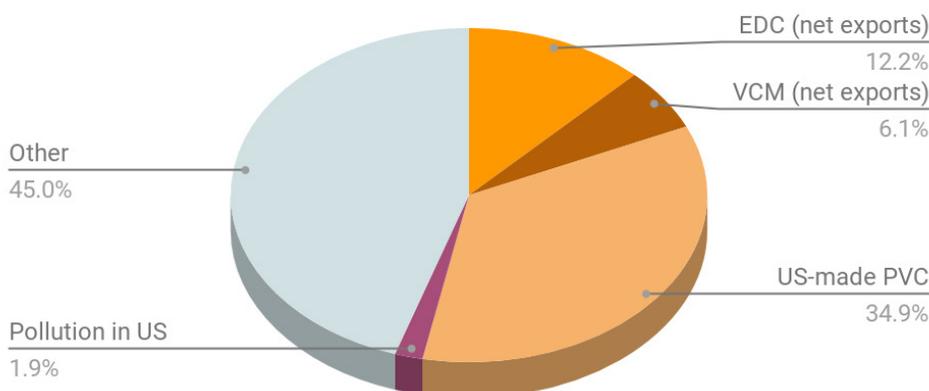
### PVC resin production in Europe

PVC production and consumption is declining in Europe. Other chemistries -- especially isocyanates and epoxies -- consume a higher share of chlorine in Europe than in the US.

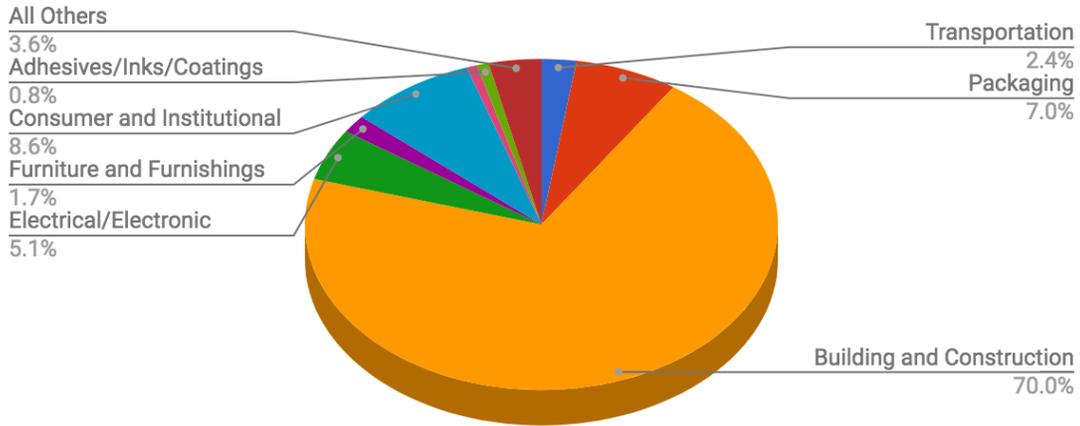
In 2012, according to industry estimates, PVC applications used one third (33.3%) of the chlorine in Europe,<sup>19</sup> compared to more than half of the chlorine made in the US. "PVC and isocyanates are the main drivers of chlor-alkali production," the European Commission found in 2014. "The production of chlorine and caustic is completely interrelated with the downstream businesses, including the PVC industry and intermediates used to manufacture PVC."

Chlorine and PVC producers in Europe have also faced increasing imports of PVC resins and of PVC's feedstocks from the US Gulf Coast and other low-cost areas. Exports from North America to Europe increased 39% in 2016.<sup>20</sup> "Climbing energy costs, limits on what technology can be used to produce the polymer, and slowing demand are all set to take place against the backdrop of increasing imports from nations that have far cheaper feedstock and energy costs," reported Platts in a 2015 report on the consolidation and contraction of the European PVC industry.<sup>21</sup> "The chlor-alkali industry still has many headwinds to meet, not least the challenge of finding new energy solutions that will allow European manufacturing (to) compete globally in the years ahead," reads an April 2018 article by the Euro Chlor trade association.<sup>22</sup>

### Fate of US-Made Chlorine, 2012-2016

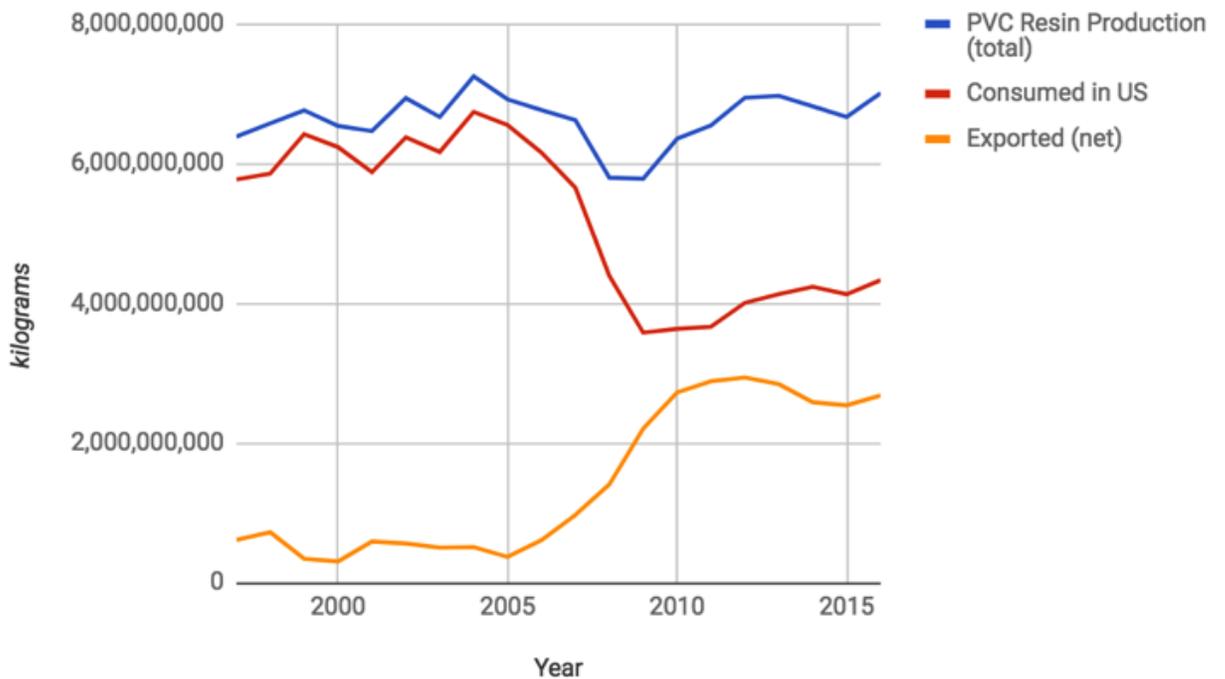


### PVC Uses, US/Canada, 2012-2016

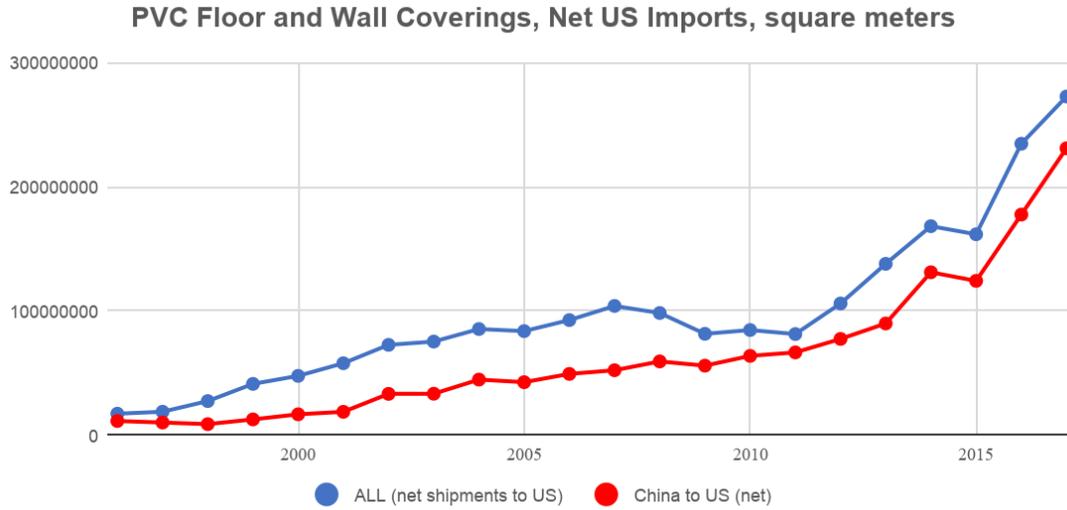


Graphic by Healthy Building Network, 2018.

### US PVC Resin Production and Fate



HBN Graph based on Chlorine Institute *Pamphlet 10*, American Chemistry Council Resin Review, International Trade Commission DataWeb. Total US PVC resin production equals the sum of PVC resin exports (net) and domestic PVC resin consumption.



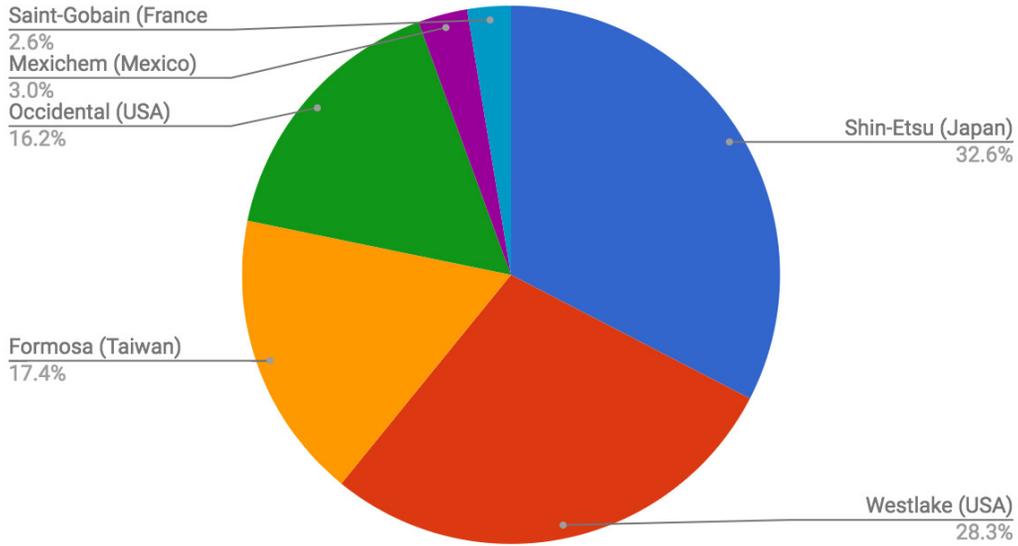
HBN Graph based on International Trade Commission DataWeb.

TABLE 7 . TOP TEN DESTINATIONS: PVC SUPPLY CHAIN EXPORTS FROM US

RANK	COUNTRY	CHLORINE	ETHYLENE DICHLORIDE	VINYL CHLORIDE MONOMER	PVC RESINS	TOTAL (KILOGRAMS)
1	Mexico	-1,495,638	974,234	489,084,065	322,718,521	811,281,182
2	China	-90,845	397,670,837	-718,363	334,399,799	731,261,428
3	Colombia	2,533	299	324,720,755	27,742,187	352,465,773
4	Canada	-239,012,851	665,657	212,116,633	287,000,604	260,770,044
5	Korea	-19,721,933	205,855,501	7,547	35,830,518	221,971,634
6	Japan	148,329	168,547,345	14,486,888	-2,189,184	180,993,378
7	India	4,309	102,006,584	7,195,185	39,518,564	148,724,642
8	Australia	5,730	2,368	97,531,064	1,731,465	99,270,626
9	Taiwan	30,909	91,369,429	0	3,266,379	94,666,718
10	Thailand	0	25,962,682	1,524	8,428,199	34,392,406

Kilograms per year net average of imports, 2012-2016. Negative figures indicate the US imported more of this item than it exported.  
 Data Source: US International Trade Commission Dataweb (HTS Codes 280110, 290315, 290321, 390410, 394021 and 390422).

### PVC Resin Production in the United States, Shares by Owner



### PVC Producers - North and South America (annual capacity)

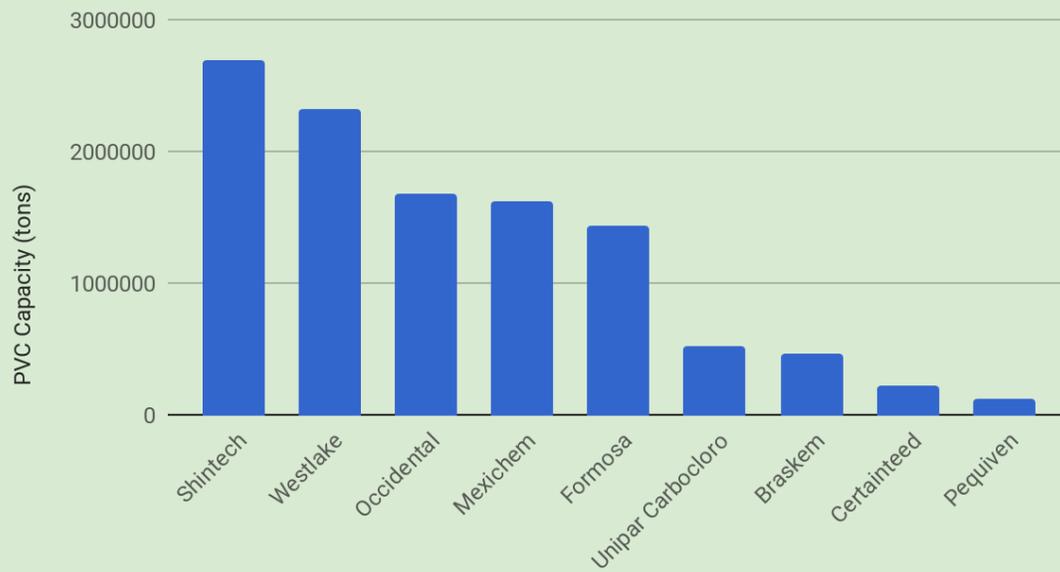


TABLE 8 . PVC RESIN PLANTS IN NORTH AND SOUTH AMERICA

RANK	OWNER	LOCATION	COUNTRY	PVC CAPACITY (1,000 MT, ESTIMATED)	CHLORINE SOURCE TECHNOLOGIES (a)	CHLORINE SOURCE (INVENTORY CODE)
1	Shin-Etsu	Freeport, Texas	USA	1450	Membrane	from AMUSA16
2	Occidental	Pasadena, Texas	USA	898	Asbestos+ Membrane	from AMUSA06 and AMUSA14
3	Mexichem	Altamira, Tamaulipas	Mexico	876	Asbestos	from AMUSA07 and AMMEX01
4	Westlake	Plaquemine, Louisiana	USA	861	Asbestos	AMUSA20 (on-site)
5	Formosa	Point Comfort, Texas	USA	816	Membrane	AMUSA03 (on-site)
6	Westlake	Calvert City, Kentucky	USA	680	Membrane+ Asbestos	AMUSA23 (on-site) + AMUSA09
7	Shin-Etsu	Plaquemine, Louisiana	USA	635	Membrane	AMUSA19 (on-site)
8	Shin-Etsu	Addis, Louisiana	USA	600	Membrane	from AMUSA19
9	Mexichem	Cartagena, Bolivar Region	Colombia	500	Asbestos	from AMUSA07 and AMMEX01
10	Formosa	Baton Rouge, Louisiana	USA	470	Membrane	from AMUSA03
11	Braskem	Maceió, Alagoas	Brazil	460	Synthetic Diaphragm	AMBRA01 (on-site)
12	Westlake	Aberdeen, Mississippi	USA	455	Membrane+ Synthetic Diaphragm	from AMUSA22
13	Occidental	Niagara Falls, Ontario	Canada	341	Asbestos	from AMUSA04
14	Westlake	Geismar, Louisiana	USA	331	Membrane	AMUSA21 (on-site)
15	Unipar Carbocloro	Santo André, São Paulo	Brazil	300	Membrane+ Mercury	AMBRA04 and from AMBRA03
16	Occidental	Deer Park, Texas	USA	275	Asbestos	AMUSA05 (on-site)
17	Unipar Carbocloro	Bahia Blanca, Buenos Aires Province	Argentina	220	Mercury	AMARG01 (on-site)
18	Certainteed	Lake Charles, Louisiana	USA	215	Membrane+ Synthetic Diaphragm	from AMUSA22
19	Occidental	Pedricktown, NJ	USA	160	Asbestos+ Membrane	from AMUSA14
20	Formosa	Delaware City, Delaware	USA	144	Membrane	from AMUSA03
21	Mexichem	Pedricktown, NJ	USA	123	Asbestos	from AMUSA07
22	Mexichem	Henry, Illinois	USA	122	Asbestos	from AMUSA06
23	Pequiven	Maracaibo	Venezuela	120	Membrane	AMVEN01 (on-site)
<b>TOTAL</b>				<b>11052</b>		

HBN estimates. Sources available in Inventory.

(a) - Per published reports as of May 31, 2018.

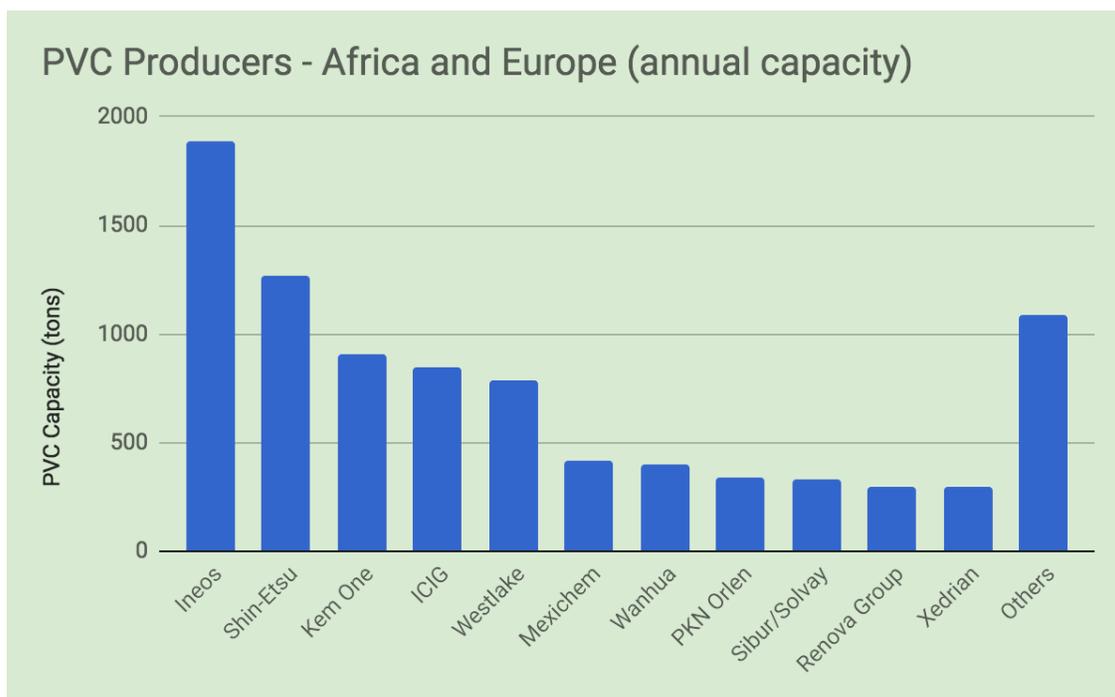


TABLE 9 . PVC RESIN PLANTS IN AFRICA AND EUROPE

RANK	OWNER	LOCATION	COUNTRY	PVC CAPACITY 1,000 MT, ESTIMATED	CHLORINE SOURCE TECHNOLOGIES (a)	CHLORINE SOURCE (INVENTORY CODE)
1	Shin-Etsu	Botlek- Rotterdam	Netherlands	620	Membrane	from EURNE01
2	Ineos	Jemeppe- sur-Sambre	Belgium	450	Membrane	EURBE01 (on-site)
3	Shin-Etsu	Pernis	Netherlands	450	Membrane	from EURNE01
4	Ineos	Newton-Aycliffe	United Kingdom	440	Membrane	from EURNO01
5	Mexichem	Marl	Germany	416	Membrane	EURDE12 (on-site)
6	Wanhua Industrial Group	Kazincbarcika	Hungary	400	Mercury+ Membrane	EURHU01 (on-site)
7	International Chemical Investors Group	Wilhelmshaven	Netherlands	370	Mercury+ Membrane (b)	from EURUK01 and EURBE03
8	PKN Orlen	Wloclawek	Poland	340	Membrane	EURPO02 (on-site)
9	Sibur and Solvay (JV)	Kstovo	Russia	330	Membrane	EURRU03 (on-site)
10	Ineos	Rheinberg	Germany	320	Synthetic diaphragm+ Membrane	EURDE11 (on-site)

Continued on next page

RANK	OWNER	LOCATION	COUNTRY	PVC CAPACITY 1,000 MT, ESTIMATED	CHLORINE SOURCE TECHNOLOGIES (a)	CHLORINE SOURCE (INVENTORY CODE)
11	Kem One	Balan	France	300	Synthetic diaphragm+ Membrane	from EURFR02 and EURFR03
12	Renova Group	Sayansk city	Russia	300	Membrane	EURRU06 (on-site)
13	Xedrian Holding	Kalush City	Ukraine	300	Membrane	EURUR01 (on-site)
14	Kem One	Berre-L'Etang	France	290	Synthetic diaphragm+ Membrane	from EURFR02
15	Ineos	Tavaux	France	260	Membrane	EURFR01 (on-site)
16	International Chemical Investors Group	Mazingarbe	France	255	Mercury+ Membrane (b)	from EURBE03
17	Sanmar Hold- ings	Port Said	Egypt	250	Membrane	AFEGY03 (on-site)
18	International Chemical Investors Group	Beek Geleen	Netherlands	225	Mercury+ Membrane (b)	from EURBE03
19	Ineos	Stenungsund	Sweden	215	Membrane	EURSV01 (on-site)
20	Westlake	Burghausen	Germany	210	Membrane	from EURDE13
21	Kem One	Saint-Fons	France	205	Synthetic diaphragm+ Membrane	from EURFR02, EURFR03 and EURFR04
22	Ineos	Porsgrunn	Norway	200	Membrane	from EURNO01
23	Shin-Etsu	Estarreja	Portugal	200	Membrane	from EURNE01 via Shin-Etsu- Rotterdam
24	JSC Bashkir- skaya Khimiya	Steritamak	Russia	160	Mercury+ Asbestos diaphragm	EURRU04 (on-site)
25	Westlake	Hürth-Knap- sack	Germany	160	Membrane	EURDE14 (on-site)
26	Westlake	Köln- Merkenich	Germany	160	Membrane	from EURDE13
27	Westlake	Gendorf	Germany	155	Membrane	EURDE13 (on-site)
28	Spolana	Neratovice	Czech Re- public	135	Membrane	from EURPO02
29	Ercros Industria	Vila-seca	Spain	120	Membrane	EURES01 (on-site)
30	Sasol	Midland	South Africa	112	Synthetic diaphragm+ Membrane	AFSAF02 (on-site)

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RANK	OWNER	LOCATION	COUNTRY	PVC CAPACITY 1,000 MT, ESTIMATED	CHLORINE SOURCE TECHNOLOGIES (a)	CHLORINE SOURCE (INVENTORY CODE)
31	Nikochem	Volgograd	Russia	110	Mercury+ Asbestos diaphragm	EURRU05 (on-site)
32	Egyptian Petrochemicals Company	Alexandria	Egypt	109	Membrane	AFEGY02 (on-site)
33	Westlake	Schkopau	Germany	100	Membrane	from EURDE08
34	Kem One	Chateau- Arnoux-Saint- Auban	France	70	Synthetic diaphragm+ Membrane	from EURFR03
35	Ynna Holding	Mohammedia	Morocco	68	Membrane	AFMOR01 (on-site)
36	Kem One	Hernani	Spain	45	Synthetic diaphragm+ Membrane	from EURFR02 and EURFR04
37	Khimprom	Volgograd	Russia	27	Mercury+ Asbestos Diaphragm	from EURRU05
<b>TOTAL</b>				<b>8877</b>		

(a) - Per published reports as of May 31, 2018.

(b) - The plant providing chlorine to this PVC manufacturer plans to convert from mercury cell to membrane technology in 2018.

## Chlorine and Other Organic Chemicals

In addition to PVC, other organic chemicals are significant consumers of chlorine. Major end products include polyurethane, polycarbonate, and epoxy.

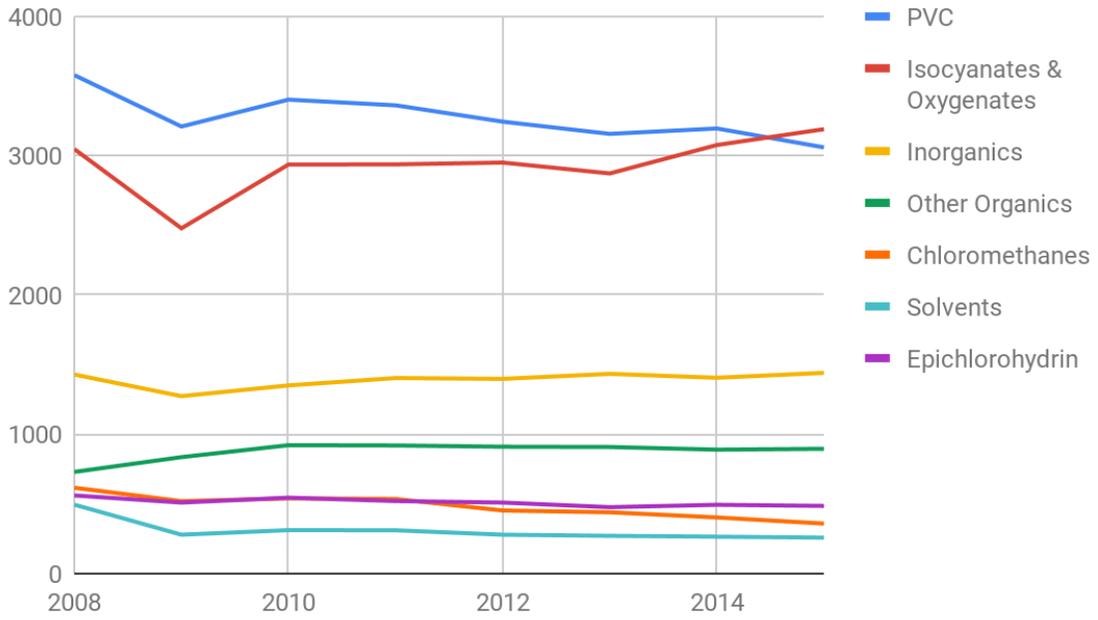
Olin, the largest producer of chlorine in the Americas, reported that the vast majority (76%) of its chlorine goes towards organic chemicals, a plurality (35%) of which went into producing polyurethane in 2016. It said 26% of its chlorine goes to PVC, 4% to epichlorohydrin (essential ingredient of epoxy), and 11% to other organic chemicals. Water treatment and inorganic chemicals accounted for just 24% of chlorine end uses.<sup>23</sup>

In 2010, an EPA report estimated that phosgene accounted for 6% of the consumption of chlorine.<sup>24</sup> Phosgene is used in the production of polyurethane and polycarbonate plastics. When chlorine reacts with carbon monoxide, phosgene is created. Phosgene, reacted with bisphenol A, forms polycarbonate plastics.<sup>25</sup> In the polyurethane chain, phosgene is reacted with amines to produce isocyanates. The reaction of isocyanates with other chemicals creates polyurethanes.

In Europe, isocyanates, oxygenates, and epichlorohydrin consume a higher proportion of chlorine than in the US. Oxygenates include phosgene and alcoholates. Alcoholates, such as sodium methylate and potassium methylate, are produced by BASF and Evonik using the mercury amalgam process in Germany, and are used in biodiesel production.

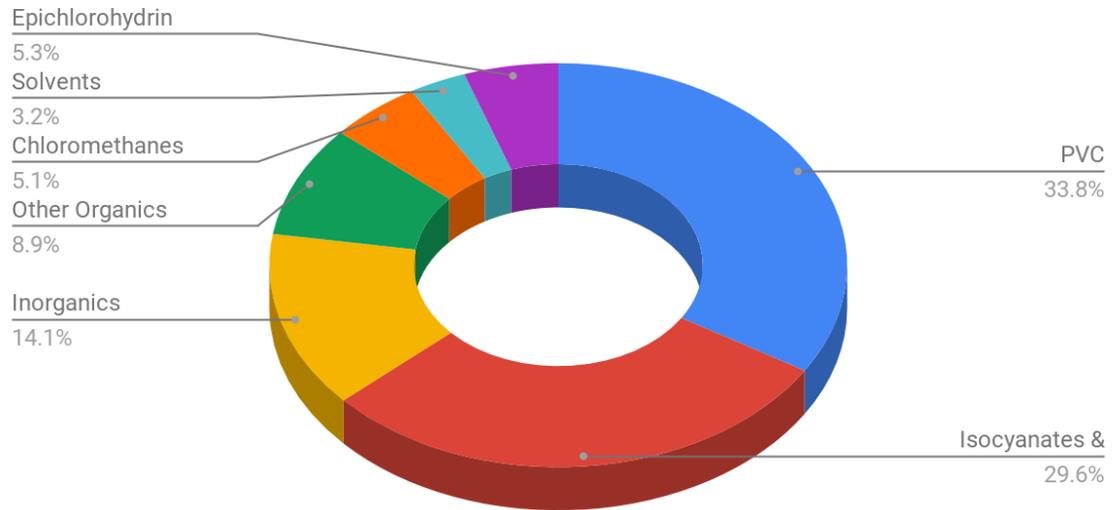
While PVC use in Europe has slowly declined, consumption of isocyanates and oxygenates has increased slightly. In 2015, Euro Chlor reported, these uses surpassed PVC consumption of chlorine for the first time. Combined, PVC, isocyanates, oxygenates, and epichlorohydrin consumed an average 68% of chlorine produced in Europe between 2008 and 2015, according to the trade association's statistics.<sup>26</sup>

### Chlorine Applications (1,000 tons), Europe



HBN graphic based on Euro Chlor Annual Reviews, 2008 to 2015.

### Shares of Europe-Made Chlorine Consumption, 2008-2015



HBN graphic based on Euro Chlor Annual Reviews, 2008 to 2015.

While commercial polyurethane, polycarbonate, and epoxy products are produced using chlorine as a feedstock, chlorine is not typically present in those final products. Polyurethane, polycarbonate, and epoxy products do not contain chlorine except when these products use additives such as chlorinated flame retardants.

In the case of polyurethane, the phosgenation process usually occurs at a remove from the production of finished goods, where isocyanates are reacted with other chemicals to produce polyurethane products such as sealants, insulation, and foam cushions. Sometimes these final chemical reactions do not occur until isocyanates are brought into buildings, when installers (professional or DIY) apply spray polyurethane-foam insulation and sealants.

In November 2017, industry experts ICIS reported that “the isocyanate industry has struggled to bring new capacity on-line quickly enough to meet the additional demand.” Most of this demand is coming from insulation sales. “With the market facing persistent supply shortages and demand growing at a faster than expected clip, isocyanate buyers had little alternative but to accept consecutive rounds of price increases, with some sellers heard to have taken a ‘take it or leave it’ attitude towards their price increase initiatives, which would normally be at least partially negotiable.”<sup>27</sup>

Epoxyes are commonly used in building and construction wet applied coatings such as paints and adhesive. Hydrochloric acid, a byproduct of chlor-alkali production, is used to make epichlorohydrin from glycerol. Epichlorohydrin is always needed for epoxy production.

Polyurethane and epoxyes are also significant consumers of caustic soda from chlor-alkali plants. These uses accounted for 17% of Olin’s caustic sales in 2016.<sup>28</sup>

Isocyanate, polycarbonate, and epoxy factories are usually located near chlor-alkali plants, as in the following cases:

- Olin’s two vertically-integrated chlorine-to-epoxy plants on the US Gulf Coast. Its plant in Freeport, Texas, uses chlorine in the on-site production of epoxyes. Olin describes this chemical complex as “the lowest cost producer of epoxyes globally.” According to a company filing in 2015, most chlorine produced at its plant in Plaquemine, Louisiana, was used in on-site epoxy and perchloroethylene production.<sup>29</sup>
- Covestro’s on-site plant in Baytown, Texas, which produces chlorine for on-site consumption in isocyanate and polycarbonate production. Covestro is the world’s leading producer of isocyanates and polycarbonates. Its Baytown plant is one of the largest producers of these chemicals.
- Olin’s Freeport, Texas, chlor-alkali plant, the hemisphere’s largest, which is co-located with Dow’s isocyanates plant.
- Occidental’s plant in Geismar, Louisiana, which is connected to BASF and Rubicon isocyanate plants along the same stretch of the Mississippi River. Westlake’s plant in Geismar, and Olin’s plant in St. Gabriel, are also part of this so-called “chlorine-isocyanate-EDC” triangle.
- Integrated chlorine-to-isocyanates plants in Brunsbüttel, Dormagen, Leverkusen, and Uredingen, Germany (owned by Covestro), Ludwigshafen, Germany (BASF), Stade, Germany (DowDuPont), Pont-de-Claix, France (Vencorex), and Kazincbarcika, Hungary (Wanhua). The Covestro plant in Brunsbüttel and Dow’s plant in Stade also produce polycarbonate plastics.
- European chemical parks anchored by chlor-alkali plants. The Pernis-Botlek-Europoort chemical complex in the Netherlands, one of the largest in the world, is supported by a 637,000-ton-capacity chlorine plant owned by AkzoNobel. Chemical plants in the complex manufacture isocyanates, polycarbonates, and VCM.

## FINDINGS: PRODUCTION TECHNOLOGIES

In the Americas, an estimated 41% of chlorine is produced using asbestos diaphragm technology and another 4% is produced using mercury cell technology. Membrane and synthetic diaphragm technology claim 48% and 7% shares for the balance. (See this report's Glossary of Notes for details of these technologies.)

Twenty-three plants use either asbestos diaphragm or mercury cells. Eight of the 12 largest plants in the Americas use asbestos diaphragm technology for some or all of their chlorine production. All but one of these plants using asbestos are located in Louisiana, Alabama, or Texas. The other is on the coast of Brazil. None of these plants' owners have announced plans to stop using asbestos.

Also in the Americas, there are at least eight mercury cell plants still in operation; six of these will be required to stop using mercury by 2025 because they are located in countries that have signed the Minamata Convention. The remaining two are located the US, which has not ratified the agreement. One of those two plans to stop using mercury by 2019; the other has not announced plans to change.

The four chlor-alkali plants in Africa with over 100,000-ton capacity do not use mercury cell or asbestos diaphragm technology.

In western Europe, one plant still uses asbestos diaphragms. DowDuPont's plant in Stade, Germany, has the capacity to produce 1,030,000 tons of chlorine per year by asbestos diaphragm technology. It is the largest chlor-alkali plant in Europe. Two smaller plants in Russia also use asbestos diaphragms.

While most mercury cell plants have closed or converted to membrane technology in Europe, at least five (three in Russia, two in Germany) will continue using mercury indefinitely. Three other plants -- two in Belgium and one in Hungary -- are converting from mercury cells to membranes but have not announced completion of those efforts as of May 2018.

Appendices A and B and companion online spreadsheets provide further details on chlor-alkali plant technologies.

### Mercury Cell Production

Mercury has been used to produce chlorine for over 120 years, but chlor-alkali production by mercury cells has dwindled in recent decades. Worldwide, no new mercury cells have been built since 1984.

Historically, Europe has been depended upon mercury for chlorine production. In 1994, mercury cells accounted for the majority (65%) of production in western Europe. In North America, the figure was 14%.<sup>30</sup> We estimate that, as of May 2018, this share was 10% in Europe and 4% in the Americas.

The decline in Europe followed a commitment, in 2001, by members of the Euro Chlor industrial association to phase out mercury cell technology by 2020.<sup>31</sup> The EU accelerated this phase-out date to December 11, 2017, under an Industrial Emissions Directive.<sup>32</sup>

Some plants are still in the process of meeting these directives and commitments. Two plants in Belgium (Ineos/Inovyn in Antwerp and Vynova in Tessenderlo) and one in Hungary (BorsodChem, owned by Wanhua Chemical of China) have been in the process of converting their mercury cells to membrane technology. However, as of May 2018, Ineos, Vynova, and Wanhua had not announced completion of these conversions.

Owners of five other plants in Europe have not said they would stop using mercury. Two are in Germany and three are in Russia.

In March 2017, the European Commission implemented the Minamata Convention, with a regulation that exempts plants that produce alcoholates.<sup>33</sup> Alcoholates are used in the production of biodiesel, as well as pigments, fragrances, and pharmaceuticals.<sup>34</sup> The only plants that use mercury cells to produce alcoholates are in Germany: BASF in Ludwigshafen and Evonik in LÜlsdorf.

In Russia, chlor-alkali producers are under no regulatory and policy commitment to phase out the use of mercury cells: the Russian government has not signed the Minamata Convention, and its producers are not members of Euro Chlor. Three plants are producing chlorine with mercury. The largest mercury cell plant in Europe is Halo-Polymer in Kirovo-Chepetsk. The other Russian mercury cell plants are BSC in Sterlitamak and Nikochem in Volgograd.

In the Americas, where at least eight chlor-alkali plants still use mercury cell technology, there has been no industry-wide commitment to phase out the use of mercury. However, most chlorine producing countries -- including Brazil, Peru, and Mexico, where mercury cells are still in use -- have signed the Minamata Convention. In 2017, this landmark agreement entered into force, meaning that enough countries have codified it into national law that it is now in effect for those countries. It bans the use of mercury in chlor-alkali production by 2025.<sup>35</sup> Unipar Carbocloro operates the two largest mercury cell plants in the Americas. The company plans to convert them both -- Bahia Blanca (Argentina) and Cubatão (Brazil) -- by 2020.

The US, however, has not ratified the Minamata Convention and in 2013, the US government informed the parties to the convention that it would exempt mercury cell chlor-alkali production from this ban (see Glossary of Notes). Two US plants still use mercury cells. One (Ashta in Ashtabula, Ohio) is currently converting to membrane cell. This project is scheduled for completion in 2019. The other -- Westlake's Natrium plant in New Martinsville, West Virginia -- has announced no such plan. Because the US government has not yet ratified the Minamata Convention (see Glossary of Notes), and there are no regulations that prevent Westlake from consuming and releasing mercury, this soon may be the last major company in North and South America to use mercury in chlor-alkali production.

Other plants operating in the Americas must stop using mercury by 2025 because the countries in which they operate have ratified the Minamata Convention. These include Braskem's Camaçari plant in Brazil, Cydsa's Iquisa plant in Coatzacoalcos, Mexico, and two Quimpac plants in Peru.

In addition to the plants discussed in this report, some smaller capacity chlor-alkali plants continue to use mercury cells to make chlorine for local markets. Contemporaneous information about these smaller plants, disconnected from global markets, is often scarce. These are listed in this project's online spreadsheets.

## Asbestos Diaphragm Production

As with mercury, asbestos diaphragm technology is over a century old. Its use is winding down, gradually, in many places. Most governments have banned all uses of asbestos, or are requiring the end of asbestos diaphragm use in chlor-alkali production no later than the year 2025. Asbestos diaphragms are most common in the US, Mexico, and Russia, where there are no regulatory or corporate initiatives to reduce the use of asbestos in chlor-alkali production, and in Germany, where the largest chlor-alkali plant on the continent operates asbestos diaphragms under an exemption to the EU ban on asbestos use.

Elsewhere, the use of asbestos is coming to a close:

- In Canada, a draft Canadian regulation would force the last plant using asbestos (Olin in Becancour, Quebec) to stop using it by 2025.
- Brazil, which enacted a national ban on asbestos mining last year, is requiring Dow to stop using asbestos diaphragms in its Aratu plant, reportedly by next year (2019). Dow is the only chlor-alkali producer still using this technology in South America. It produces at least 10% of the world's propylene dichloride in Aratu, and ships it to a plant in Freeport, Texas, where Dow produces isocyanates.
- In western Europe, where asbestos once accounted for a quarter of chlor-alkali technology, only one plant continues to use asbestos diaphragms.<sup>36</sup> (Kem One's plants in Fos-sur-Mer and Lavéra, Vencorex's plant in Le Pont de Claix, France, and Solvay's plant in Rheinburg, Germany, converted to synthetic diaphragms by 2012. In Bydgoszcz, Poland, a large asbestos diaphragm chlor-alkali plant shut down entirely in 2012.<sup>37</sup>) However, the last asbestos diaphragm plant is the largest chlor-alkali plant in all of Europe: Dow's complex in Stade, Germany.

There are no announced plans to close or convert two asbestos diaphragm production units in Russia. These two plants - Bashkirskaya Khimiya in Sterlitamak and Nikochem in Volgograd - produce chlorine using both asbestos diaphragms and mercury cells.

In the US and Mexico, there have been some reductions in asbestos diaphragm usage as the industry has contracted and consolidated. However, in recent years, no plans have been announced to convert the 13 plants that still use asbestos in those countries. The plant owners (Occidental, Olin, Westlake, and Mexichem) have no regulatory obligation to do so. The US chemical industry has not said it would stop using asbestos in chlor-alkali production. To the contrary, it is lobbying the EPA against restricting its use under the Toxic Substances Control Act.<sup>38</sup>

The chlor-alkali industry is the only remaining consumer of asbestos in the United States. “The (US) chlor-alkali industry accounted for nearly 100% of asbestos mineral consumption in 2017,” according to the US Geological Survey. “The chlor-alkali industry accounted for nearly all domestic consumption of asbestos minerals in 2017, rising from an estimated 35% in 2010.”<sup>39</sup>

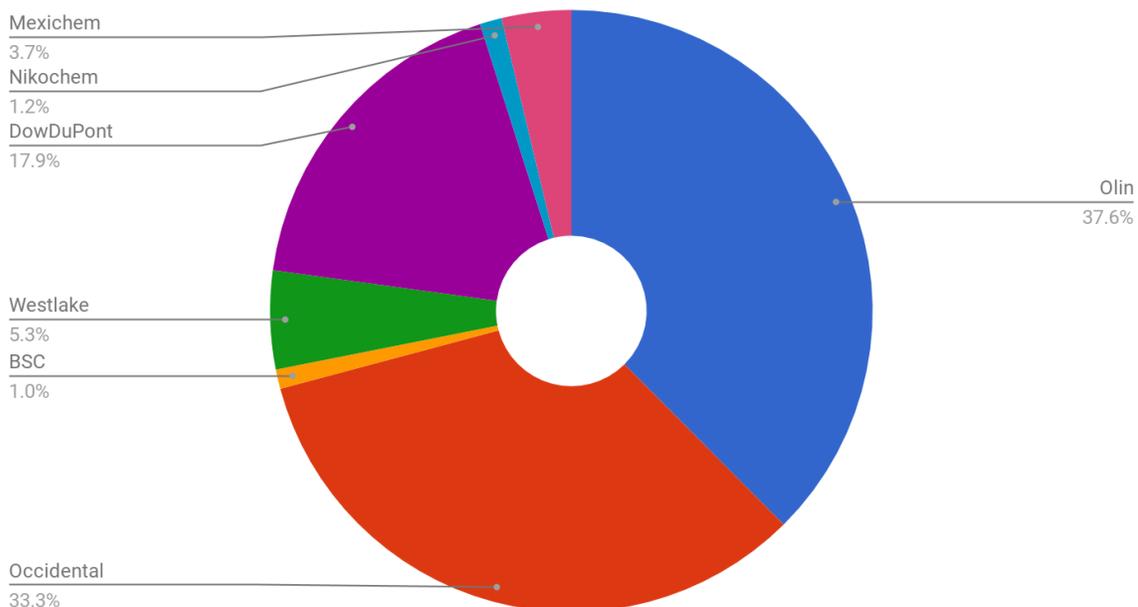
Our report finds that asbestos diaphragms account for about 40% of the overall chlorine production in the US and in the Americas as a whole.

The hemisphere’s two largest chlorine producers, Olin and Occidental, rely on asbestos diaphragms for most of their chlorine production. HBN estimates that 75% of Occidental’s and 55% of Olin’s capacity comes from asbestos diaphragms.

US chlor-alkali producers appear to be stockpiling asbestos in anticipation of Brazil’s exit from asbestos mining, and, perhaps, of US regulations through the Toxic Substances Control Act. When Brazil’s Supreme Court banned asbestos production and use in December 2017, Eternit announced it would stop mining. But in early 2018, Eternit resumed mining asbestos, almost exclusively to supply the global chlor-alkali industry.

The chlor-alkali industry also imports asbestos from Russia. Since 2014, Dow and Olin have imported over 33 tons of asbestos from Uralasbest in Russia to Louisiana, including a 7.8-ton shipment in April 2018.<sup>40</sup> Mines in Kazakhstan, China, and Zimbabwe also may be future sources of the mineral for the US industry.<sup>41</sup>

### Asbestos Diaphragm Chlorine Producers, Americas and Europe



## Synthetic Diaphragm & Membrane Cell Production

The chlor-alkali industry evolves slowly, but the introduction of membrane cell production in the 1970s transformed production in some parts of the world. The first membrane cells producing chlorine and caustic soda were introduced in Japan in 1975. The country, reacting to the tragedy of Minamata Bay, quickly converted and closed all mercury cell plants. Japan completed its conversion to ion-exchange processes by the late 1980s.<sup>42</sup>

In the Americas, the use of membrane cells grew slowly at first, and more rapidly in the past 20 years, but still lags behind Africa, Europe, and Japan. In 1986, membrane cells accounted for 3% of chlor-alkali production capacity in the US. This share rose to 16% in 1999, according to the Chlorine Institute.<sup>43</sup> In 2018, HBN estimates, nearly half of the capacity in the Americas uses membrane cells.

Most plants now in operation in the Americas started producing chlorine over 50 years ago. For the past few decades, synthetic diaphragm and membrane cells have gradually replaced asbestos diaphragm and mercury cells in some plants. HBN estimates that around 40% of the chlorine produced in the Americas originates in 18 plants that exclusively use membrane or synthetic diaphragm technology. These plants do not use asbestos or mercury.

Many are vertically integrated chemical operations in which all chlorine is consumed on-site or nearby. Yet in the Americas, HBN identified just two vertically integrated PVC plants in which, it seems, all of the chlorine originates only with membrane or synthetic diaphragm technology: Formosa Plastics in Point Comfort, Texas, and the Pequiven El Tablazo plant in Zulia, Venezuela. These two plants account for less than 9% of the PVC capacity in the Americas.

Some integrated PVC plants that may appear to avoid chlorine with asbestos or mercury cell origins may not produce enough chlorine to support on-site demand. They may add chlorine from other chlor-alkali plants that do use these technologies. For example, Unipar Carbocloro's integrated chlorine-to-PVC plant in Santo Andre stopped using mercury cells in 2009, but it doesn't produce enough chlorine to match its capacity to produce PVC. So it meets this demand with a steady flow of EDC from its chlor-alkali plant just beyond a mountain range, toward the coast, in Cubatão. The Cubatão plant uses three different types of technologies to produce chlorine: synthetic diaphragm, membrane, and mercury cell.

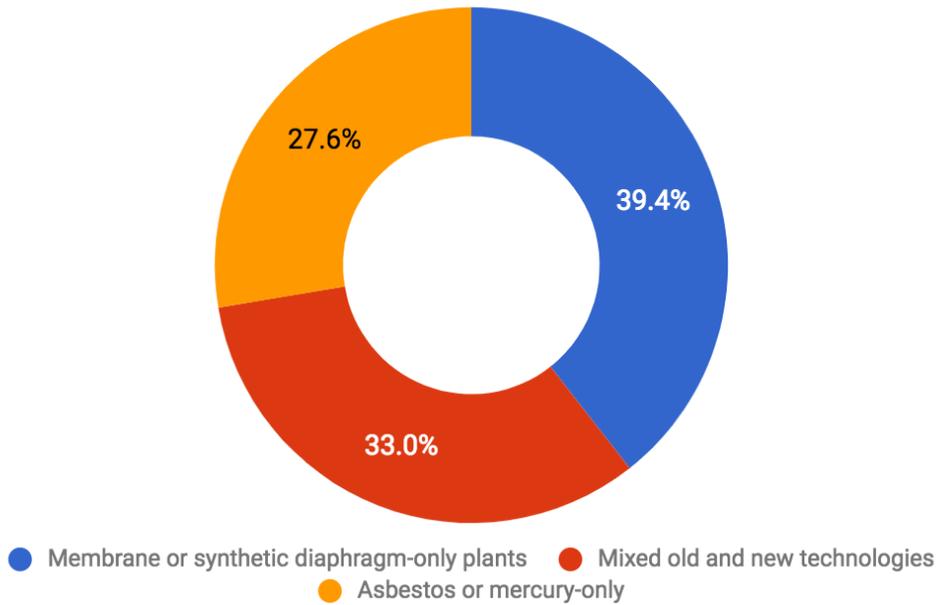
Interlocking supply chains that supplement on-site resources with proximate ones are common in places with multiple production facilities, such as the heart of the chlor-alkali industry, Plaquemine, Louisiana, where pipelines exchange feedstocks between chlor-alkali, EDC, VCM, PVC, isocyanate, and other plants.

Many plants are in a long-term period of transition and use both older (asbestos/mercury) and relatively recent (membrane/synthetic diaphragm) means of production. Six plants that use a mixture of technologies account for about one-third of the chlorine produced in the Americas. Their production capacities, as a whole, are split evenly between older technology and newer.

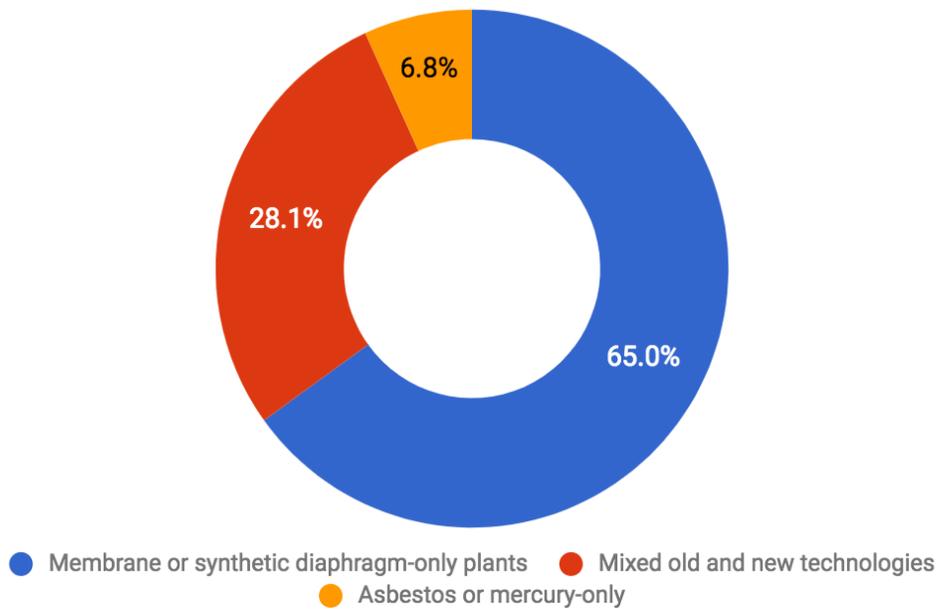
Taking these plants into account, HBN estimates that around 60% of chlorine made in the Americas comes from plants that use asbestos diaphragm or mercury cells exclusively or in combination with membrane or synthetic diaphragm units.

In Europe, a higher proportion of chlorine plants have converted to membrane and synthetic diaphragm technology. An estimated 65% of chlorine production is from plants that use only these technologies. An estimated 28% of chlorine in Europe comes from plants that use mercury cells or asbestos diaphragms in combination with units that use membrane technology. About 7% of chlorine in Europe is produced by plants that use only mercury and/or asbestos.

### Share of Chlorine Production by Technology (Americas)



### Share of Chlorine Production by Technology (Europe)



## FINDINGS: POLLUTANTS

HBN examined data from national pollutant registries in Canada and the US for the chlor-alkali plants detailed in this Inventory, and for the VCM, EDC, and PVC plants that are associated with them. Our review includes three essential materials in chlor-alkali production operations (asbestos, mercury, and PFAS). We also considered releases of the following chlorinated substances from the production of chlorine and chlorinated compounds: carbon tetrachloride, chlorine, chloroform, dioxins, ethylene dichloride (EDC, also called 1,2-dichloroethane), hexachlorobutadiene (HCBd), hydrochloric acid, polychlorinated biphenyls (PCBs), and vinyl chloride monomer (VCM).

Research for this Inventory also revealed another trend that is not well documented: the release of PVC dust and pellets. We review this issue at the end of this section.

Pollutant release rates, on a per-capacity basis, vary significantly between facilities. A European Union report in 2014 found that “Emission and consumption levels of the chlor-alkali industry are quite specific to the cell technique used but also depend on the specifications of the products (O<sub>2</sub> or CO<sub>2</sub> content, for example), the purity of the incoming salt, and the geographic location of the plant.”

### Method of analysis

Each year, chemical plant operators in the US and Canada must report how much pollution (for certain substances) came from their factories. They must also report on where it went: whether it went directly into air or water, or was managed in some way, such as placed in a landfill or burned in an incinerator. The information is self-reported to the federal environmental agencies. The data are often based on mass balances from chemists and chemical engineering experts, rather than from actual monitoring data. With those caveats in mind, US and Canadian pollutant release registries can be valuable resources for understanding the relative amounts of each pollutant coming from each plant, and identifying plants that release more pollutants than others. These data also can be compared to industry standards.

In Europe, pollutant release inventory data is incomplete and less reliable for comparison purposes. A search of the European Pollutant Release and Transfer Register (E-PRTR) found no data for several chlor-alkali plants. A European Commission review of E-PRTR data found that reporting of chlorinated organic and heavy metal pollutants is “incomplete.... This is particularly the case for the energy and chemical sectors.”<sup>44</sup>

Of the chemicals HBN analyzed, European data are most robust for chlorine, EDC, and VCM, and are sporadic for others.

There are no comparable pollutant reporting systems in other regions covered by this report, including Africa, South America, and the former Soviet Union.

The HBN Chlorine Inventory (this report) tracks the material flow of chlorine from chlor-alkali cell to resin, and attempts to quantify annual rates of releases of chlorinated pollutants based on company reports to federal agencies of the US or Canada. The findings below are based on release data for three production materials (asbestos, mercury, and PFAS) and nine chlorinated pollutants. Further details are available in this report’s Inventory and Appendices, as well as in spreadsheets available on this project’s home page.

In addition to the pollutants discussed below, other substances may be released from chlor-alkali and PVC production, such as heavy metals from impurities in raw materials.<sup>45</sup>

The term “releases” includes many pathways from which pollutants leave the production chain.

For US and Canadian plants, this report’s analysis includes all pollutants released into the air or water, in underground injection wells, landfills, and incinerators, and transfers to other facilities for disposal, recycling, or treatment. However, this analysis of US and Canadian releases does not include pollutants that are treated or recycled on-site.

For European Union plants, this report analyzes only air and water releases because the E-PRTR does not include most other types of releases in its reports, which limits our analysis to air and water releases, a subset of what is reported in the US and Canada. While the EU registry provides a format for companies to report releases to land or transfers off-site, few plant owners in Europe provide this information.

Chemical plants produce and market a variety of chlorinated substances. Some do not operate chlor-alkali cells, but instead import chlorine to feed the production of EDC, VCM, and/or PVC resin. Some produce only chlorine, others VCM.

In order to normalize release data among plants with different production configurations, HBN estimated the amount of chlorine required to produce each plant's chlorinated products, as expressed in annual capacity. From these data points, we determined release rates per each plant's estimated chlorine throughput, expressed as kilograms per 1,000-ton capacity. The Glossary of Notes provides further details as to how we calculate chlorine content and throughput.

## Releases of Production Materials

Asbestos and PFAS in diaphragms and membranes wear down under the intense conditions of chlor-alkali production. These production materials become pollutants. Mercury cells are loaded with many tons of mercury, which volatilize into cellrooms, and are deposited into surrounding buildings that, ultimately, are landfilled.

Plant operators are required to report releases of asbestos and mercury; however, they are not required to do so for PFAS used in membranes and synthetic diaphragms.

## ASBESTOS

The mining, use, and disposal of asbestos has long impacted human health worldwide. Asbestos fibers can build up in and damage peoples' lungs. It also can lead to cancers of the lung, including mesothelioma.<sup>46</sup>

"When using asbestos diaphragms, the diaphragm cell technique inherently gives rise to the release of asbestos," according to an EU report on chlor-alkali technologies. The report says each ton of asbestos diaphragm chlor-alkali production capacity generates between 64 and 160 grams of asbestos waste. The amount of asbestos used per cell depends on the diaphragm's composition. Some use 100% asbestos, others use a mixture of asbestos and PFAS polymers.<sup>47</sup>

Asbestos is hazardous when it is airborne, which happens during mining and packaging and unpacking of bags of asbestos.

It is leaving a legacy of cancer and contaminated water across Brazil, in communities such as Bom Jesus da Serra in Bahia, where asbestos was mined for 30 years, and in Minaçu, Goiás, the main source of asbestos used by US chlorine producers. A team of researchers tracked the health of asbestos miners in Minaçu from 1997 to 2000. They found that 1.4% of the miners developed diseases caused by asbestos.<sup>48</sup>

Similar concerns exist for miners working for Uralasbest in Russia, at least on the part of public health advocates. According to one recent investigation, "Seventy thousand people live in Asbest, once known as 'the dying city' for its extraordinary rates of lung cancer and other asbestos-related diseases."<sup>49</sup>

Chlor-alkali plants also can be sources of airborne asbestos. In the Zachem plant in Bydgoszcz, Poland, measurements of asbestos were taken every six months, for 15 years (1996 to 2010) in a workshop that contained a mixer that prepared "asbestos pulp." These measurements found a range of 5,000 to 30,000 fibers per cubic meter. (By comparison, the EU Hazardous Substances Regulation of 1993 limits concentrations to 1,000 fibers per cubic meter.<sup>50</sup>) Zachem closed the Bydgoszcz plant in 2012.<sup>51</sup>

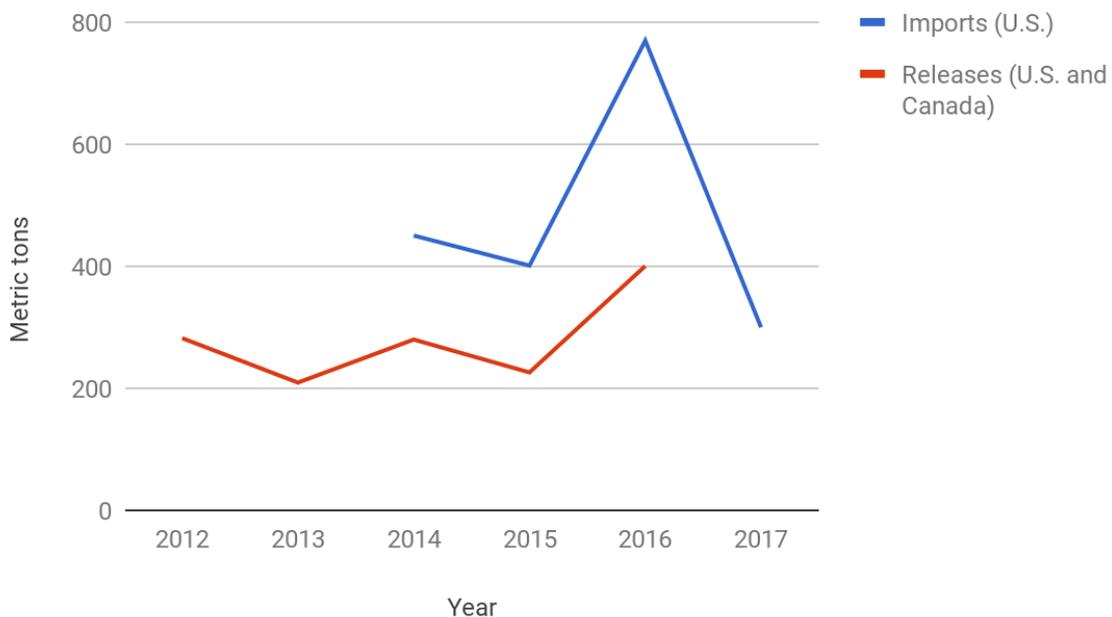
From 2012 to 2016, Occidental Chemical reported releasing asbestos out of stacks of three chlor-alkali plants. These asbestos air releases, per year, averaged 7.32 kg in Ingleside, Texas, 0.34 kg in Convent, Louisiana, and 0.02 kg in Hahnville (Taft), Louisiana. During the same time frame, Westlake Chemical reported releasing an average of 2.08 kg from its Plaquemine, Louisiana, chlor-alkali plant.

In the EU, only Dow uses asbestos diaphragm technology. Dow has not reported any asbestos releases for this plant in Stade, Germany. Dow has stockpiled enough asbestos to continue operations until 2025 - during which time this asbestos will be released mainly as solid waste.

Asbestos diaphragms can last anywhere from six months to 10 years, depending upon operating conditions. At the end of service, these diaphragms may be “terminally treated, chemically treated and/or landfilled, depending on the legislation of the country,” according to the EU.<sup>52</sup>

Between 2014 and 2017, US chlor-alkali producers imported an average of 480 tons of asbestos per year, mostly from Brazil, all of which ultimately will be released as waste, mostly into landfills. From 2012-2015, for example, Dow (now Olin) reported disposing of 570 tons of asbestos from its Plaquemine, Louisiana, plant into landfills.<sup>53</sup>

## Chlor-Alkali Industry Asbestos Imports and Releases



HBN graphic based on USGS Mineral Commodity Survey and US EPA Toxics Release Inventory data.

## MERCURY

According to the EU, the amount of mercury in a single chlor-alkali production cell can be as high as 6 tons. It reported that, as of December 2012, 34 plants in Europe had 6,053 tons of mercury in cells and another 1,005 tons of mercury stored on-site.<sup>54</sup>

In 2005, the EPA estimated that global chlor-alkali and VCM demand for mercury was 1,319 tons per year, more than any other industry in the world.<sup>55</sup> All of this has or will become pollution. “The mercury cell technique inherently gives rise to environmental releases of mercury,” notes the EU.<sup>56</sup>

Public health and environmental experts have long considered mercury to be a priority pollutant for global elimination from industrial use. It is one of the most toxic substances on earth, causing irreversible neurological damage

to people. From South Africa to Venezuela to Japan, thousands of workers and nearby residents have died from exposure to mercury from chlor-alkali plants and related operations, including recycling and waste disposal.

Industry data has stated that each ton of chlorine produced using mercury cell technology consumes 16.6 grams of mercury, of which 11.4 grams ultimately are disposed on land, 1.9 grams are emitted into the air, 0.2 grams are discharged to the water, 0.4 grams become contaminants in products, and 2.6 grams are “unaccounted for,” according to Joe Thornton, author of *Pandora’s Poison*.<sup>57</sup> He warned that this data was “prepared by the chlorine industry for facilities in Europe and may not accurately represent global averages.”

“Most of the mercury which leaves an installation is disposed of with waste,” according to the EU report. “Releases to the environment from the installation mostly occur to the atmosphere as diffuse emissions from the cell room. Significant emissions may also occur during decommissioning of the installation. In 2010, the total annual mercury emissions to air of the chlor-alkali industry in the EU amounted to approximately 7% of the total anthropogenic mercury emissions to air in this region.”

E-PRTR emissions data rely upon industry reports. According to their reports, from 2012-2016, chlor-alkali producers with mercury cell technology companies released an average combined total of 1.4 tons of mercury to air and water. Releases declined as plants closed. The four leading sources of mercury emissions from chlor-alkali production closed by 2017. Average reported emissions to air and water declined from 1.7 tons in 2012 to 1.1 tons in 2016.

The en masse deconstruction of mercury cell plants in Europe is generating increased waste in the form of contaminated materials, such as sludge, activated carbon filters, brickwork and concrete, the cells, and surrounding asphalt and soil.<sup>58</sup>

## Mercury into the Air

According to the EU report, mercury cell plants release mercury pollution into the air at a rate of 0.11 to 1.78 grams per ton of capacity. An EU project in 2003 measured total mercury air emissions from a plant in Italy at a rate of 54 grams of mercury per hour. Overall, this project found that total emissions of mercury to air were “two to nine times higher than those reported by Euro Chlor,” an industry association.<sup>59</sup>

In the US, Westlake’s Natrium plant released an average of 73.8 kgs of mercury into the air each year, from 2012 to 2016, according to company data. The Ashta Chemicals plant released an average of 18 kg per year. The Natrium plant, with capacity to produce 100,000 tons per year of chlorine from mercury cells, therefore released mercury at a rate of 0.74 grams per ton capacity. Ashta, with a 47,000-ton-per-year chlorine capacity, released it at a rate of 0.38 grams-per-ton capacity. Since 1987, the two plants, combined, have released over 23.8 metric tons of mercury into the air. (See Appendix for further details).

## Mercury in Water and Aquatic Food Chains

According to the EU report, mercury cell plants release mercury pollution into water at a rate of zero to 1.65 grams per ton of chlorine produced.<sup>60</sup>

Most mercury cell plants are near an ocean or an estuary. Chronic air and wastewater discharges concentrate in sediment and lead to the bioaccumulation of mercury in aquatic biota, including fish, often at levels that exceed those safe for people to eat them.<sup>61</sup>

The small company Quimpac operates export-oriented mercury cell plants on the Pacific coast of Peru, and directly discharges mercury wastes into the Pacific Ocean. So, too, does the Braskem chlor-alkali plant in Bahia, Brazil, which produces PVC for the construction market.

The Natrium chlor-alkali plant in West Virginia has released at least 715 kilograms into the Ohio River since 1987. The Ashtabula plant has released over 26 kg of mercury into water.<sup>62</sup>

The two mercury plants in Germany that will continue using mercury cells indefinitely - BASF in Ludwigshafen and Evonik in LÜlsdorf - are located on the Rhine. Over the last 10 available years of data, cumulatively, BASF and Evonik released over 2 tons of mercury into the air; Evonik also estimated releasing 32 kg of mercury into the Rhine.<sup>63</sup>

## Mercury Waste Recycling and Disposal

Over time, mercury in the air around chlor-alkali cells settles into surrounding building materials and soils. Mercury cells and the buildings and grounds around them become hazardous wastes when they are decommissioned.

The disposal and recycling of waste from mercury cells has dispersed mercury into surrounding communities and around the world. As we detail in the Inventory section of this report:

- In the 1980s and 1990s, companies in Europe and the US shipped thousands of drums of depleted mercuric chloride catalyst to a company in South Africa that falsely claimed to recycle it. Thor Chemical, in Cato Ridge, South Africa, claimed it was “recycling” mercury waste from around the world. Instead, it burned a portion of the waste, stored and dumped the bulk of it, and in the process poisoned its workers and the surrounding environment with some of the worst mercury contamination documented in the world. Two Thor employees died of mercury poisoning.
- Until 2004, the Unipar Carbocloro plant (Cubatão, São Paulo, Brazil) shipped mercury waste to a recycling company in Paulínia, Campinas, Brazil. This practice ended after researchers found “up to 1,352 ng/m<sup>3</sup> mercury in the air” near the recycling facility, which was located next to a school.<sup>64</sup>
- In the US, Ashta Chemicals of Ohio ships most of its mercury waste to a “metals recovery” facility in Union Grove, Wisconsin. Much of it is never recycled, but rather, buried in Alabama. Waste Management Inc.’s landfill in Emelle, Alabama, has been a leading destination of chemical industry hazardous waste for several decades. Most of the mercury waste from Westlake’s Natrium plant in West Virginia also goes to Emelle. In 2012-2013 alone, the Emelle landfill received over 46.7 tons of liquid mercury waste from the Natrium plant. Emelle received over 5,000 tons of mercury-contaminated waste -- including debris from dismantled mercury cell plants -- since 2001, according to HBN’s review of U.S. EPA Toxics Release Inventory data.<sup>65</sup>

## PER- AND POLYFLUOROALKYL SUBSTANCES (PFAS)

Per- and polyfluoroalkyl substances (PFAS), a class of chemicals also referred to as perfluorinated compounds, are now used in most chlor-alkali plants worldwide. However, there is very little published research on the potential release of these chemicals from this use.

National pollutant registries in Canada and the US do not require reporting releases of PFAS from chlor-alkali plants. A study of two membrane chlor-alkali plants in Europe hints at the potential scale of unreported PFAS releases across the industry. Depletion from use, they found, requires resins to be “regenerated approximately 30 times per year.” The researchers found that the plants released “ion exchange resin wastes” at rates between 4 and 6.7 grams per ton of annual chlorine capacity.<sup>66</sup>

Applying these rates to combined annual chlor-alkali production capacities reveals a substantial potential mass of lost membrane resins: between 30.7 and 51.5 tons for Europe, 2.4 to 4.1 tons for Africa, and 31.9 to 53.4 tons for the Americas.

Another concern recently emerged: In 2017, PFAS releases into water were documented at one of the leading sources of membranes for the chlor-alkali industry: The Chemours plant in Fayetteville, North Carolina, which produces membranes with the Nafion™ brand name.<sup>67</sup>

The Chemours plant discharges wastewater into the Cape Fear River. The US EPA detected two PFAS substances in the Cape Fear River in August 2017 that it linked to Nafion membrane production. It dubbed these compounds “Nafion byproducts 1 and 2. Within a week of this finding, the North Carolina Department of Environmental Quality (DEQ) said it “demanded that Chemours stop the release of Nafion byproducts.” The DEQ said

“little information is known about the potential health effects of GenX [another PFAS produced at the Chemours Fayetteville plant] and less is known about the Nafion byproducts.”<sup>68</sup>

Public health and environmental officials are increasingly concerned about PFAS. Production of this class of chemicals has contaminated air, water, land, fish, animals, crops, and people across the US. For example, a scientific panel recently found “probable links” between DuPont’s Washington Works, Ohio, production of PFOA (a PFAS chemical) and certain medical conditions in people living near the factory. These include high cholesterol, kidney cancer, pregnancy-induced hypertension, testicular cancer, thyroid disease, and ulcerative colitis.<sup>69</sup>

In May 2015, over 200 scientists published the Madrid Statement, which recommends that consumers should “whenever possible, avoid products containing, or manufactured using” these chemicals.<sup>70</sup>

On September 18, 2017, the EPA conducted more sampling in the Cape Fear River. It found “Nafion byproduct 1 levels of 6,560 parts per trillion (ppt) and Nafion byproduct 2 levels of 45,200 ppt at one of the plant’s outfalls,” according to the Wilmington Star-News. DuPont apparently since complied with an order to stop water discharges of Nafion byproducts, but faces increasing public pressure.<sup>71</sup> In February, dozens of nearby residents sued DuPont in federal court, claiming that the company “secretly released GenX and similar compounds into the groundwater, lakes, air, soil and Cape Fear River,” reported the *Fayetteville Observer*.<sup>72</sup>

## Chlorinated Releases

### The US and Canada

We found great differences in the chlorinated pollutant release rates between chlor-alkali plants that produce only chlorine and those that also produce EDC, VCM, and/or PVC. Significantly higher amounts of chlorinated substances are released in the PVC production chain than in plants that do not produce PVC feedstocks. These chemicals impact people and the environment, from aquatic food chains to Earth’s stratosphere.

Our analysis focused on the last five years of available US and Canadian pollutant release reports (2012-2016). As noted at the beginning of this section, for plants located in these two countries, we considered all releases into the air or water, underground injection wells, landfills and incinerators, and transfers to other facilities for disposal, recycling, or treatment. Our analysis did not include pollutants that are treated or recycled on-site. It also does not include pollution from plants that are now closed.

In the aggregate, for plants reporting releases of these chemicals, we found the following median rates, per 1,000 tons of chlorine throughput:

- 117.8 kg EDC
- 42.5 kg VCM
- 5.8 kg hydrochloric acid
- 4.7 kg chloroform
- 4.2 kg carbon tetrachloride
- 2.3 kg hexachlorobutadiene
- 2.26 kg chlorine
- 0.002 grams PCBs
- 0.001 grams dioxins (Toxicity Equivalent Weight)

We compared individual plants’ releases with these median release rates to identify outliers and trends. Chlorinated pollutant release rates (including chlorine, hydrochloric acid, and organochlorine chemicals) do not appear to correlate with technologies used to produce the chlorine. For example, chemical plants that released the four highest rates of chlorinated pollutants all use membranes, but so do most of the plants with the lowest release rates per chlorine throughput. (See Supplemental Table: Excess Chlorinated Pollutant Release Ratings - (US and Canada).

Plants that produce VCM release the most chlorinated pollution. Seven of the 8 locations with the highest release rates per chlorine capacity in the US and Canada all produce VCM. Westlake owns four of these seven, including the leading source of chlorinated pollution: Calvert City, Kentucky. Westlake in Calvert City reported the highest rates of EDC and VCM releases and the second highest rate of chlorine and dioxin releases in the US and Canada. Formosa Plastics' plant in Point Comfort, Texas, released carbon tetrachloride, and chloroform at rates higher than any other. Olin and Occidental plants in Freeport and LaPorte, Texas, accounted for 97% of the industry's reported PCBs releases. Both plants produce VCM.

Plants that produce mainly chlorine or EDC generally have the lowest rates of chlorinated pollution, although there are exceptions such as Westlake's Natrium chlorine plant, which led the industry in hydrochloric acid releases from 2012 to 2016.

Further details are available in: Supplemental Table: Excess Chlorinated Release Ratings (US and Canada), which accompanies this report at [www.healthybuilding.net](http://www.healthybuilding.net).

## CARBON TETRACHLORIDE

Carbon tetrachloride ( $\text{CCl}_4$ ) is an organochlorine compound. It is a toxicant, a global warming gas, and contributes to the depletion of Earth's protective ozone layer. The US EPA is considering restricting its production under the Toxic Substances Control Act.

$\text{CCl}_4$  can form as a byproduct of chlor-alkali production when organic contaminants are introduced from brine or equipment.<sup>73</sup> It can also form during the phosgenation of toluenediamine to produce toluene diisocyanates used in polyurethane.<sup>74</sup>

Some chlor-alkali plants intentionally reuse  $\text{CCl}_4$  in production of VCM. It can be used to eliminate nitrogen trichloride and nitrogen tetrachloride, recover chlorine from tail gas, or reduce the use of natural gas. According to a United Nations technical team, until 2000, a Brazilian manufacturer enhanced the conversion of EDC to VCM using  $\text{CCl}_4$ , "thereby reducing use of natural gas and net operating cost."<sup>75</sup>

An EU report says the use of  $\text{CCl}_4$  for eliminating nitrogen trichloride results in up to 3 grams of  $\text{CCl}_4$  air emissions per ton chlorine capacity. Using  $\text{CCl}_4$  to recover chlorine from tail gas results in as much as 30 grams emissions per ton capacity.<sup>76</sup>

Mexichem's plant in Veracruz, Mexico, consumed an average of 78 tons of  $\text{CCl}_4$  per year between 1994 and 2004. A company submission to the United Nations Environment Programme calculated that 206 kgs (20.6%) are released to the atmosphere for each ton of  $\text{CCl}_4$  consumed as a process agent.<sup>77</sup> These figures indicate that the chlor-alkali plant was releasing an average of 16.07 tons (16,070,000 grams) of  $\text{CCl}_4$  per year. The plant had an estimated chlorine capacity of 98,000 tons per year, which means it was releasing at least 164 grams of  $\text{CCl}_4$  per ton chlorine capacity, or more than five times the rate found in processes identified in the EU report.

Between 2012 and 2015, according to US TRI data, half of the 10 leading sources of carbon tetrachloride releases were chemical complexes with chlor-alkali plants.

Some of these plants use or sell carbon tetrachloride as feedstock for other products, such as chloromethanes and blowing agents.

Occidental's plants in Wichita, Kansas, and Geismar, Louisiana, which ranked as the country's second and third leading sources of carbon tetrachloride releases, produce carbon tetrachloride for sale.<sup>78</sup> Olin reported  $\text{CCl}_4$  releases at its plants in Plaquemine, Louisiana, and Freeport, Texas. It markets carbon tetrachloride for use in fluorocarbon and other chemical production.<sup>79</sup>

Releases from plants that offer  $\text{CCl}_4$  for fluorocarbon production may soon increase dramatically due to new blowing agents. A 2017 air permit for Occidental's Geismar facility "includes an increase in carbon tetrachloride."<sup>80</sup> This anticipated increase may be related to a joint venture with Dow Chemical to produce "the new chlorocarbon,

known as HCC-1230xa,” used in the production of HFO-1234yf, a new chemical used in automotive cooling systems. Hydrofluoroolefins (HFOs) are the third generation of coolants and blowing agents to replace CFCs. The first wave of replacements were hydrochlorofluorocarbons (HCFCs), which also deplete stratospheric ozone, and then hydrofluorocarbons (HFCs), which are potent global warming agents. While HFOs do not deplete stratospheric ozone or contribute much to global warming, directly, some HFOs use carbon tetrachloride as a process agent.<sup>81</sup> These include the above referenced HFO-1234yf, which is used in automotive cooling systems, and HFO-1234ze, which is used as a blowing agent for polyurethane and polystyrene insulation. HFO-1234ze is a replacement for both HFC-134a and HFC-152a.<sup>82</sup>

At Westlake’s complex in Calvert City, Kentucky, which ranked fifth in carbon tetrachloride releases, there are no apparent connections to products such as HFO. Rather, releases appear connected to VCM and PVC production. The plant reported releasing over one ton of  $\text{CCl}_4$  in 2012 and 2013, and over 5 tons per year after the completion of a project to expand PVC capacity in 2014.<sup>83</sup>

Formosa Plastics reported, on average, 1.54 million kg of  $\text{CCl}_4$  releases from production per year from 2012 to 2016, in Point Comfort, Texas. Here, too, there is no apparent connection to production of other chemicals; instead, the carbon tetrachloride appears to be wholly unintentional, as the company reported burning it all in an on-site energy recovery unit. Formosa, with a chlorine production capacity of 916,000 tons per year, generated the most  $\text{CCl}_4$  in the industry, both in volume and rate. It generated 1,692 grams of carbon tetrachloride per ton of capacity, which is 10 times higher than the rate reported by the Mexichem Veracruz plant.

The E-PRTR contains no reported emissions of carbon tetrachloride from chlorine plants in the European Union between 2012 and 2016. Manufacturers are required to report  $\text{CCl}_4$  releases in excess of 100 kg per year. However, European scientists tracking carbon tetrachloride emissions say the industry is likely not reporting emissions. Their review of the database did not find any information for  $\text{CCl}_4$  releases from Euro Chlor members between 2007 and 2014. The experts (Graziozi et al) found that “when comparing our estimates with emissions from industrial activities declared to the E-PRTR, we found the E-PRTR to be strongly (on average 35 times) underestimated, reinforcing the incompleteness of available information.”<sup>84</sup>

## Impact on Earth’s Protective Ozone Layer

A global scientific team recently endeavored to account for all the possible sources, and fates, of carbon tetrachloride, which is highly destructive to Earth’s ozone layer.<sup>85</sup> Under the terms of the Montreal Protocol to protect the ozone layer, in 1995, developed countries eliminated many uses for carbon tetrachloride (such as its use as a solvent in cleaning fluids, lacquers, as a dry cleaning agent, and as a grain fumigant). Developing countries, according to the United Nations Environment Programme, achieved a total phase-out of carbon tetrachloride products (if not production) in 2010.

However, the Montreal Protocol phase-outs exempted the use of  $\text{CCl}_4$  as a chemical feedstock, and this use is growing. In 1993, a technical committee, comprised primarily of chemical-industry experts, assured parties to the Montreal Protocol that worldwide usage of  $\text{CCl}_4$  as a chemical feedstock will not exceed 5,000 tons per year. The panel predicted that this use as a feedstock “should be substantially reduced over the next 5 years” and “can be completely destroyed,” implying that it would not be released.<sup>86</sup>

From 2012 to 2016, according to HBN’s analysis of TRI data, the US chlor-alkali industry reported releasing an average of 4,373 tons of carbon tetrachloride per year.

However, scientists are finding that much more may go unreported, and are concerned that  $\text{CCl}_4$  from chlor-alkali plants may be extending the damage to Earth’s stratosphere.

In 2016, the SPARC Report on the Mystery of Carbon Tetrachloride found that the production of chlorine and other chlorinated substances was releasing and consuming much more carbon tetrachloride than previously understood. “ $\text{CCl}_4$  is not decreasing in the atmosphere as rapidly as expected, given what we know about its total lifetime (based on loss processes), and the small remaining emissions that are known,” wrote the authors. They concluded that emissions of carbon tetrachloride during its production, and fugitive emissions from its use as a

chemical feedstock, have been significantly unreported and underestimated. The research team estimated that the chlor-alkali industry, worldwide, was responsible for about 10,000 metric tons of unreported  $\text{CCl}_4$  releases, or about 40% of all unreported releases.<sup>87</sup>

Researchers estimate that between 0.03 to 0.4 kilograms of carbon tetrachloride are released into the atmosphere for every ton of chlorine produced.<sup>88</sup> Accordingly, a plant producing 100,000 tons of chlorine would emit between 3 and 40 tons (3,000 to 40,000 kg) of carbon tetrachloride.

Using the rate of 0.4 kg per ton of chlorine produced, chlor-alkali plants in Europe (11,069,000 tons of estimated chlorine capacity), the Americas (16,634,000 tons), and Africa (728,000 tons) have the combined capacity to release 11,372 tons of  $\text{CCl}_4$ .

## CHLORINE

The Inventory section of this report recounts a number of fires and explosions that have damaged many of this industry's factories. These accidents sometimes release clouds of highly-toxic chlorine gas onto neighboring communities, injuring and killing hundreds of workers and neighbors.

A recent EU report says that emissions of chlorine from fugitive emissions, weather, accidents, startup and shut-down operations, and other incidents may "contribute significantly to the overall emissions of a chlor-alkali plant." These are in addition to routine releases. EU estimates that between 1% and 8% of the chlorine produced in these plants is released - but mostly recaptured - in waste gases.<sup>89</sup>

All stages of production, from chlor-alkali to EDC/VCM cracking to PVC production, chronically release chlorine. The EU report gives a range of 0.01 to 15.0 grams of chlorine emissions into the air per ton of chlorine produced.<sup>90</sup>

Our analysis of US and Canadian pollution reports found a median rate of 2.3 kgs of chlorine reported released as waste gas per 1,000 tons of chlorine throughput. Several plants released chlorine at much higher rates. The Westlake plant in Calvert City, Kentucky, and the Occidental Chemical plant in Wichita, Kansas, released chlorine at rates of more than 150 kg per 1,000 tons of chlorine throughput capacity between 2012 and 2016. Most of Calvert City's releases were into the air; the Wichita plant's releases were mainly into underground injection wells.

Combined, the US and Canadian chlor-alkali and PVC industry reports releasing 423 tons of chlorine gas each year into the air.

The industry in the EU reported releasing just 72 tons of "chlorine and inorganic compounds (as HCl)" into the air.

## DIOXINS AND PCBS

The manufacturing of PVC from chlorine generates highly toxic chemicals called dioxins and polychlorinated biphenyls (PCBs). Dioxins and PCBs are persistent bioaccumulative toxicants that travel around the globe through the air.<sup>91</sup> They accumulate in fat tissue and concentrate as they go up the food chain.

One producer describes the formation of dioxins during the oxychlorination process of EDC and VCM production as inevitable. "The processes used by ICI to produce vinyl chloride monomer, trichloroethylene and perchloroethylene involve oxychlorination stages," explained Imperial Chemical Industries in 1994. "The oxychlorination stage in the vinyl chloride process makes 1,2-dichloroethane which is converted into vinyl chloride by pyrolysis. In the process for making trichloroethylene and perchloroethylene an oxychlorination reactor is used to convert raw materials directly into solvent products. It has been known since the publication of a paper in 1989 that these oxychlorination reactions generate polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). The reactions include all of the ingredients and conditions necessary to form PCDD/PCDFs, i.e., air or oxygen, a hydrocarbon (ethylene etc), chlorine or hydrogen chloride, a copper catalyst, an ideal temperature and an adequate residence time. It is difficult to see how any of these conditions could be modified so as to prevent PCDD/PCDF formation without seriously impairing the reaction for which the process is designed."<sup>92</sup>

Another producer noted a similar connection between PCB formation and EDC/VCM production. “PCBs can be formed in trace quantities any time that chlorine in any reactive form is contacted with carbon or compounds of carbon at elevated temperatures and/or in the presence of a catalyst,” Dow noted in a 1981 submission to EPA.<sup>93</sup>

Dioxins and PCBs even may be present in products that contain PVC. Suspension PVC resins tested at two Swedish PVC facilities in the 1990s contained dioxins and PCB levels ranging from 0.86 to 8.69 parts per trillion.<sup>94</sup> “(M)any chemicals may contain low levels of PCB contaminants due to use of chlorine in their manufacture,” notes a 2014 Washington Department of Ecology report. These chemicals include titanium dioxide (TiO<sub>2</sub>), a widely used pigment. TiO<sub>2</sub> manufacturers use chlorine to purify ores. The department found PCBs in food packaging and paints -- the highest amount detected was 330 ppb in a phthalo-green paint colorant -- which it attributed to pigments.<sup>95</sup>

The chlor-alkali industry in the US and Canada self-reports dioxin releases to federal agencies each year. The reported amounts vary greatly between plants. From 2012 to 2016, the industry in the US and Canada reported total releases of 58.6 TEQ grams of dioxin releases. (For an explanation of TEQ grams, see Glossary of Notes).

The 4 highest dioxin release rates were reported from facilities that produce VCM. Thirteen plants with VCM units in the US accounted for over 90% of the chlorine industry’s dioxin releases (107 out of 117 grams [TEQ] per year as reported to the US EPA):

In the EU, for the 2012 to 2016 period, the industry reported releases of just 0.0006 TEQ grams dioxins and furans into the air and water. Again, it must be noted that considerable data gaps exist in the E-PRTR.

Six EDC/VCM plants in the US reported PCB releases between 2012 and 2016, at an average combined rate of 59.9 kilograms per year. Two plants accounted for 97% of these releases: Olin/Dow in Freeport, Texas (35.6 kg per year) and Occidental in La Porte, Texas (22.4 kg per year). Most of these releases were transfers to landfills and incinerators. The Olin/Dow plant in Freeport released more PCBs into the air (3.3 pounds per year). Occidental in La Porte, Olin/Dow and Westlake in Plaquemine, Louisiana, and Westlake in Lake Charles, Louisiana, also reported PCB emissions into the air (0.2 pounds or less per year). Occidental in Deer Park, Texas, reported transferring an average of 2.02 kg PCBs to a wastewater treatment plant. Occidental in La Porte reported discharging an average 0.02 kg (20 grams) of PCBs into the Houston Ship Channel.

In Europe, one plant - Ercros in Vila-seca, Spain - reported PCB releases. It measured releases of PCBs into water at rates of 400 grams in 2014, 754 grams in 2015, and 850 grams in 2016.<sup>96</sup> The Vila-seca plant is a chlorine-to-PVC resin facility.

## ETHYLENE DICHLORIDE

The reaction of chlorine with ethylene creates 1,2-dichloroethane, which is commonly called ethylene dichloride (EDC). EDC cracking units, in turn, split EDC into vinyl chloride monomer (VCM) and hydrochloric acid. These two processes usually, but not always, occur on the same site. In some cases, EDC is shipped to another site for cracking into VCM. EDC is released during both processes: during the exothermic reaction of chlorine with ethylene to make EDC, and again during the EDC cracking operation.

“Exposure to low levels of ethylene dichloride can occur from breathing ambient or workplace air,” notes the EPA. “Inhalation of concentrated ethylene dichloride vapor can induce effects on the human nervous system, liver, and kidneys, as well as respiratory distress, cardiac arrhythmia, nausea, and vomiting.”<sup>97</sup> The US Centers for Disease Control identify EDC as an occupational carcinogen, and California includes EDC on its Proposition 65 list of carcinogens.<sup>98</sup>

Fifteen plants in the US reported EDC releases to the TRI from 2012 to 2016. These factories released 149 tons of EDC per year into the air. Far more EDC - 89% of all releases - was burned in incinerators that also produce energy. The Westlake Calvert City plant was the leading source of EDC air emissions in the US (over 25 tons per year).

While EDC releases are inevitable in VCM production, some plants release more than others: Formosa’s plant in Point Comfort, Louisiana, and Westlake’s plants in Plaquemine and Lake Charles, Louisiana, and Calvert City, Kentucky, release EDC at rates more than ten times the industry median in the US.

In the EU, 20 plants reported an average of 770 tons-per-year of EDC releases, combined, from 2012 to 2016. Most (88%) of these reported releases came from five plants (Vynova plants in Wilhelmshaven, Netherlands, Runcorn, UK, and Tessenderlo, Belgium; and Kem One plants in Lavéra and Fos-sur-Mer, France). The Vynova plants in Wilhelmshaven and Runcorn reported over 200 tons of EDC releases into the air each year, each. These plants, individually, reported more EDC releases into the air than all the US plants combined.

## HEXACHLOROBUTADIENE (HCBD)

HCBD is a highly persistent and bioaccumulative carcinogen. The EPA is currently considering restrictions under the Toxic Substances Control Act (TSCA).

According to Euro Chlor, which represents the European chlor-alkali industry, “The primary source of hexachlorobutadiene is inadvertent production as a by-product of the manufacture of chlorinated hydrocarbons such as perchloroethylene, trichloroethylene and carbon tetrachloride, where it occurs in the heavy fractions.”<sup>99</sup>

The US chlor-alkali industry produces substantial volumes of HCBD waste, at least 4,500 metric tons per year.<sup>100</sup> Three complexes in Louisiana are responsible for 99% of all HCBD waste reported to the EPA in 2016: Westlake in Lake Charles, Occidental Chemical in Geismar, and Olin in Plaquemine. Olin acquired this plant from Dow in 2015.

Fenceline communities and chlorine-plant workers may be exposed to high levels of HCBD through air and water pollution from these facilities. “People who live in source-dominated areas (at or near hazardous waste sites or chlorinated hydrocarbon production plants) and workers in these areas are potentially exposed to high levels of hexachlorobutadiene,” the Agency for Toxic Substances and Disease Registry (ATSDR) reported in 1994. Individuals who consume large amounts of fish from contaminated waters may also be exposed to above-average levels of hexachlorobutadiene,” ATSDR reported in 1994.<sup>101</sup>

Westlake, Occidental, and Olin release considerable amounts of HCBD into Louisiana’s water, and in underground injection wells. TRI data also reveal accidental releases of HCBD at one plant (nearly 10,000 pounds in two years at the Westlake Eagle 2 plant in Lake Charles).

HCBD detection may indicate the presence of dioxins. A study funded by PPG Industries (which at the time had EDC/VCM assets that are now owned by Westlake) found that its plant was discharging up to 0.18 kgs of HCBD per day into adjacent waterways. A University of Amsterdam scientist in 1989 described these discharges “as important indicators for the thermochemical formation of PCDDs [dioxins] and PCDFs [furans].”<sup>102</sup>

Chlorine producers transfer hazardous HCBD wastes to facilities that burn hazardous waste. These include cement kilns in Cape Girardeau, Missouri, Logansport, Indiana, and Port Arthur, Texas, and an incinerator in East Liverpool, Ohio.<sup>103</sup>

The EU’s incomplete E-PRTR included only two reports of HCBD releases from 2012 to 2016. Inovyn (Ineos) reported releasing 149.8 kg of HCBD from its Tavaux, France, plant, and 1.8 kg from its Jemeppe-sur-Sambre, Belgium, plant.

## HYDROGEN CHLORIDE / HYDROCHLORIC ACID

Hydrogen chloride (HCl) gas is a byproduct of processes that make chlorinated substances, especially EDC, an essential feedstock for PVC resins.<sup>104</sup> “Hydrogen chloride gas can irritate the lungs, causing a cough and shortness of breath. Breathing high levels of the gas or vapor can lead to a build-up of fluid in the lungs, which may cause death. Because hydrochloric acid is corrosive, it can cause eye damage, even blindness, if splashed in the eyes,” warns the ATSDR.<sup>105</sup>

HCl is intentionally produced by combining chlorine and hydrogen in so-called “acid burners.”<sup>106</sup> Chemical companies use HCl in the production of a wide range of chemicals including bisphenols, isocyanates, and PTFE (most commonly known as Teflon).<sup>107</sup>

The leading source of hydrochloric acid releases in the US and Canada, by rate and total kilograms, is Westlake's Natrium plant in West Virginia. It released an average of 312 tons of HCl per year, which is 59% of the US and Canadian industry's overall total (530 tons of HCl releases per year). Most (87%) of these releases were into the air.

## VINYL CHLORIDE MONOMER (VCM)

Vinyl chloride monomer (VCM) is a carcinogen and gene mutagen.<sup>108</sup> VCM emissions occur during the production of VCM and PVC.

The Australian PVC industry has standards for emissions from resin manufacturing. It set limits of 30 grams of VCM emissions per ton of suspension PVC (S-PVC) resins and 1000 grams (1 kg) per ton of emulsion PVC (E-PVC) resins.<sup>109</sup> The European Council of Vinyl Manufacturers (ECVM) also has voluntary agreements in place. These charters, established in the 1990s, have the same limit for E-PVC emissions as does Australia. However, its limit for S-PVC -- 100 grams emissions per ton resin -- is over three times more permissive than the Australian industry standard.<sup>110</sup>

In the building industry, S-PVC resins are used in pipes (including drinking water piping) and windows. E-PVC resins are used in flooring, wall coverings, and furniture fabric.

In 2018, the European PVC industry released a standard called the VinylPlus Product label for construction products. It uses the same VCM emissions standards established 20 years ago.<sup>111</sup> The ECVM industry council does not count releases of pollutants to incinerators or "third party" waste treatment facilities.<sup>112</sup>

The Vinyl Institute, an industry association based in the US, does not appear to have established similar voluntary limits for its members. There appear to be no North American charters or industry agreements to limit VCM emissions into the air and as residuals in products. These potential releases are not addressed in the GreenCircle product label program that the association promotes. An ASTM standard for testing VCM residuals exists, but is not mentioned on the Vinyl Institute or GreenCircle websites.

ASTM standard D 3749, a method to test for residual VCM in PVC resins, warns that "vinyl chloride monomer is a cancer-suspect agent and must never be released to the laboratory atmosphere, even at low ppm levels."<sup>113</sup>

About 3% of all VCM releases reported to EPA were into the air. Considering only these air releases, 9 PVC plants in the US exceeded 30 grams per ton of PVC capacity, which is the Australian industry's limit for suspension PVC resins. One of these plants -- Formosa Plastics' PVC plant in Delaware City -- exceeded the European vinyl industry's limit (100 grams per ton capacity) for suspension PVC resins. The Delaware City plant uses chlorine that originated in Formosa's membrane cell plant in Point Comfort, Texas, and was processed in Formosa's VCM plant in Baton Rouge, Louisiana. This location has been a Superfund site since 1983 because EDC, VCM, and trichloroethylene contaminate the groundwater.<sup>114</sup>

In addition to direct releases to air through fugitive and stack emissions, VCM releases contribute to pollution from on-site incinerators, boilers, and furnaces to burn toxic production wastes. Over 96% of the reported VCM releases from chlor-alkali plants are sent to so-called "energy recovery" units on-site. These units are known sources of dioxin and other highly toxic air pollutants.

Accounting for transfers of VCM to on-site waste burners increases calculated amounts of VCM released per ton of PVC resin production. This release point is included in our analysis of excess pollutants per plant.

In three plants, combined releases of VCM into the air and into on-site "energy recovery" units exceed rates of 1,000 grams per PVC production capacity, which is the European and Australian industry limit for emulsion PVC resins. Westlake's Calvert City plant led all with combined release rates of 2,893 grams VCM per ton PVC capacity. It averaged nearly 2,000 tons VCM releases overall per year. Formosa's Point Comfort plant and Westlake's Plaquemine plant also exceeded 1,000 grams VCM releases to air and energy recovery per ton PVC capacity.

Occidental's VCM plant in Ingleside was also a leading source of VCM emissions. It does not produce PVC resins, but provides VCM to Mexichem PVC resin plants in Colombia, Mexico, and the US. It released almost 1,000 tons per year VCM to on-site waste burners.

TABLE 10 . REPORTED VCM RELEASES INTO THE AIR, TOP 10, EU, 2012 TO 2016

PVC RESIN PRODUCER	VCM RELEASES (KILOGRAMS)	PVC CAPACITY (EST., TONS)	GRAMS VCM RE-LEASED PER TON
Kem One - Saint Auban, France	42,100	70,000	587
Kem One - Hernani, Spain	11,665	45,000	259
Ineos (Inovyn) - Stenungsund, Sweden	41,924	215,000	195
Kem One - Saint Fons, France	26,088	205,000	127
Ineos (Inovyn) - Tavaux, France	30,737	260,000	118
Ineos (Inovyn) - Herøya, Norway	23,181	200,000	116
Mexichem (Vestolit) - Marl, Germany	47,840	416,000	115
Westlake (Vinnolit) - Schkopau, Germany	9,970	100,000	100
Westlake (Vinnolit) - Hürth-Knapsack	13,480	160,000	84
Vynova - Wilhelmshaven	27,670	370,000	75

Data source: European Pollutant Release and Transfer Register (E-PRTR)..

In Europe, 34 PVC, VCM, and EDC factories reported releasing vinyl chloride monomer from 2012 to 2016. No release data could be found in the E-PRTR for three EDC/VCM plants (Inovyn in Antwerp, Belgium, and Dow in Schkopau and Stade, Germany), and two PVC resin manufacturers (Vynova in Beek Geleen, Netherlands, and Westlake (Vinnolit) in Burghausen, Germany).

The largest releases were reported from Kem One in Lavéra, France, which makes VCM (525,000 tons of capacity), but does not directly produce PVC resin. It reported an average of 90.1 tons of VCM releases per year to air.

Among the 26 EU PVC-manufacturing sites that reported VCM releases to air or water from 2012 to 2016 (See Appendix C – Pollution and online spreadsheets for further details):

- 17 plants reported releasing more than 30 grams of VCM per ton of PVC (the Australian industry association's limit for suspension PVC resins).
- 7 of these 17 plants reported releasing over 100 grams of VCM per ton of PVC (the European industry association's limit for suspension PVC resins). Kem One's PVC plant in Saint Auban, France, reported the highest rate: 601 grams of VCM per ton of chlorine.

Many PVC plants in Europe do not produce VCM. To fully account for releases of VCM per ton of capacity, upstream VCM source releases would be included in calculations for these plants. For example, Kem One owns an integrated network of chlorine, EDC, VCM, and PVC resin plants in France and Spain with a combined PVC-resin capacity of 910,000 tons. According to Kem One's reports to the E-PRTR, these plants in Balan, Berre, Lavéra, Saint Auban, Saint Fons, France, and in Hernani, Spain, released a combined 180 tons of VCM per year, or 197.8 grams of VCM per ton of PVC resin capacity. Balan and Berre produce only PVC resins; Kem One's E-PRTR reported releases for these plants average under 30 grams of VCM per ton of resin apiece.

VCM is also present as a residual in PVC resin. In the 1970s, some PVC products, such as vinyl records, contained well over 100 parts per million (ppm) of residual VCM (rVCM). PVC resin manufacturers have since limited these concentrations by using degassing techniques. More degassing occurs with some resins than with others.

The Australian Green Building Council has established a “GreenStar” certification that limits residual VCM in finished resin powder to 1 ppm.<sup>115</sup> Members of the European Council of Vinyl Manufacturers committed to limit rVCM concentrations in emulsion PVC products to below 1 ppm. For suspension PVC, ECVI limits residuals to 1 gram per ton for food and medical applications, but allows up to 5 ppm in other suspension PVC.<sup>116</sup>

Resins with residual VCM content higher than 5 ppm are sold in the US market, such as a resin sold by PolyOne in 2011 that contained up to 8.5 ppm of residual VCM.<sup>117</sup> The US-based Vinyl Institute has resisted EPA efforts to reduce the amounts of rVCM allowed in many PVC resins. In 2011, the trade association opposed a proposed rule to reduce allowed rVCM from 400 ppm to 0.48 ppm in suspension PVC resins and from 2000 ppm to 55 ppm in dispersion resins. It said “all PVC production units will be unable to comply with the proposed limits.”<sup>118</sup>

NSF-ANSI 61, a standard for minimizing health effects from drinking-water systems, limits the allowable levels of rVCM in pipe to 3.2 ppm.<sup>119</sup> Over 9,500 pipes sold in the US were sampled for residual VCM between 1998 and 2015, according to a 2017 Vinyl Institute presentation. At least 95 PVC pipes contained at least 3.2 ppm of rVCM. According to the presenter, many of these pipes with higher than permitted levels of rVCM “were produced off shore.”<sup>120</sup>

## PVC DUST AND PELLETS

Some PVC manufacturing plants release PVC dust which contaminates neighboring communities.

For example:

- The Ineos PVC facility in Newton Aycliffe, U.K., which uses VCM made in Norway, was fined £16,000 for releasing 56 tons of particle-laden gas in 2010. According to Food and Water Watch, these gases “left white dust containing PVC and vinyl chloride on nearby homes and gardens.”<sup>121</sup>
- According to a 1995 TNO report, the AkzoNobel PVC plant in Botlek, Netherlands, released 140 tons of PVC powder in the air in 1990, as well as 200 tons of PVC in sewage sludge and 76 tons of “PVC coagulate.” The emissions came from washing-tower and ventilation systems.<sup>122</sup>

The U.S. National Institutes for Health warns that “exposure to PVC dust may cause asthma and affect the lungs.”<sup>123</sup>

In April 2017, local residents “announced their intent to sue Formosa Plastics for ‘significant, chronic, and ongoing’ Clean Water Act violations that have polluted Lavaca Bay and other waterways,” according to KAVU-TV of Victoria, Texas. Formosa Plastics’ PVC resin plant in Point Comfort, Texas, is the fifth largest in North and South America. “The suit will seek penalties for illegally dumping plastic pellets and PVC dust that could amount to over \$45 million for violations in the last 14 months.”<sup>124</sup>

Microplastic PVC pollution in the ocean is another concern. Local environmentalists charge that for more than a decade PVC manufacturer Formosa Plastics has been illegally dumping PVC pellets into the Gulf of Mexico from its Point Comfort, Texas, plant. According to Texas RioGrande Legal Aid:

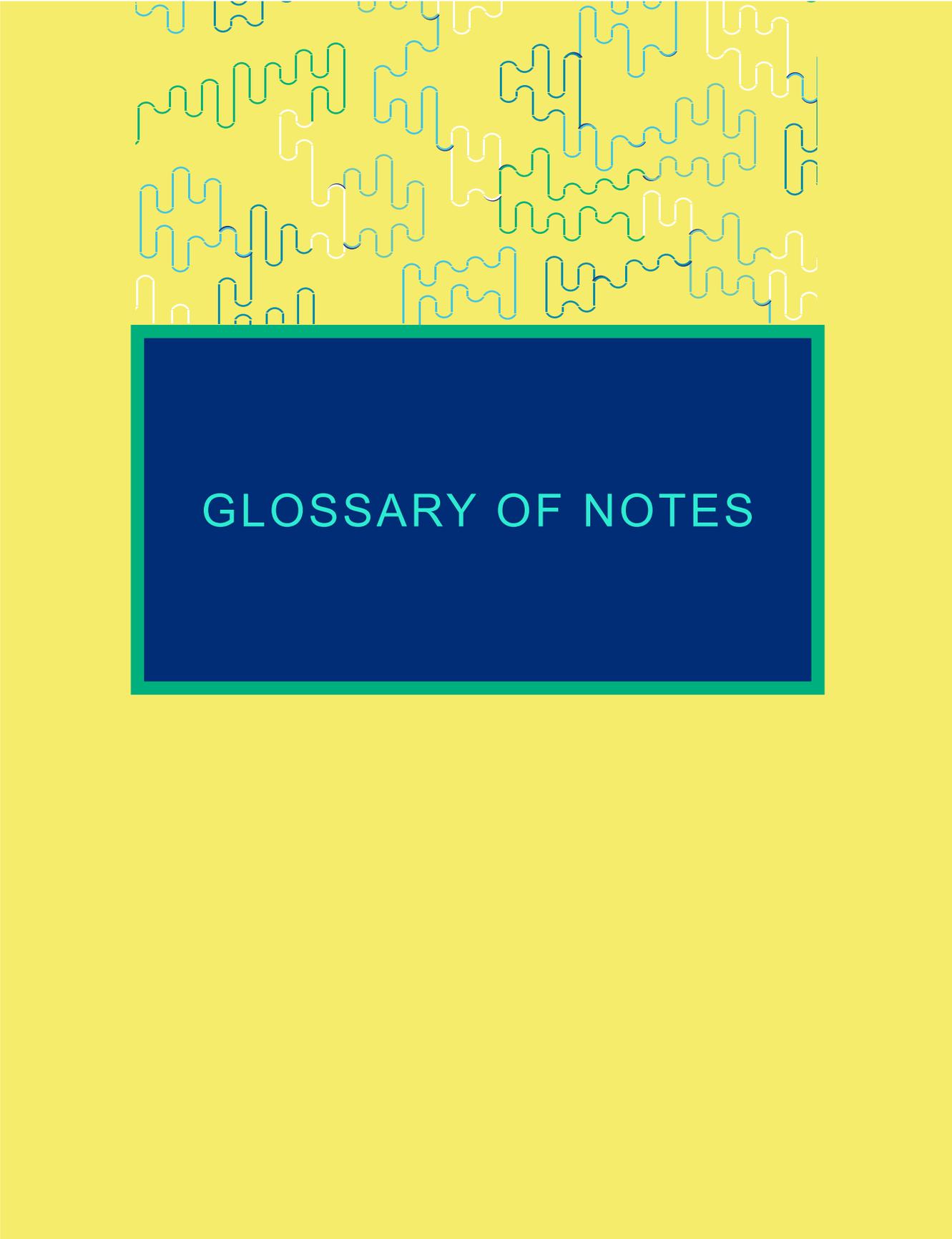
In 1992, the Environmental Protection Agency released a 130-page report entitled *Plastic Pellets in the Aquatic Environment: Sources and Recommendations*, which warned that the pellets, which stay in the environment for 10 years, “have become of particular concern.” The EPA recommended applying “significant penalties” when industries discharge plastic pellets into water.

In 2004 and 2010, the EPA documented Formosa’s problems with a settling pond spilling plastic pellets, and again in 2010, the EPA found the same problem, as part of investigations of the Point Comfort facility.<sup>125</sup>

In 2016 the state of Texas found the company guilty of illegally discharging PVC pellets, but took no enforcement action. Local community groups have continued to document plastic pellet releases from the factory over 20 miles of waterways leading to the Gulf, and in July 2017 filed suit in federal court, seeking \$57 million in fines under the federal Clean Water Act.

PVC resins are denser than seawater and are likely to sink close to where they are discharged. Bottom feeders, such as barnacles, lugworms, and amphipods, may ingest the PVC resins. “A wide range of [marine] vertebrates and invertebrates have been shown to ingest and accumulate plastic debris; however, little is known about the biological effects,” reported a University of Plymouth (U.K.) research team in 2009. They noted that these particles, in other organisms, “exert damage through the combined effect of their intrinsic toxicity and their large surface area. For example inhalation of PVC dust by humans can cause, depending on monomer composition and size, lung and liver damage through tissue fibrosis and cancer.”<sup>126</sup>

Research on potential impacts of PVC on bottom feeders has started to emerge in recent years. A 2016 *Environmental Pollution* article notes, “Lugworms (*Arenicola marina*) fed PVC particles for four weeks fed less, had reduced lipid reserves, and increased inflammatory response. In addition, gut retention times were 1.5 times that of the controls, indicating the use of extended energy-intensive digestive processes. In another study, PVC was found to increase susceptibility of *A. marina* to oxidative stress.”<sup>127</sup>



GLOSSARY OF NOTES

## GLOSSARY OF NOTES

### WEIGHTS, CAPACITIES, AND OTHER FACTORS

#### Capacities

Capacity information reported by companies and others is inherently unreliable.

“It is generally recognized that published capacity figures frequently do not correspond very closely to actual plant capacity,” reads an article in the *Journal of the Electrochemical Industry*. “Published capacities are often overstated because (1) design capacities presume the continuous production of one type of resin and all producers make various types of resins in each plant and (2) there are scheduled and unscheduled shutdowns which are not taken into consideration in so-called nameplate capacity figures.”<sup>128</sup>

According to American Chemistry Council statistics, PVC plants utilized 89.2% of their aggregate capacity in 2016, up from an average of 83.3% in the previous decade.<sup>129</sup>

#### Chemical Conversion Factors

The polyvinyl chloride (PVC) industry states that “57% of PVC is chlorine.”<sup>130</sup> That figure merely describes the elemental composition of PVC (carbon and hydrogen account for 43%, chlorine 57%), but it does not account for all the chlorine that is consumed and released in the production of PVC. Throughout the vinyl supply chain, from chlor-alkali production to EDC and VCM manufacturing to polymerization into PVC, chlorine is lost in fugitive emissions (such as leaks in pipes or tankers carrying feedstock) and as by-products. These chronic and routine releases end up in air, water, and solid waste, and increase the actual amounts of chlorine that must be produced to feed PVC production.

For this report, when calculating the amount of chlorine required to support PVC capacities, we typically use a ratio of 0.61 kilograms (kg) chlorine input per kg of PVC. This is based on chemical conversion rates in standard references<sup>131</sup> and on lists of conversion factors published by petrochemical industry authorities Orbichem and Platt’s.<sup>132</sup> Values from these sources are shown in the table below. To calculate how much chlorine is lost in these reactions, we have taken the amount of chlorine that is required for the overall reaction (0.61 kg Cl / kg PVC) and subtracted the amount of chlorine that ends up in the PVC (0.5672 kg Cl / kg PVC) to arrive at 0.04 kg Cl lost / kg PVC produced. In other words, 7% of the chlorine used by this method is released into the environment or subsumed by by-products, and 93% ends up in PVC.

TABLE 11 . CHEMICAL CONVERSIONS IN PVC PRODUCTION

REACTION STEP	MASS RATIO
Chlorine to VCM	0.59
VCM to PVC	1.03
Overall Reaction: Chlorine to PVC	0.61

Orbichem offers a caveat about its listed rates of conversion: its figures reflect “world average conditions (and are) not necessarily representative of best modern technology.” Nor, most likely, are they representative of the worst conditions.

In addition to chlorine releases, our report uses the following table to calculate chlorine present in releases of other hazardous chemicals in the PVC supply chain.

TABLE 12 . CHLORINE IN CHEMICALS

CHEMICAL	CHEMICAL FORMULA	CHLORINE % OF CHEMICAL BY WEIGHT
Chlorine	Cl <sub>2</sub>	100%
Hydrochloric Acid	HCl	97.24%
Carbon Tetrachloride	CCl <sub>4</sub>	92.19%
Chloroform	CHCl <sub>3</sub>	89.09%
Hexachlorobutadiene	C <sub>4</sub> Cl <sub>6</sub>	81.58%
Ethylene Dichloride (EDC)	C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub>	71.66%
Vinyl Chloride Monomer (VCM)	C <sub>2</sub> H <sub>3</sub> Cl	56.72%
Polyvinyl Chloride (PVC)	(C <sub>2</sub> H <sub>3</sub> Cl) <sub>n</sub>	56.72%

Based on molar mass of chlorine in chemical as calculated in Lenntech online calculator.<sup>133</sup>

There are many ways in which chlorine leaves the production chain, including: pollution (e.g., releases into air, water, and transfers to disposal facilities); on-site treatment; and incorporation in by-products.

Regardless of the actual release rates, Stringer and Johnston note, “the ideal situation - the avoidance of the use of hazardous materials - is impossible within the PVC manufacturing process since the primary feedstocks are themselves inherently hazardous.”<sup>134</sup>

See Findings for further analysis, Inventory for notable plant-specific findings, and Appendices for detailed US and Canadian release information.

### Electrochemical Unit (ECU)

Chlor-alkali plant capacity is sometimes expressed in Electrochemical Units, which are equivalent to a plant’s full installed capacity to produce chlorine, in metric tons (see Capacities note above). A 1 ECU plant has the capacity to produce 1 metric ton of chlorine and 1.1 metric tons of caustic soda.

According to Euro Chlor, an industry association, “By the nature of the chemical reaction, chlorine, caustic soda and hydrogen are always manufactured in a fixed ratio: 1.1 ton of caustic and 0.03 ton of hydrogen per ton of chlorine. This product combination is called an Electrochemical Unit or ECU.”<sup>135</sup>

The European Union describes the ECU’s ratio as “1,070–1,128 kg of caustic and approximately 28 kg of hydrogen gas per tonne of Cl<sub>2</sub> produced.”<sup>136</sup>

For this report, we used this definition to interpret chlorine and other production capacities when they were reported in ECU.

### Toxic Equivalents (TEQs) and Toxic Equivalency Factors (TEFs)

This report’s analysis of dioxin pollution uses Toxic Equivalents, EPA’s preferred measure. Dioxins are a compound group with wildly varying toxicities among its many individual members. The most toxic individual members of the dioxin compound group, like 2,3,7,8-tetrachlorodibenzo-p-dioxin (commonly referred to as dioxin), can do great harm at very low concentrations.

The agency explains: “EPA calculates weighted values called toxic equivalents (TEQs) from the individual mass quantity data reported by facilities and the associated Toxic Equivalency Factors (TEFs). TEQs allow for a better understanding of the toxicity of releases and waste management activities at facilities that report to the TRI Program.”<sup>137</sup>

## Units of Measure

Metric is the preferred measuring system in this report. Where the term *ton* is used without a qualifier it should be read as a metric ton. A metric ton (1,000 kilograms) is the equivalent of 2,204.6 pounds; a kilogram is 2.2046 pounds. When sources report in pounds and other English units, these data are converted to metric units.

## TECHNOLOGIES

### About the Chlor-Alkali Process

The chlor-alkali process consists of three essential components: salt, energy, and technology. From these, the industry produces chlorine and caustic soda.

The supply chain usually begins with the collection of sodium chloride. (Another salt, potassium chloride, is used in some plants.)

Chlor-alkali plants obtain sodium chloride from three kinds of sources: wells (liquid salt; brine), mines (rock salt), and fields (solar-evaporated salt, typically from seawater). These sources influence the type of materials used in chlor-alkali plants. “While the diaphragm process can take full advantage of cheap brine available from brine wells, the mercury process requires solid salt to achieve efficient utilization of salt, although it can also operate with brine as a raw material where that is sufficiently cheap to offset the high unit consumption,” notes a dissertation by Masaru Yarime.<sup>138</sup>

In Europe and Japan, the industry developed near rock salt mines, and predominantly used mercury cells. In the United States, it proliferated around reservoirs of brine, and mostly used asbestos diaphragms. The geography of the chlor-alkali industry also reflects other regional mineral resources, such as asbestos mines in the northern US and Quebec, and mercury mines in the Iberian peninsula.<sup>139</sup>

Production further concentrates in areas with relatively inexpensive energy resources. The chlor-alkali process uses “an extraordinarily powerful electric current,” which passes over water saturated with salt (that is, brine), explains Joe Thornton in *Pandora’s Poison*. “In the special environment of a chlor-alkali ‘cell’ - the chamber in which chlorine is produced - electrical energy forces the chloride atoms out of their stable form and into a new, more reactive chemical state.... At the end of the chlor-alkali process, the sodium is still in an ionic state, but the chlorine is not.”<sup>140</sup>

Plants listed in this report employ four kinds of materials. The first producers in the 19th century used mercury cells and asbestos diaphragms; through the early 1970s, mercury and asbestos continued to be the dominant production materials. Beginning in the 1980s, new plants are using membranes and synthetic diaphragms made of perfluorinated chemicals. Some older plants have switched to using these materials, many have closed, and others still use mercury or asbestos.

### Asbestos Diaphragm

Asbestos minerals are thin, strong, and fibrous. These qualities led to the widespread use of asbestos in filters in various applications, from the late 1700s and the dawn of the Industrial Revolution, to the end of the 20th century. Most applications no longer use asbestos.

“The diaphragm cell technique was developed in the 1880s in the United States and was the first commercial technique used to produce chlorine and caustic soda from brine,” explains a recent European Union (EU) report.<sup>141</sup>

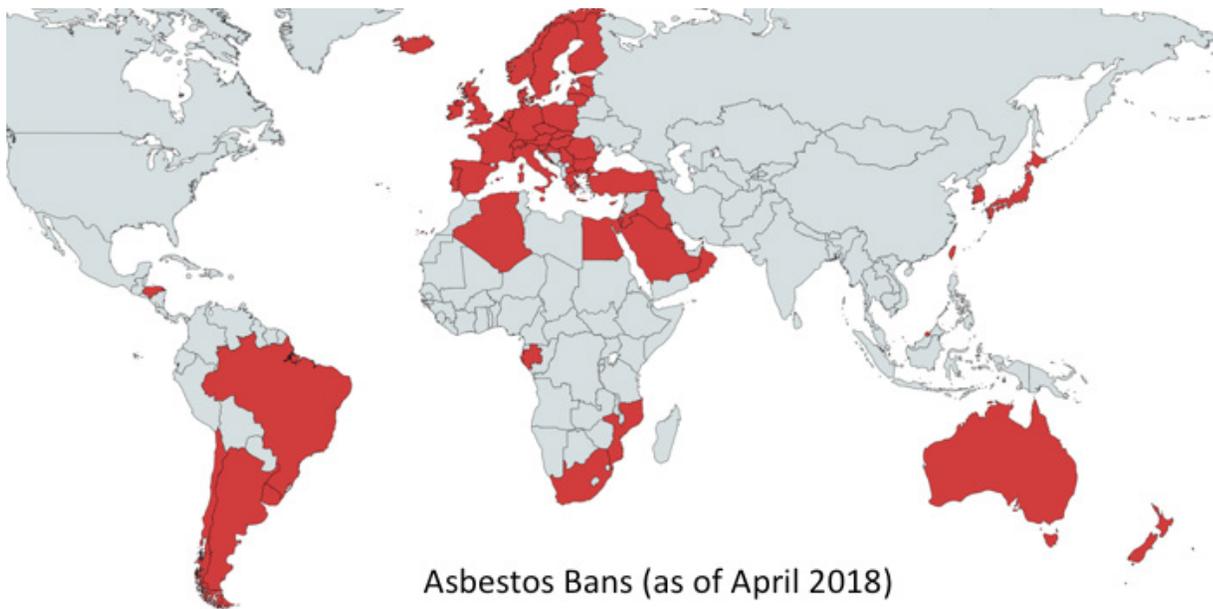
In chlor-alkali electrolytic cells with asbestos diaphragms, brine is split into chlorine gas and sodium at the positive charged end called the anode. Asbestos diaphragms are semipermeable filters that allow sodium ions (but not chlorine gas) to pass through and react with water to form sodium hydroxide and hydrogen gas in the negative

(cathode) terminal of the cell. The diaphragm separator also prevents sodium hydroxide from coming into contact with chlorine gas.<sup>142</sup>

Most, but not all chlor-alkali cell diaphragms are made of asbestos. Some use a combination of asbestos and fluorochemicals, and others use only synthetic (non-asbestos) diaphragms. See below for further discussion.

Asbestos diaphragm technology requires more energy than that of membrane cells and does not produce a comparably high quality of caustic soda as mercury cell plants.<sup>143</sup>

According to the International Ban Asbestos Secretariat, 63 countries have banned all uses of asbestos as of April 6, 2018.<sup>144</sup>



HBN Graphic.

## Membrane Cells

The ion exchange membrane technique is “similar to the diaphragm process, except that a synthetic membrane rather than asbestos is used to separate the compartments in which chlorine and caustic are formed,” says Joe Thornton in *Pandora’s Poison*. This membrane is made from perfluorinated substances.<sup>145</sup>

Membrane cell technology avoids the use of mercury and asbestos, and is less expensive to operate than those older technologies.<sup>146</sup> An EU report says this process makes a “very pure caustic soda solution” and uses “less energy than the other techniques.”<sup>147</sup>

These energy savings are “highly dependent on the quality of the membrane, which must be manufactured from perfluoro compounds to withstand the aggressive conditions within the cell,” according to Ruth Stringer and Paul Johnston in *Chlorine and the Environment*.<sup>148</sup>

DuPont produced the first commercial ion exchange membrane, which it called Nafion. This membrane is made from the copolymerization of tetrafluoroethylene polymer and perfluorovinyl ether.<sup>149</sup> Asahi Glass of Japan developed a different membrane, called Flemion, which a 1980 US Department of Energy report described as “a perfluoropolymer synthesized by a unique process from basic fluorochemicals.”<sup>150</sup>

“The membranes used in the chlor-alkali industry are commonly made of perfluorinated polymers,” says the EU report. “The membranes may have one to three layers, but generally consist of two layers. One of these layers consists of a perfluorinated polymer with substituted carboxylic groups and is adjacent to the cathodic side. The other layer consists of a perfluorinated polymer with substituted sulphonic groups and is adjacent to the anodic side.”<sup>151</sup>

DuPont developed this industry-standard membrane in the 1960s, produced by its Chemours division in Fayetteville, North Carolina. See Pollution Findings section of this report for further information.

There is little information available on the origins, release, or environmental fates of fluorochemicals used in membrane cells.

## Mercury Cells

Mercury is a highly toxic heavy metal that is mined only in a few countries.<sup>152</sup> Global demand for many uses is dwindling; soon, all uses, including chlor-alkali production, will be banned in countries that have ratified the Minamata Convention.

Chlor-alkali plants have used mercury in Europe since 1892.<sup>153</sup> In this process, salt is split into chlorine gas and sodium at the anode (where the electrical current enters the chamber). A shallow film of liquid mercury forms the chamber’s cathode. As the mercury flows from one side of the cell to the other another, sodium amalgamates with the mercury. The amalgam flows on to another cell, where it reacts with water and creates caustic soda and hydrogen gas.<sup>154</sup>

Caustic soda produced via mercury cell routinely contains mercury, at quite significant levels: 20 to 100 parts per million by weight. A carbon-coated filter removes much - but not all - of this mercury.<sup>155</sup>

The production of vinyl chloride monomer (VCM) also can release mercury. The typical practice, outside of China, has been to react chlorine with ethylene and oxygen (making EDC), and then crack that compound to make VCM. In China, however, most chemical companies have used another method. The Royal Society of Chemistry explains that the industry exploited China’s “vast coal resources, turning coal into calcium carbide and from there acetylene. Producers then get VCM by reacting acetylene and hydrogen chloride gas using a *mercury (II) chloride catalyst* [emphasis added] supported on activated carbon.”<sup>156</sup>

The most notorious case of mercury pollution occurred in Minamata, Japan, where the Nippon Chisso Corporation operated a PVC plant after World War II. The complex used mercury catalysts in the production of vinyl chloride monomer and fertilizer and dumped untreated mercury wastes into Minamata Bay. Mercury compounds biomagnify (increase in concentration at higher levels in the food chain) through aquatic food chains. Mercury in fish-laden diets attacked Minamata residents’ central nervous systems and caused widespread birth defects. By the 1990s, tens of thousands of people were suffering from chronic effects of mercury poisoning, known as “Minamata Disease.” At least 1,196 people were killed.<sup>157</sup>

VCM production by the acetylene method continues to be common in China, but nowhere else. The last company in the US to use this method was Borden Chemicals in Louisiana, which closed operations in 2001.

The Minamata Convention, a new global agreement, entered into force in 2017. It aims to reduce the production of mercury catalysts in VCM production by half by 2020. The Minamata Convention also bans the use of mercury in chlor-alkali production by 2025. As of April 16, 2018, there were 67 ratifying parties to the convention, including China.<sup>158</sup> The United States has “accepted,” but not ratified, the Minamata Convention. On October 18, 2013, US Secretary of State John Kerry notified the parties to the convention that the US government “hereby registers for an exemption” from the ban on using mercury to make chlorine and caustic soda.<sup>159</sup>

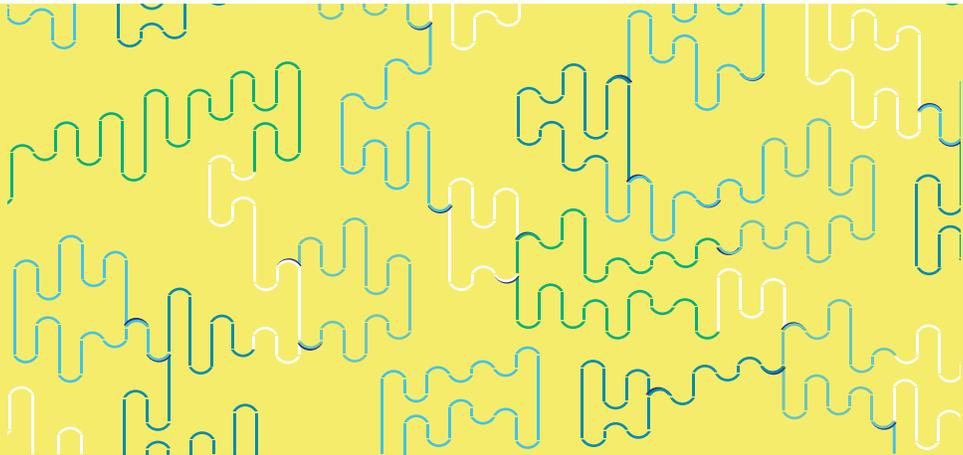
In Russia, where three chlor-alkali plants use mercury cell technology, the RusChlor industry association advocates for continuing all three methods of production.<sup>160</sup>



PMX® (short for Polyramix®) diaphragms are a direct replacement for asbestos diaphragms. They are made of free zirconia particles and PTFE fibers embedded with zirconia particles, and have a porosity similar to that of asbestos.<sup>163</sup>

The Tephram® diaphragms are comprised of layers of PTFE fibers and microfibers, a perfluorinated ion-exchange resin, and a topcoat of metal oxides. During operation, additional materials (such as magnesium hydroxide) are added near the anode of the chamber; these materials help to improve Tephram® diaphragm performance, according to the EU.<sup>164</sup>

As with membrane cells, there is little information available on the origins, release, or environmental fates of fluorochemicals used in synthetic diaphragms.



# THE INVENTORY

## REGION: THE AMERICAS (EXCEPT USA)

### ARGENTINA

#### INVENTORY CODE: AMARG01

- **Plant Name:** *Unipar Carbocloro - Bahia Blanca*
- **Owner:** Unipar Carbocloro, through its Unipar Indupa subsidiary. Formerly owned by Solvay Group (1996-2016) and a consortium of Dow, Itochu, and YPF (1993-1995).<sup>165</sup>
- **Location:** Bahia Blanca, Buenos Aires, Argentina.
- **Process:** Mercury.<sup>166</sup>
- **Year Opened:** 1986.<sup>167</sup>
- **Capacities** (tons per year): 163,000 tons chlorine, 231,000 tons VCM (in 2014<sup>168</sup>); 220,000 tons PVC (in 2016<sup>169</sup>). Reported PVC capacity exceeds known on-site chlorine capacity to provide sufficient feedstock. Likely consumes chlorine from other facilities as well as from its own.
- **Capacity Rank** (Western Hemisphere): 4th of 41 plants overall. Largest of 8 mercury cell plants.
- **Technology Conversions:** Owners plan to convert this plant from mercury cell to membrane technology between 2019 and 2020. This is the last chlor-alkali plant in Argentina still using mercury.<sup>170</sup>
- **Markets:** According to a *Bloomberg* profile of Unipar Indupa, the company produces PVC products “for use in automotive, building and construction, consumer goods, electrical and electronics, healthcare, packaging, plumbing, and wire and cable markets. The company also provides chemicals, such as caustic soda or sodium hydroxide liquid and prills for various applications in aluminum, paper and pulp, chemicals, soaps and detergents, cleaning, refinery, metalworks, food, textile, water treatment, and other industries.”<sup>171</sup>
- **Pollution:**
  - August 20, 2000: A leak in a 15-year-old pipe released a massive cloud of chlorine; however, a strong wind blew the cloud away from densely populated areas, averting tragedy.<sup>172</sup>
  - Greenpeace scientists surveyed the adjacent environment three times between 1996 and 2000. They identified vinyl chloride, hexachlorobenzene, and mercury in an open waste canal leading to the bay (Bahia Blanca), and in channels running through and around the complex. One sediment sample in the main discharge contained 14.98 parts per million (ppm) mercury. Sediment in a runoff channel 1.9 kilometers from the plant’s ethylene pipes registered 21.29 ppm mercury.<sup>173</sup>
  - Scientists from a federal Argentine institute have tracked and found elevated mercury levels in sediment, fish, and crabs in the bay, which they attribute to the nearby chemical complex.<sup>174</sup>

### BRAZIL

#### INVENTORY CODE: AMBRA01

- **Plant Name:** *Braskem - Maceió*
- **Company:** Braskem. Originally Salgema Indústria Química S.A., then Trikem, which became part of Braskem.<sup>175</sup>
- **Location:** Maceió, Alagoas, Brazil.
- **Process:** Synthetic (non-asbestos) diaphragm.<sup>176</sup> Conversion from asbestos diaphragm completed in 2016.
- **Year Opened:** 1977.
- **Capacities** (tons per year): 409,400 tons chlorine (2016).<sup>177</sup> 460,000 tons PVC (2012).<sup>178</sup> Reported PVC capacity exceeds known on-site chlorine capacity to provide sufficient feedstock. Likely consumes chlorine from other facilities as well as from its own.

- **Capacity Rank** (Western Hemisphere): 13th of 41 plants overall. Largest of 5 synthetic diaphragm plants.
- **Technology Conversions:** Opened in 1977 with asbestos diaphragm, 250,000 tons capacity.<sup>179</sup> Conversion from diaphragm completed in December 2016. Braskem reported, “Our largest chlor-alkali plant located in Alagoas previously used asbestos cell technology to produce chlorine and caustic soda. Such technology can no longer be used in new petrochemical production facilities under Brazilian legislation and the global trend has been to ban this technology. As a result, in November 2016, we concluded our shift to newer diaphragm technology and banned asbestos technology from our plants.”<sup>180</sup>
- **Markets:** PVC produced at this plant is used mainly in building and construction.<sup>181</sup>
- **Pollution:**
  - A local union reported that three dichloroethane leaks from this plant on October 10, 2010, led to a large chemical overflow from a tank containment dam, “causing contamination of the soil and environment,” according to Antônio Freitas, director of Sindipetro AL / SE. The accident may have contaminated the water table, according to the union.<sup>182</sup>
  - In May 2011, two serious accidents took place, two days apart. In one, a pipe ruptured, injuring five workers. In the second, a chlorine leak sickened 130 people, including 20 children. People reported smelling chlorine up to three kilometers away from the plant. Symptoms included “intoxication, respiratory problems, vomiting and severe headaches,” according to a news report.<sup>183</sup> The Secretaria Municipal do Meio Ambiente in Maceio fined Braskem \$1.1 million for these accidents.<sup>184</sup>

## INVENTORY CODE: AMBRA02

- **Plant name:** *Braskem - Camaçari Petrochemical*
- **Owner:** Braskem. Formerly Companhia Petroquímica Camaçari / Companhia Química do Recôncavo (CQR).
- **Location:** Polo Petroquímico, Bahia, Brazil.
- **Process:** Mercury (as of 2016).
- **Year Opened:** 1963/1979.<sup>185</sup> The mercury cell plant was originally opened in 1963, in Lobato, a suburb of Salvador, Bahia, where it was operated by Companhia Química do Recôncavo (CQR). The factory was moved to Camaçari in 1979.<sup>186</sup>
- **Capacities** (tons per year): 70,300 tons per year chlorine (2016).<sup>187</sup> Estimated 56,000 tons PVC capacity based on chemical conversion rates (see Glossary).
- **Capacity Rank** (Western Hemisphere): 36th of 41 plants overall. 5th of 8 mercury cell plants.
- **Markets:** PVC production for construction.<sup>188</sup>
- **Technology Conversions:** Braskem has not announced plans to convert this 54-year-old plant to non-mercury technology. The company’s 2016 annual report notes, “The vinyl plant situated in the Camaçari Petrochemical pole employs mercury cell technology for the production of chlorine, this technology may no longer be used in new petrochemical industrial units under the terms of recent Brazilian legislation, due, in part, to environmental concerns relative to mercury emissions resulting from this industrial process.”<sup>189</sup> In 2017, Brazil ratified the Minamata Convention, which prohibits the use of mercury cells in chlor-alkali production by 2025.<sup>190</sup> Braskem described efforts to replace the mercury cells as being “in a conceptual stage” as of 2012.<sup>191</sup>
- **Pollution:**
  - The federal government sued Braskem in 2014 to clean up mercury pollution released by the mercury cell plant while it operated near Salvador. According to the Bahia prosecutors, the CQR plant released liquid mercury chloride directly into the sea. The plant poured an estimated two to four kilograms of mercury per day into Baía de Itapagipe.<sup>192</sup>

## INVENTORY CODE: AMBRA03

- **Plant Name:** *Unipar Carbocloro - Cubatão*
- **Owner:** Unipar Carbocloro. Unipar acquired Occidental Petroleum's share of their Carbocloro joint venture in 2013.<sup>193</sup>
- **Location:** Cubatão, São Paulo, Brazil
- **Processes:** Mercury, membrane, and synthetic diaphragm.
- **Year Opened:** 1965.<sup>194</sup>
- **Capacities** (tons per year): Total: 355,000 (2014), of which installed mercury capacity was reported to be 107,100 tons; synthetic diaphragm capacity, 147,900 tons; and membrane, 100,000 tons.<sup>195</sup>
- **Capacity Rank** (Western Hemisphere): 15th of 41 plants overall. Second of eight mercury cell plants, 18th of 24 membrane plants, and 4th of 5 synthetic diaphragm plants.
- **Technology Conversions:**
  - Prompted by a State of São Paulo ban on asbestos, the plant owners converted the asbestos diaphragms to synthetic diaphragms (Polyramix™, or PMX, diaphragms), in 2011.<sup>196</sup> In 2014, it was one of ten plants worldwide to use non-asbestos diaphragm technology.<sup>197</sup> (Braskem in Maceió, Brazil [AMBRA01] converted to synthetic diaphragm technology in 2016.)
  - According to a government report, Unipar Carbocloro plans to convert its mercury cells to membrane technology by the end of 2019.<sup>198</sup> Brazil, having ratified the Minamata Convention, will ban the use of mercury in chlor-alkali production in 2025.
- **Markets:** EDC produced in Cubatão is a feedstock for Unipar Carbocloro's Santo Andre 300,000 ton PVC complex.<sup>199</sup>
- **Pollution:**
  - In 2006, the Associação de Combate aos POPs (ACPO), a São Paulo-based environmental group, filed a complaint<sup>200</sup> with federal prosecutors claiming numerous environmental impacts from the plant's ongoing use of mercury cells. The cells produce a mud containing 5.7% mercury. Among the group's claims:
    - The plant for many years incorporated mercury-laced mud in concrete blocks used in on-site construction.
    - The plant for many years stored mercury waste on-site "in silos which caused environmental contamination."
    - Until 2004, the company shipped mercury waste to a waste recycling company in Paulínia, Campinas, in the neighboring state of São Paulo. This practice ended after researchers found "up to 1,352 ng/m<sup>3</sup> mercury in the air." The recycling facility was located next to a school.
    - The company shipped an estimated 4,560 kilograms of untreated mercury mud to a landfill -- Tribel (Tratamento de Resíduos Industriais de Belford Roxo S.A) -- in the state of Rio de Janeiro. A Greenpeace research lab found mercury levels as high as 244 parts per million (ppm) in the landfill.
  - University of Campinas researchers estimated that the waste recycling company in Paulínia released 25 kilograms of mercury into the air in 2000.<sup>201</sup>
  - In April 1998, Greenpeace drew samples of Cubatão River sediment adjacent to and effluent from Carbocloro and found mercury levels as high as 15.6 ppm. Soil typically contains less than 0.5 ppm mercury. "The source of this mercury remains unclear, although the possibility that it has arisen as a result of the manufacture of chlorine at the Carbocloro mercury cell chlor-alkali facility should be investigated further. It is understood that this section of the river was being dredged at the time of sampling. In this case the dredged material could act as a significant source of volatile mercury to the atmosphere, as well as to the water through resuspension of contaminated sediment. This also applies to the organic contamination discussed above. The final fate of this dredged material should be monitored closely," suggested Greenpeace.<sup>202</sup>

- The São Paulo state environmental agency fined the company several times between 1989 and 1994 for exceeding permitted mercury concentrations in water discharges.<sup>203</sup>

## INVENTORY CODE: AMBRA04

- **Plant Name:** Unipar Carbocloro - Santo André
- **Owner:** Unipar Carbocloro (formerly Solvay Indupa).
- **Location:** Santo André, São Paulo, Brazil.
- **Process:** Membrane.
- **Year Opened:** 1941. Originally named Industrias Quimicas Electrocloro. Solvay later acquired majority stake. In December 2016, Unipar Carbocloro acquired Solvay Indupa, including this plant.<sup>204</sup>
- **Capacities** (tons per year): 155,000 tons chlorine; 300,000 tons VCM; 273,000 tons suspension PVC; 27,000 tons emulsion PVC (2016).<sup>205</sup> This plant also receives EDC from Unipar Carbocloro's nearby plant in Cubatão (AMBRA03).
- **Capacity Rank** (Western Hemisphere): 31th of 41 plants overall. 16th of 24 membrane plants.
- **Technology Conversions:**
  - Plant was established in 1941 under the name Industrias Quimicas Electrocloro.
  - It produced vinyl chloride monomer using the acetylene/VCM process between 1955 and 1996. Thereafter, it switched to the balanced (non-acetylene) process (see Glossary).<sup>206</sup>
  - In 2009, the chlor-alkali plant stopped using mercury cells and converted to membrane technology. The \$150 million project increased capacity from 115,000 to 155,000 tons of chlorine per year.<sup>207</sup>
- **Markets:** Automotive, building and construction, consumer goods, electrical, healthcare, packaging, plumbing, and wire cabling.<sup>208</sup>
- **Pollution:**
  - "Landfill mining" of this plant's wastes resulted in dioxin and dibenzofuran contamination of dairy products in Europe in 1997. Researchers from Brazil and Germany pieced this chain of events together in a 2012 article. The Santo André plant, for many decades, produced vinyl chloride monomer using the acetylene/VCM process. This process is catalyzed by mercury chloride, and it produces a waste called "lime milk." The lime milk from a Brazil PVC plant contaminated cow's milk in Germany with high concentrations of dioxins and dibenzofurans. An estimated 1.4 million tons of acetylene/VCM lime milk was stored in the landfill. In 1997, Carbotex, a Brazilian company, used some of this waste from the landfill to "treat" citrus pulp pellets used as cattle feed across the Atlantic, in Europe. It added the lime milk at a 2% concentration to adjust the pH of the feed. As a result, according to the researchers, "after years of slowly declining values, the mean dioxin content in milk (in SW Germany) rose from 0.62 to 1.41 pg I-TEQ/g fat within half a year." The peak concentration in these samples was almost 8 pg I-TEQ/g fat. Within weeks, similar concentrations in milk and dairy products were reported from several regions in Germany and other European Union member states."<sup>209</sup> Solvay, then the plant owner, contended that a risk assessment "showed that our lime residues were acceptable for use in construction applications... Our deliveries to Carbotex traditionally matched chemical specifications corresponding to uses in the construction sector. We were surprised to learn that this lime was used for other applications such as animal feed processing. Once informed of a potential problem, we immediately stopped delivery of our lime on 5 August 1998."<sup>210</sup>

## INVENTORY CODE: AMBRA05

- **Plant name:** *Dow Química - Aratu*
- **Owner:** DowDuPont Inc. Dow merged with DuPont in 2017.
- **Location:** Bahia, Brazil.
- **Process:** Asbestos diaphragm.<sup>211</sup>

- **Year Opened:** 1977.<sup>212</sup>
- **Capacities** (tons per year): 415,000 tons chlorine (2014).<sup>213</sup>
- **Capacity Rank** (Western Hemisphere): 12th of 41 plants overall. 7th of 11 asbestos diaphragm plants.
- **Technology Conversions:**
  - On December 27, 2017, the governor of Bahia vetoed legislation that would have allowed Dow to continue using asbestos at this plant until 2026.<sup>214</sup> This action followed a federal Supreme Court decision on November 29, 2017, to ban all extraction and consumption of asbestos in Brazil.<sup>215</sup> Dow reportedly agreed to convert to non-asbestos technology by 2019, six years earlier than it had planned.<sup>216</sup>
- **Markets:**
  - On-site production of propylene dichloride - a feedstock for isocyanate production<sup>217</sup> - and propylene oxide.
  - Dow produced carbon tetrachloride and perchloroethylene on this site until 2009.<sup>218</sup>
  - The plant also was connected to a toluene diisocyanates plant in Camaçari, which Dow closed in 2011.<sup>219</sup>
  - Dow ships an average of 16,000 metric tons of propylene dichloride per year from Aratu, Brazil, to Freeport, Texas,<sup>220</sup> where Dow produces toluene diisocyanate.<sup>221</sup> These shipments equal about one-tenth of the global production of propylene dichloride.<sup>222</sup>
- **Pollution:**
  - The mining of asbestos, outlawed by Brazil's Supreme Court in December 2017, left a legacy of cancer and contaminated water across Brazil, in communities like Bom Jesus da Serra in Bahia, where asbestos was mined for 30 years,<sup>223</sup> and in Minaçu, Goiás, Brazil, the main source of asbestos used in the chlorine industry of the Western Hemisphere. A team of researchers tracked the health of asbestos miners in Minaçu from 1997 to 2000. They found that 1.4% of the miners developed diseases caused by asbestos.<sup>224</sup>

## CANADA

### INVENTORY CODE: AMCAN01

- **Plant Name:** *Chemtrade - North Vancouver*
- **Owner:** Chemtrade Logistics Income Fund, which acquired Canexus Corporation in 2017.<sup>225</sup>
- **Location:** North Vancouver, British Columbia, Canada.
- **Process:** Membrane. Converted from asbestos diaphragm in 2010.
- **Year Opened:** 1957.
- **Capacities** (tons per year): 231,000 tons chlorine (2014)<sup>226</sup>
- **Capacity Rank** (Western Hemisphere): 26th of 41 plants overall. 11th of 24 membrane plants.
- **Technology Conversions:** Converted from asbestos diaphragm to membrane in 2010.<sup>227</sup>
- **Markets:** Produces chlorine, caustic soda, and hydrochloric acid (62,700 dry metric tons).<sup>228</sup> According to a company prospectus, this plant's products include caustic soda sold to pulp and paper mills in western Canada and the Pacific Northwest; chlorine for water treatment and "general industrial applications" in the United States; and hydrochloric acid for "multiple industrial applications" in the Pacific Northwest.<sup>229</sup> According to a SmartRail coalition report in 2007, most of the plant's chlorine is shipped by rail to the United States. "Canexus ships out more than 1,700 rail chlorine tanker cars each year, each containing some 90 tons of the gas," it reported. "The vast majority of this chlorine is shipped to the United States over BNSF rails through South Surrey and White Rock (more than 90% of all the plant's production)..."<sup>230</sup> Marty Cove, logistics manager for Canexus, told the Canadian Parliament Transport Committee in 2014, "We don't ship much chlorine in Canada, to be honest with you. The vast majority of our chlorine goes to the U.S."<sup>231</sup> Destinations include East Texas, Missouri, and Illinois.

- **Pollution:**

- According to the *Vancouver Observer*, a chlorine leak hospitalized four workers on March 2, 2011. Community leaders have long expressed concern about the plant's proximity to a densely populated area.<sup>232</sup>
- Air permit allows 0.87 metric tons chlorine and 0.42 metric tons hydrochloric acid, for which the company requested increases to 0.99 and 0.58 tons respectively in 2015.<sup>233</sup>
- On Nov. 16, 2016, three workers required treatment after exposure to a chlorine leak. "The leak happened as workers were filling a rail car with chlorine," according to a local news report.<sup>234</sup>
- For more pollutant release information, see Appendix.

## INVENTORY CODE: AMCAN02

- **Plant Name:** *Westlake - Beauharnois*
- **Owner:** Westlake Chemical Corp. Westlake purchased Axiall, the previous owner, in 2016.<sup>235</sup> Axiall formed in 2013 from the merger of Georgia Gulf Corp. and PPG Industries' chemicals business.<sup>236</sup>
- **Location:** Beauharnois, Québec, Canada.
- **Process:** Membrane.<sup>237</sup>
- **Year Opened:** 1948. Converted from mercury cell to membrane in 1991.<sup>238</sup>
- **Capacities** (tons per year): 88,000 tons of chlorine (1992).<sup>239</sup> 46,500 tons of sodium hypochlorite and 26,200 tons of hydrochloric acid.<sup>240</sup>
- **Capacity Rank** (Western Hemisphere): 35th of 41 plants overall. 19th of 24 membrane plants.
- **Technology Conversions:** Converted from mercury to membrane in 1991.<sup>241</sup> According to Oceana, "PPG announced in mid-June 1989 that it would convert its Beauharnois, Quebec, mercury-based chlor-alkali facility to membrane-cell technology. At the time, the conversion was expected to finish in December 1990 - or about 18 months after the announcement. However, the factory conversion was not completed until May 1991 - or 23 months after the announcement."<sup>242</sup>
- **Markets:** Manufactures chlorine, sodium hydroxide, sodium hypochlorite, and hydrochloric acid.<sup>243</sup> Sells to consumer, forestry, manufacturing, medical, biotechnology, and chemical product manufacturers.<sup>244</sup>
- **Pollution:**
  - "Between 1984 and 1987, the plant in Beauharnois discharged approximately 200 grams of mercury a day," according to researchers of mercury pollution in the St. Lawrence estuarine system.<sup>245</sup>
  - Environment Canada found that this plant "lost" on average 5 grams of mercury per ton of chlorine produced between 1986 and 1989. Emissions into the air represented the highest proportion of these losses. Mercury was also released in effluent, solid waste, and products.<sup>246</sup>
  - This is the only Canadian chlor-alkali plant to have reported dioxin release data from 2012 to 2016.

## INVENTORY CODE: AMCAN03

- **Plant Name:** *Olin - Bécancour*
- **Owner:** Olin Canada (formerly Société PCI Chimie), subsidiary of Olin Corporation.
- **Location:** Bécancour, Québec, Canada
- **Process:** Asbestos diaphragm and membrane.
- **Year Opened:** 1974.<sup>247</sup>
- **Capacities** (tons per year): Total: 175,000 tons chlorine (diaphragm 110,000 tons; membrane 65,000 tons).<sup>248</sup> In 2014, an explosion led to the permanent closure of 185,000 tons chlorine production capacity.<sup>249</sup> Capacity in 2014 (pre-explosion) was: diaphragm (297,000 tons) and membrane (65,000 tons).<sup>250</sup> It imports about 15 tons of asbestos per year.

- **Capacity Rank** (Western Hemisphere): 28th of 41 plants overall. 14th of 15 asbestos plants, 21st of 24 membrane plants.
- **Technology Conversions:**
  - Olin has not announced plans to replace its asbestos diaphragms. It is the only chlor-alkali plant in Canada that still uses asbestos. A proposed Canadian regulation phases out the use of asbestos in chlor-alkali production by 2025.<sup>251</sup>
  - In 2014, Olin permanently closed 185,000 tons of production capacity at the Bécancour plant.<sup>252</sup>
- **Markets:** Main products are bleach, hydrochloric acid, chlorine, and caustic soda, which are sold to consumers in Canada and the USA.<sup>253</sup> Primary markets for its hydrochloric acid are the steel, food, and chemical sectors.<sup>254</sup>
- **Pollution:**
  - *June 25, 2014:* A condenser containing chlorine exploded and destroyed one of Olin's two chlor-alkali factories (BEC-1) in Bécancour.<sup>255</sup> According to a CTV News Montreal report, "Witnesses reported seeing a large yellow cloud, which would likely be chlorine gas, coming from the factory. Reporters on site right after the explosion said the fumes were overpowering." A man delivering pizza in the area was overcome by gas but expected to fully recover. No other hospitalizations were reported.<sup>256</sup> In December 2014, Olin announced it would "permanently close the portion of its Bécancour, Quebec, Canada facility that has been shut down since late June 2014."<sup>257</sup>
  - According to Canadian National Pollutant Release Inventory data, this plant released 20.6 tons of chloroform per year from 2012 to 2016. This is more than double the industry median rate of chloroform releases on a per capacity basis.

## MEXICO

### INVENTORY CODE: AMMEX01

- **Plant Name:** *Mexichem - PMV Plant Chloro-Sosa*
- **Owners:** Mexichem and Pemex (joint venture).
- **Location:** Pajaritos Petrochemical Industrial Complex, Coatzacoalcos, Veracruz, Mexico.
- **Process:** Asbestos diaphragm.<sup>258</sup>
- **Year Opened:** 1980.<sup>259</sup>
- **Capacities** (tons per year): 260,000 tons chlorine, 286,000 tons caustic soda, and 20,000 tons sodium hypochlorite.<sup>260</sup>
- **Capacity Rank** (Western Hemisphere): 20th of 41 plants overall. 12th of 14 asbestos plants.
- **Technology Conversions:**
  - Originally a government enterprise named Cloro de Tehuantepec; later owned by Pennwalt Química. In 1998, Pennwalt and PVC manufacturer Polímeros de Mexico, S.A. de C.V. combined to form Mexichem.<sup>261</sup> The plant's initial capacity (236,000 metric tons per year chlorine) exceeded all existing Mexican capacity at the time.<sup>262</sup>
  - In December 2017, Mexichem and Pemex decided not to rebuild an associated vinyl chloride monomer plant, which was destroyed in a deadly explosion in 2016. The PMV joint venture will continue to operate the chlor-alkali plant, according to Mexichem.<sup>263</sup>
- **Markets:**
  - The destroyed VCM plant, Clorados III, was the main consumer of the chlor-alkali plant's chlorine, but there have been "several other clients." Petrochem reported after the explosion that "in addition to the VCM it receives from this plant, Mexichem also buys VCM from the US through a contract with OxyVinyls, and on a spot basis from Axiall, to feed its PVC production in Mexico."<sup>264</sup>
  - Mexichem owns PVC plants throughout the Americas, including:
    - Two plants in the USA (Pedricktown NJ and Henry, Illinois, with a combined capacity of 250,000 tons per year;

- Two of the ten largest PVC plants in the hemisphere, the 876,000 ton per year plant in the Gulf Coast city of Altamira, Mexico, and the 500,000 ton per year PVC plant in Cartagena, Colombia.
- **Pollution:**
  - “On April 20th, 2016, an explosion occurred in the VCM plant inside the Petrochemical Complex Pajaritos, where two of the three facilities of PMV are located (VCM and Ethylene). The chlorine and caustic soda plant is located on a separate site. There was no damage to the chlorine-caustic soda plant, but there was business interruption in the supply of raw material. The VCM plant (Clorados III) is the one that sustained most of the damage, the major economic impact of which was the write-off of the asset and the shutdown of that plant,” Mexichem said in its 2016 annual report.<sup>265</sup>

The explosion killed 32 people, all contractors. Another 136 people were injured.<sup>266</sup> Preliminary findings on the cause of this tragedy allegedly have been kept secret.<sup>267</sup> Federal environment agency officials found high levels of hazardous substances in the area after the explosion, including EDC, hydrochloric acid, and cupric chloride.<sup>268</sup>
  - Fishing interests say that the plant has polluted the water with sodium hypochlorite.<sup>269</sup>
  - The plant consumed an average 78 tons of carbon tetrachloride (CTC) between 1994 and 2004. A company submission to the United Nations Environment Programme calculated that 206 kilograms (20.6%) are released to the atmosphere for each ton of CTC consumed as a process agent.<sup>270</sup> Carbon tetrachloride is highly destructive to earth’s ozone layer.<sup>271</sup>

## INVENTORY CODE: AMMEX02

- **Plant Name:** *Cydsa - IQUISA Coatzacoalcos*
- **Owner:** Industria Quimica del Istmo SA (IQUISA) is a subsidiary of CYDSA.
- **Location:** Pajaritos Petrochemical Industrial Complex, Allende, Veracruz, Mexico. Near the PMV chlor-alkali plant in Coatzacoalcos.
- **Process:** Mercury.
- **Year Opened:** 1967.<sup>272</sup>
- **Capacities** (tons per year): 98,000 tons of chlorine, 110,000 tons caustic soda, 91,250 tons hydrochloric acid (2016).<sup>273</sup>
- **Capacity Rank** (Western Hemisphere): 34th of 41 plants overall. 4th of 8 mercury plants.
- **Technology Conversions:**
  - In 2015, Mexico ratified the Minamata Convention, which prohibits the use of mercury cells in chlor-alkali production by 2025.<sup>274</sup>
  - CYDSA has not announced plans to stop using mercury at its Coatzacoalcos plant.
  - According to a 2016 United Nations Environmental Programme (UNEP) Global Mercury Partnership business plan, “Mexico is encouraging a private company (IQUISA-CYDSA) to seek financing to switch to membrane cells at their two plants in Mexico.”<sup>275</sup>
- **Markets:**
  - Petrochemical, chemical, cellulose and paper, water purification and sanitation.<sup>276</sup>
  - Exports to Central America.<sup>277</sup>
- **Pollution:**
  - In a study published in 2016, 20 out of 22 hair samples taken from local residents found mercury at possibly harmful levels.<sup>278</sup> “There is a hidden economic cost, in addition to the environmental and health costs of exposure to mercury,” said Fernando Bejarano of the Center for Analysis and Action on Toxics and their Alternatives (CAATA). “When the industry argues that it can not afford to stop using mercury, or the government says it is very costly, they do not consider the damage to the future.”<sup>279</sup>

- In tests published in 2013, mean mercury levels from 15 different fish samples in the Coatzacoalcos River were found to be higher than the US EPA reference dose of 0.22 ppm. The IQUISA Coatzacoalcos chlor-alkali plant was identified as one of two major sources of mercury pollution in the region.<sup>280</sup>

### INVENTORY CODE: AMMEX03

- **Plant Name:** *Cydsa - IQUISA Noreste*
- **Owner:** Industria Quimica del Istmo SA (IQUISA) is a subsidiary of CYDSA.
- **Location:** Garcia, Monterrey, Nuevo Leon.
- **Process:** Membrane.<sup>281</sup>
- **Year Opened:** 1958 (original mercury cell plant).<sup>282</sup>
- **Capacities** (tons per year): 60,000 tons chlorine; 68,000 tons caustic soda. Can produce 12,000 tons of chlorine in cylinders.<sup>283</sup>
- **Capacity Rank** (Western Hemisphere): 37th of 41 plants overall. 22nd of 24 membrane plants.
- **Technology Conversions:**
  - Conversion from mercury cell to membrane completed in March 2016.<sup>284</sup>
- **Markets:**
  - Chlorine: PVC, pigments, water disinfection.
  - Caustic soda: Paper industry, soap, detergents, chemicals.
  - Hydrochloric acid: Steel, food, and other industrial processes.
  - Sodium hypochlorite: bleach production, water treatment.<sup>285</sup>

### INVENTORY CODE: AMMEX04

- **Plant Name:** *Cydsa - IQUISA Santa Clara*
- **Owner:** CYDSA. Industria Quimica del Istmo SA (IQUISA) is a subsidiary of CYDSA, which purchased this plant from Mexichem in 2010.<sup>286</sup>
- **Location:** Ecatepec de Morelos, State of Mexico, Mexico.
- **Process:** Membrane.
- **Year Opened:** 1958 (original mercury cell plant). Converted from mercury to membrane in 2007.<sup>287</sup>
- **Capacities** (tons per year): 38,500 tons of chlorine, 43,350 of caustic soda, 150,000 tons of sodium hypochlorite, and 70,000 tons of hydrochloric acid (2016).<sup>288</sup>
- **Capacity Rank** (Western Hemisphere): 40th of 41 plants overall. 24th of 24 membrane plants.
- **Technology Conversions:** Converted from mercury cell to membrane in 2007.
- **Pollution:**
  - A commission of the environment ministers of Canada, Mexico, and the U.S. reported in 2011 that then-owner Mexichem did not provide information it requested about the fate of unused mercury after the plant converted to membrane technology.<sup>289</sup>
  - The plant is located in the middle of what a Los Angeles Times article in 2016 described as “one of Mexico’s most troubled cities.”<sup>290</sup> CYDSA’s 2014 annual report says that it has allocated around US\$10 million for land remediation due to pollution here and at another site.<sup>291</sup>

### INVENTORY CODE: AMMEX05

- **Plant Name:** *Mexichem - El Salto*
- **Owner:** Mexichem, whose predecessor acquired Quimica Pennwalt, the company that opened the plant, in 1997.<sup>292</sup>

- **Location:** El Salto, Jalisco, Mexico.
- **Process:** Asbestos Diaphragm.
- **Year Opened:** 1976 (started chlor-alkali production). Pennsalt, later named Quimica Pennwalt, had been producing insecticides on this site since 1951.<sup>293</sup>
- **Capacities** (tons per year): 40,000 tons chlorine, 70,000 tons sodium hypochlorite, and 26,000 tons of hydrochloric acid (2012).<sup>294</sup>
- **Capacity Rank** (Western Hemisphere): 39th of 41 plants overall. Smallest of 15 asbestos diaphragm plants.
- **Technology Conversions:** None announced.
- **Markets:** According to Mexichem, this plant's chemicals are used in the "production of PVC resin and products derived from salt, chlorine and caustic soda. Mexichem's plants in Altamira, Tlaxcala, the State of Mexico, and El Salto supply hundreds of companies, sustaining the value chain of countless products." Many products are exported.<sup>295</sup>
- **Pollution:** The industrial corridor of Jalisco, including this plant, contribute to "a channel of industrial waste that has destroyed wildlife and the possibility of using its waters [for any other purpose]," claims a Guadalajara research team.<sup>296</sup>

## PERU

### INVENTORY CODE: AMPER01

- **Plant Name:** Quimpac - Oquendo-Callao
- **Owner:** Quimpac (formerly known as Química del Pacífico S.A).
- **Location:** Callao, Lima, Peru.
- **Process:** Membrane and mercury.
- **Year Opened:** 1964 (mercury), 2014 (membrane).
- **Capacities** (tons per year): Estimated 117,000 tons chlorine (58,000 tons from membrane technology, 49,000 tons from mercury cells). Two Quimpac plants in Peru (Oquendo and Paramonga) have a combined 76,000 tons chlorine capacity from mercury cell technology.<sup>297</sup> In 2008, the Oquendo plant reportedly had 54,000 tons caustic soda capacity<sup>298</sup>, which corresponds with a 49,000 tons chlorine capacity.<sup>299</sup> It added a new membrane chlor-alkali plant in 2014, with a capacity of 64,000 tons caustic soda, or 58,000 tons chlorine.<sup>300</sup>
- **Capacity Rank** (Western Hemisphere): 33rd of 41 plants overall. 6th of 8 mercury cell plants, 23rd of 24 membrane plants.
- **Technology Conversions:**
  - In 2002, the Inter-American Investment Corporation (IIC) - part of the Inter-American Development Bank - approved a \$10 million loan toward Quimpac infrastructure improvements. For the Oquendo-Callao plant, the loan financed filters to reduce mercury in brine sludge, and to reduce mercury in caustic soda produced by the plant. These measures were designed to bring mercury levels in plant effluent into conformance with global standards.<sup>301</sup>
  - A Quimpac advisor told a U.S. Geological Survey official in 2007 that there were "no immediate plans to change to non-mercury chlor-alkali production."<sup>302</sup>
  - In 2008, Quimpac announced plans to double capacity at the Oquendo plant.<sup>303</sup>
  - In a meeting with Peruvian government officials in 2010, Quimpac officials reported "confirmed the company's intention to replace the mercury process," according to Asahi Glass. However, no specific efforts towards this end have been announced.<sup>304</sup>
  - Construction of an additional new plant, based on membrane technology, was completed in 2014.
  - Quimpac, in a meeting with Peruvian government officials in 2010 "confirmed the company's intention to replace the mercury process," according to Asahi Glass. However, no specific efforts towards this end have been announced as of early 2018.<sup>305</sup>

- Mercury cell production at this plant must end by 2025, under the terms of the Minamata Convention. Peru is a ratifying party to this agreement, which entered into force on August 6, 2017.<sup>306</sup>
- **Markets:**
  - Merchant sales.<sup>307</sup> According to Quimpac, it exports caustic soda, chlorine, hydrochloric acid, dicalcium phosphate, and refined salt. Its main markets are Chile, Colombia, Ecuador, and the United States.<sup>308</sup>
  - The Oquendo plant expansion in 2014 was “entirely for the foreign market.”<sup>309</sup>
  - From 2010 to 2017, Quimpac exported an average 85,000 metric tons of bulk liquids from the Oquendo plant through its terminal in Callao.<sup>310</sup>
  - Quimpac ships an average of 52,000 metric tons of liquid caustic soda each year from Peru to the United States.<sup>311</sup>
- **Pollution:**
  - The IIC loaned Quimpac \$10 million in 2002 for safety and environmental improvements. The IIC noted that the Oquendo plant’s effluent received only a “primary treatment” before being discharged into the ocean.<sup>312</sup>

## INVENTORY CODE: AMPER02

- **Plant Name:** *Quimpac - Paramonga*
- **Owner:** Quimpac SA (acquired Sociedad Paramonga in 1997).
- **Location:** Paramonga, Lima, Peru.
- **Process:** Mercury.<sup>313</sup>
- **Year Opened:** 1961, in pulp and paper complex (WA Grace - Papelero de Paramonga).
- **Capacities** (tons per year): Estimated 27,000 tons chlorine.<sup>314</sup>
- **Capacity Rank** (Western Hemisphere): Smallest of 41 plants overall. 8th of 8 mercury cell plants.
- **Technology Conversions:**
  - In 2002, the Inter-American Investment Corporation (IIC) - part of the Inter-American Development Bank - approved a \$10 million loan for environmental and safety infrastructure improvements at Quimpac’s plants in Peru. In Paramonga, the loan financed filters to reduce mercury in brine sludge, and to reduce mercury in caustic soda and hydrogen produced by the plant.<sup>315</sup>
  - A Quimpac advisor told a U.S. Geological Survey official in 2007 that “there were no immediate plans to change to non-mercury chlor-alkali production.”<sup>316</sup>
  - In a meeting with Peruvian government officials in 2010, Quimpac officials reportedly “confirmed the company’s intention to replace the mercury process,” according to Asahi Glass. However, no specific efforts towards this end have been announced.<sup>317</sup>
- **Markets:**
  - Merchant sales.<sup>318</sup> According to Quimpac, it exports caustic soda, chlorine, hydrochloric acid, dicalcium phosphate, and refined salt. Its main markets are Chile, Colombia, Ecuador, and the United States.<sup>319</sup>
  - Plant produced PVC in the 1970s.<sup>320</sup>
  - From 2010 to 2017, Quimpac shipped an average of 98,000 metric tons of bulk liquids from Paramonga through its terminal in Supe.<sup>321</sup>
  - Quimpac exports an average of 52,000 metric tons of liquid caustic soda each year from Peru to the United States.<sup>322</sup>
- **Pollution:**
  - The IIC loaned Quimpac \$10 million in 2002 for safety and environmental improvements. The IIC noted “the uneven use of safety equipment... the lack of chlorine detectors and the difficulties in accessing emergency equipment at the Paramonga chemical plant.” It also noted that the plant’s effluent received only a “primary treatment” before being discharged into the ocean.<sup>323</sup>

- Peru's Office of the Public Defenders noted in 2013 that residents of the Nueva Esperanza community in Paramonga "demand the cessation of environmental contamination by industrial emissions generated by the company Agro Industrial Paramonga S.A.A. and the companies PANASA, CARTOPAC and QUIMPAC S.A. They also request the relocation of the population that is adjacent to the companies that operate in the area."<sup>324</sup>

## VENEZUELA

### INVENTORY CODE: AMVEN01

- **Plant Name:** *Pequiven - El Tablazo*
- **Owner:** Government of Venezuela (through Petroquímica de Venezuela S.A. [Pequiven]).
- **Location:** Maracaibo.
- **Process:** Membrane (OxyTech).<sup>325</sup> Converted from mercury in 1992.
- **Year Opened:** Commissioned in 1976.<sup>326</sup> Originally named Venezolana Industria de Plásticos (25% owned - and managed - by The B.F. Goodrich Company and 75% by the Venezuelan government and private investors). Originally designed for PVC production capacity of 50,000 tons per year.<sup>327</sup>
- **Capacities** (tons per year): 120,000 tons chlorine, 134,000 tons caustic soda, and 32,000 tons hydrochloric acid (2004). 120,000 tons PVC capacity (2005).<sup>328</sup>
- **Capacity Rank** (Western Hemisphere): 32nd of 41 plants overall. 17th of 24 membrane plants.
- **Technology Conversions:**
  - Converted from mercury cell to membrane between 1988 and 1992.<sup>329</sup>
- **Markets:**
  - Produces PVC, chlorine, hydrochloric acid, sodium hypochlorite.<sup>330</sup>
  - Chlorine is almost entirely consumed on-site for producing PVC; the balance is used by the government for water sanitation.<sup>331</sup>
  - In 2005, the Hugo Chavez government envisioned devoting at least half of the plant's 120,000 tons of PVC capacity "to the production of materials for 30,000 houses," according to an Inter Press Service article. "The price of each would be roughly 11,600 dollars, which is one third less expensive than if other materials were used, according to studies by the Ministry of Housing and Habitat."<sup>332</sup>
- **Pollution:**
  - Prior to converting to membrane technology in 1992, this chlor-alkali allegedly poisoned 228 workers with mercury. In November 2016, former workers called upon the company and government to fulfill an agreement to provide workers with housing, a pension and medicine. According to Freddy Pitre, a former worker, "More than half of our affected colleagues have died and they have not given them their homes, they have only complied with the medicines."<sup>333</sup>
  - A large fire consumed the complex in 1990. Thereafter, nearby residents of El Hornito Viejo organized a successful campaign to be relocated. The residents were relocated but not otherwise compensated. The old town was razed to the ground.<sup>334</sup>
  - Researchers in 1991 identified mercury in water and air pollution from the El Tablazo chlor-alkali plant, along with chlorine gas pollution.<sup>335</sup>
  - All told, Pequiven allegedly released about 70 tons of mercury over a 10-year period.<sup>336</sup>

## REGION: UNITED STATES

### INVENTORY CODE: AMUSA01

- **Plant Name:** ASHTA - *Ashtabula*
- **Owner:** ASHTA Chemicals.
- **Location:** Ashtabula, Ohio, USA.
- **Process:** Mercury cell.
- **Year Opened:** 1963.<sup>337</sup>
- **Capacities** (tons per year): 47,421 tons chlorine (2009).<sup>338</sup>
- **Capacity Rank** (Western Hemisphere): 38th of 41 plants overall. 7th out of 8 mercury cell plants.
- **Technology Conversions:**
  - On June 25, 2014, ASHTA Chemicals announced plans for “eliminating the use of mercury in its manufacturing process... The project is expected to take between 24 and 30 months to complete and will replace the current mercury cell processing technology with membrane cell technology.”<sup>339</sup>
  - In December 2017, ASHTA started work on the project to replace the mercury cells. “The project is expected to take two years to complete, with construction wrapping up in 2019,” reported the *Star Beacon*.<sup>340</sup>
- **Markets:**
  - “ASHTA’s production facility is located adjacent to the titanium dioxide plant to which it sells 100% of its chlorine,” according to the U.S. Environmental Protection Agency (EPA).<sup>341</sup> The titanium dioxide plant, Cristal, is a subsidiary of Tasnee, a private joint stock Saudi company. Tasnee is one of the largest titanium dioxide producers in the world.<sup>342</sup> Cristal sells titanium dioxide - a common pigment and filler - to paint, paper, and plastics manufacturers.<sup>343</sup>
  - ASHTA also markets potassium hydroxide, potassium carbonate, and chloropicrin.<sup>344</sup>
  - According to the Ohio EPA, “Chloropicrin is synthesized by reacting nitromethane with a potassium hypochlorite solution. Chloropicrin is blended with 1,3-dichloropropene for a customer.”<sup>345</sup>
  - Initially, under previous owners, this plant produced chlorine for a General Tire PVC plant in Ashtabula.<sup>346</sup> General Tire’s PVC plant closed in 1984. In 1998, the *Houston Chronicle* reported on previously undisclosed company documents, tying extreme levels of contaminated air in the plant to many cases of angiosarcoma, a cancer that can be traced to VCM.<sup>347</sup>
- **Pollution:**
  - ASHTA Chemicals is one of only two chlor-alkali plants in the US that still use mercury to produce chlorine. Oceana, an environmental advocacy non-profit, named it one of “the Filthy Five” in 2007; three of the others have closed (the only other mercury cell user is Westlake’s plant in West Virginia). Oceana noted that, in 2005, “the plant reported emitting 813 pounds of mercury into the air, making it the third largest mercury air polluter in the state. Even though mercury-free technology has been readily available since the early 1970s, in the nineteen years between 1987 and 2005, the Ashta plant reported emitting more than 27,000 pounds of mercury into the air.”<sup>348</sup>
  - In 1995, the EPA published The Great Lakes Initiative, water quality guidelines for the region, which established a limit of 1.3 nanograms of mercury per liter.<sup>349</sup> Ashta Chemicals has operated under a consent order that allows much higher levels of mercury discharges: 250 nanograms per liter (ng/L). According to Ohio EPA data, Ashta’s discharges into Lake Erie in 2012 and 2013 averaged between 82 and 173 ng/L.<sup>350</sup>
  - On April 10, 2010, Oceana reported on records it obtained from the Ohio EPA: “Ashta Chemicals reported ‘losing’ 415 pounds of toxic mercury in 2009. In the past, Ashta reported ‘lost’ mercury to the US EPA as ‘fugitive’ mercury emissions, which are released from the plant without being measured. Therefore, it’s likely that much if not all of this ‘lost’ mercury was emitted into Ohio’s air. For

the past three years, Ashta Chemicals reported to the US EPA that it emitted no fugitive mercury into the air. Oceana challenged these findings with its own air monitoring, which suggested the plant was in fact emitting mercury, and those findings are corroborated by the company's report to the Ohio EPA. These reports reveal that the company has carelessly handled and tracked its toxic mercury, which threatens public health.<sup>351</sup> Among other alarming findings from its report to the Ohio EPA, Oceana also reported: "The company buried highly-contaminated materials on its grounds, without first evaluating how these materials would affect local soils and run-off; company employees discovered a liquid mercury "spill" on the plant's roof; [and], the company reported it did not wash down its hydrogen piping system from July through November, an essential practice to reduce mercury emissions."

- In December 2014, ASHTA Chemicals stated that it was in the process of eliminating its use of mercury cell technology in Ashtabula, but did not break ground until December 2017. The company says it will complete the \$100 million product in 2019.<sup>352</sup> During the intervening four years (2015 to 2018), it will generate more than 10 tons of mercury waste, according to Ashta Chemical's Toxics Release Inventory submissions to the EPA.<sup>353</sup>
- For more pollutant release information, see Appendix.

## INVENTORY CODE: AMUSA02

- **Plant Name:** *Covestro - Baytown*
- **Owner:** Covestro. Covestro spun off from Bayer in 2015. Bayer terminated control over Covestro in September 2017.<sup>354</sup> Originally operated under Bayer subsidiary, Mobay Chemical Co.<sup>355</sup>
- **Location:** Baytown, Texas, USA.
- **Process:** Membrane.<sup>356</sup>
- **Year Opened:** 1972. Opened by Bayer to supply chlorine for on-site toluene diisocyanate production.<sup>357</sup>
- **Capacities** (tons per year): 363,000 tons chlorine (2006).<sup>358</sup> Chemical production plant capacities include 320,000 tons of methylene diisocyanate (MDI), 225,000 tons of toluene diisocyanates (TDI), and 230,000 tons of polycarbonates.<sup>359</sup>
- **Capacity Rank** (Western Hemisphere): 14th of 41 plants overall. 5th out of 24 membrane plants.
- **Technology Conversions:**
  - Expanded chlorine capacity in 1975, using Uhde membrane technology.<sup>360</sup>
  - "Between 1996 and 2001, the company doubled its manufacturing capacity with what was then its largest-ever capital expansion of \$1.4 billion," according to Covestro.<sup>361</sup>
  - Expanded chlorine production capacity in 2005.<sup>362</sup>
  - In 2017, plant shut down for two weeks due to flooding from Hurricane Harvey.<sup>363</sup>
- **Markets:**
  - Facility produces chlorine, isocyanates, polycarbonates, chlorine, sodium hydroxide solution, hydrochloric acid, and hydrogen.
  - Covestro is the world's leading producer of isocyanates and polycarbonates. Its Baytown plant is one of the largest producers of these chemicals, all of which rely upon chlorine chemistry.<sup>364</sup> Baytown, Texas, Shanghai, China, and Leverkusen, Germany, are Covestro's worldwide isocyanate factories.<sup>365</sup>
  - This plant sells isocyanates and polycarbonates worldwide. Exported product trade names include Bayblend (polycarbonate), Bayhydrol (polyurethane), and Desmodur (isocyanates).<sup>366</sup>
- **Pollution:**
  - This facility reported 1.4 million pounds of toxic releases from 2006 to 2009, including diisocyanates, phosgene, chlorine, TDI, and methylene diphenyl diamine/toluene diamine (MDA, the precursor to MDI).<sup>367</sup>
  - In 2009, Bayer denied an EPA-funded contractor's request to sample wastewater treatment plant effluent for polychlorinated biphenyls (PCBs).<sup>368</sup> The contractor was researching potential sources

of PCB contamination in the Houston Ship Channel. The request was based on the “extremely high number of transformers” on the Lower Cedar Bayou.<sup>369</sup>

- In 2016, the Union of Concerned Scientists listed this plant among the top four industrial facilities impacting the communities of Galena Park and Harrisburg/Manchester. The UCS explained that residents of these Houston neighborhoods “are predominantly African American, Hispanic, and low income” and “face far greater health risks than the members of more white and affluent communities like West Oaks/Eldridge and Bellaire, given their proximity to chemical facilities that pollute the surrounding air, water, and soil.”<sup>370</sup>
- In 2017, the plant shut down for two weeks due to Hurricane Harvey. *Chemical & Engineering News* noted, “Although closing down a refinery or chemical plant is a safe move in the face of a massive storm, it is not without side effects. Even when plant operators receive a few days’ warning, unplanned shutdowns lead facilities to emit volatile chemicals in amounts that far exceed air pollution permit levels. During unplanned shutdown activities, emissions control equipment is not fully functional.”<sup>371</sup>
- For more pollutant release information, see Appendix.

## INVENTORY CODE: AMUSA03

- **Plant Name:** *Formosa Plastics - Point Comfort*
- **Location:** Point Comfort, Texas, USA.
- **Owner:** Formosa Plastics Corporation (Taiwan).
- **Process:** Membrane.
- **Year Opened:** 1983.<sup>372</sup>
- **Capacities** (tons per year): Chlorine: 910,000, Caustic Soda: 1,000,000 tons (2017).<sup>373</sup> EDC capacity: 1.13 million tons (2008).<sup>374</sup> VCM capacity: 753,000 tons (2017).<sup>375</sup> PVC capacity: 816,000 tons (2017).<sup>376</sup>
- **Capacity Rank** (Western Hemisphere): 5th of 41 plants overall. 4th of 24 membrane plants.
- **Technology Conversions:**
  - In 1994, Formosa invested in a \$1.5 billion project to add chlor-alkali and EDC capacity, as well olefin, polyethylene, polypropylene, power co-generation, and wastewater treatment capacity. “At the time, this expansion was the largest one-time, private investment in the state of Texas,” according to Formosa Plastics.<sup>377</sup>
  - On Sept. 29, 2009, the US Justice Department and EPA announced, “Formosa Plastics Corp., Texas, and Formosa Plastics Corp., Louisiana, will spend more than \$10 million on pollution controls to address air, water, and hazardous waste violations at two petrochemical plants in Point Comfort, Texas, and Baton Rouge, Louisiana.”<sup>378</sup>
- **Markets:**
  - Chlorine is consumed in-house for production of EDC and VCM, which are feedstocks of PVC resin made on-site.
  - Chlorine produced in Point Comfort is also consumed in Formosa’s Baton Rouge, Louisiana, VCM plant. When Formosa closed a chlor-alkali plant in Baton Rouge in 2004, ICIS reported the company “said that it would supply its customers from its 965,000 mt/year plant at Point Comfort, TX as well as through swap- arrangements with other producers.”<sup>379</sup> The Baton Rouge plant has a reported capacity of 575,000 metric tons per year.<sup>380</sup> VCM produced in Baton Rouge is consumed on-site (470,000 tpy PVC<sup>381</sup>) and Formosa’s PVC plant in Delaware City, Delaware (144,000 tpy<sup>382</sup>).
  - Formosa Plastics, the world’s largest PVC producer, exports PVC resin from Point Comfort to much of the world. Between March 2015 and February 2018, a three-year period, more than 93,131 metric tons of Formosa PVC resins were exported from Houston to ports around the world, including destinations in Argentina, Bangladesh, Brazil, Bulgaria, Cameroon, Cape Verde, Cayman Islands, Chile, China, Columbia, Congo, Côte d’Ivoire, Dominican Republic, Ecuador, Egypt, France, Guatemala, Guinea, India, Israel, Italy, Jordan, Kenya, Lebanon, Nigeria, Oman,

Pakistan, Panama, Peru, Portugal, Qatar, Senegal, Slovenia, Spain, Togo, Tunisia, Turkey, Ukraine, United Arab Emirates, United Kingdom, and Uruguay.<sup>383</sup>

- **Pollution:**

- In 1982, according to the US EPA, “Formosa reported discharges of 1,2-dichloroethane (EDC) to the former wastewater treatment plant area and releases of EDC to the soil and groundwater in the PVC production area.”<sup>384</sup>
- In 1991, the EPA “required Formosa to conduct corrective actions, including an RCRA Facility Investigation, a Corrective Measures Study, and Corrective Measures Implementation according to a specific schedule.”<sup>385</sup>
- “In 1993, Formosa reported a discharge of EDC when a tank collapsed in the Chlor Alkali Plant. Surface soils were removed, and a pump and treat system was emplaced to remediate contamination in saturated soils and groundwater,” reported the EPA.<sup>386</sup>
- In 1994, Greenpeace reported that samples taken from this plant “of heavy ends from the distillation of VCM contained 761 ppb total dioxin.”<sup>387</sup>
- In 2004, the EPA “required Formosa to conduct corrective actions in the area affected by the 1993 discharge of EDC.... Formosa has reported multiple volatile organic compounds (VOCs), including chlorinated hydrocarbons (EDC) and daughter products, chloroform, and benzene, in the soil and groundwater above health-based risk levels in site investigations conducted from 1988 to the present.... There have been several reports over the operating period at the plant that described releases of chlorinated hydrocarbons to the nearby Cox Creek.”<sup>388</sup>
- From 2012 to 2016, on a per capacity basis, HBN estimates that the Formosa Plastics plant in Point Comfort reported releasing more chloroform and carbon tetrachloride than any other chlor-alkali producer in the US and Canada. It ranked second for EDC and fourth for VCM releases per capacity.
- In April 2017, local residents “announced their intent to sue Formosa Plastics for ‘significant, chronic, and ongoing’ Clean Water Act violations that have polluted Lavaca Bay and other waterways,” according to *KAVU-TV* of Victoria, Texas. “The suit will seek penalties for illegally dumping plastic pellets and PVC dust that could amount to over \$45 million for violations in the last 14 months.”<sup>389</sup>
- Part of the plant was off-line for a few hours, reported *Plastics News*, “after almost 170 pounds of vinyl chloride monomer (VCM) were released from a 3-inch de-gas line at the site between April 12-13, [2017], according to a filing with the Texas Commission on Environmental Quality.”<sup>390</sup>
- The EPA provided extensive documentation of pollution at this plant in response to EPA Freedom of Information Act Request No. EPA-R6-2017-008965, available from: <https://www.epa.gov/foia>.
- For more pollutant release information, see Appendix.

## INVENTORY CODE: AMUSA04

- **Plant Name:** *OxyChem - Niagara Falls NY*
- **Owner:** Occidental Petroleum, through its Occidental Chemical (OxyChem) subsidiary. Occidental acquired Hooker Chemical, the original owner, in 1968. The plant continued to operate under the Hooker name after the acquisition.
- **Location:** Niagara Falls, New York, USA.
- **Process:** Asbestos Diaphragm.<sup>391</sup>
- **Year Opened:** 1906.<sup>392</sup>
- **Capacities** (tons per year): 335,000 tons chlorine (2006).<sup>393</sup>
- **Capacity Rank** (Western Hemisphere): 17th of 41 plants overall. 10th of 15 asbestos diaphragm plants.

- **Technology Conversions:**

- In 1975, Hooker was in the engineering phase of a project to expand production by about 150,000 tons of chlorine per year through diaphragm technology.<sup>394</sup>

- **Markets:**

- Produces caustic soda, chlorine, hydrochloric acid, and sodium hypochlorite.<sup>395</sup>
- A rail line runs from Niagara Falls, New York, to the OxyVinyls plant, which unloads VCM by rail on the other side of the Niagara River, in Niagara Falls, Ontario, Canada. Occidental's Ontario PVC plant VCM supplies were reportedly impacted by Hurricane Harvey in 2017, which temporarily closed the company's Deer Park, Texas, VCM plant (AMUSA05).<sup>396</sup> OxyVinyls, the only PVC resin manufacturer in Canada, has a 341,000 metric tons per year PVC production capacity.<sup>397</sup> About half of its production is sold in Canada, the other half in the US.<sup>398</sup>
- According to the EPA, in 2001, the OxyChem chemical plant's products also included chlorotoluene and parachlorobenzotrifluoride (used in the manufacture of biocides).<sup>399</sup> However, as the New York State Department of Environmental Conservation noted in 2014, "Over the last fifteen years numerous production operations have been shut down and removed."<sup>400</sup>

- **Pollution:**

- In 1942, Hooker purchased an abandoned canal (the Love Canal) in Niagara Falls, drained it, lined it with clay, and dumped toxic waste into it for the next dozen years.
- By 1952, according to the US Dept. of Justice, "approximately 21,000 tons of chemicals, including caustics, alkalines, fatty acids and chlorinated hydrocarbons (dioxin) from the manufacture of dyes, perfumes, solvents for rubber and synthetic resins were buried to a depth of 20-25 feet in and around the Canal." Hooker sold the Canal to the town, which built the 99th Street School atop it. By the end of the decade, residents began finding "pools of oil and colored liquids in their yards and basements."<sup>401</sup>
- In 1971, the International Joint Commission reported that Hooker was discharging up to a half pound of mercury per day directly into the Niagara River.<sup>402</sup>
- In 1975, an internal Occidental (Hooker) company memo, later published by the *New York Times*, stated that chlorine gas was "a serious problem area." There were "union, neighborhood and industrial complaints, compounded by fitful operation of mercury cells as described above." Further, "we don't have the capacity to handle and control the blowgas." The official expressed concern about the "possibility of being shut down by the [U.S.] Environmental Protection Agency if poorly treated effluent were sampled [for mercury], explaining, "We presently treat, sample for analysis, and dump. Analytical results are known only after effluents have been dumped."<sup>403</sup>
- On December 19, 1975, the UPI wire service reported that "clouds of deadly chlorine gas killed four persons and injured 87 others after a railroad tank car at the Hooker Chemical plant exploded and unleashed the gas over this honeymoon resort city Sunday night. Authorities said persons three miles from the blast scene were injured by the toxic fumes. Company officials said the explosion of unknown origin occurred in one of three tank cars used for storage of recovered chlorine."<sup>404</sup>
- By 1978, under pressure from a grassroots campaign led by Lois Gibbs of the Love Canal Homeowners Association, President Jimmy Carter declared a health emergency in the community.<sup>405</sup>
- On April 17, 1979, the EPA announced "one of largest environmental complaints ever lodged by the Federal government against a major corporation." It said the DOJ "acting on behalf of EPA, has filed four suits against Hooker Chemical Co., and its parent corporation, Occidental Petroleum Corporation, requesting the company clean up four chemical waste dumpsites in Niagara Falls, New York, which are posing substantial danger to residents of the area. The suits seek a total of \$117,580,000 in clean-up costs from Hooker as well as reimbursement for more than \$7 million spent by Federal agencies in emergency measures at Hooker's Love Canal waste disposal site, and unspecified civil penalties. The sites involved, each the subject of separate actions, are Love Canal, Hyde Park, 102nd Street and the "S" Area landfill. All four were used by the Hooker Chemical Company to dispose of its chemical wastes."<sup>406</sup>

- In January 1992, the EPA reported that “interim corrective measures for the Mercury Area (former Building U-75) were completed.... During the interim corrective measures, more than 33 tons of mercury were recovered from the area.”<sup>407</sup> The former mercury cell processing building was demolished and elemental mercury was removed from surrounding soil and fill.<sup>408</sup>
- In 1995, Occidental Chemical Corp. agreed to reimburse the EPA \$129 million for its cleanup costs.<sup>409</sup>
- In 2013, Occidental Chemical Niagara Falls imported more than 13 tons of chrysotile asbestos from the Cana Brava mine and processing plant in Minaçu, Goiás State, Brazil.<sup>410</sup> A team of researchers tracked the health of Cana Brava miners from 1997 to 2000, and found that 1.4% of the workers developed diseases caused by asbestos.<sup>411</sup>
- Residents outside the evacuated area of Love Canal continue to report health concerns and toxic waste leaking into their homes and yards. In 2017, Lois Gibbs warned, “There is a misconception that it’s been cleaned up, but there’s still 20,000 tons of chemicals and no one has taken a single barrel out. The waste that leaked into the soil is still there.”<sup>412</sup>
- For more pollutant release information, see Appendix.

## INVENTORY CODE: AMUSA05

- **Plant Name:** *OxyChem - Deer Park*
- **Owner:** Occidental Petroleum. Plant is operated by its Occidental Chemical (OxyChem) subsidiary. Oxy bought the site’s VCM unit from Shell in 1987.<sup>413</sup>
- **Location:** Deer Park, Texas, USA.
- **Process:** Asbestos diaphragm. Mercury was closed as of 2008.<sup>414</sup>
- **Year Opened:** 1938.<sup>415</sup>
- **Capacities** (tons per year): 295,000 tons chlorine (2011).<sup>416</sup> 275,000 tons PVC (2012).<sup>417</sup> 955,000 tons EDC (2006). 590,000 tons VCM (2003).<sup>418</sup>
- **Capacity Rank** (Western Hemisphere): 19th of 41 plants overall. 11th of 15 asbestos diaphragm plants.
- **Technology Conversions:**
  - Expanded chlorine capacity in 1995-96.<sup>419</sup>
  - In 2001, Oceana, an international oceans advocacy non-profit organization, reported, “Texas’ last mercury-cell chlorine plant, an OxyVinyl plant located in Deer Park and owned by Occidental Chemicals Corporation, was temporarily closed (‘idled’) in 2001 because of financial constraints. Though not currently operating, the plant could resume operations in future.”
  - Mercury cells were closed as of 2008.<sup>420</sup>
  - In 2008 the company announced plans to redesign stripper columns at its Pasadena and Deer Park, Texas, plants “which are expected to reduce overall emissions by more than 50 percent.”<sup>421</sup>
- **Markets:**
  - Captive, vertically-integrated producer: chlorine is consumed in production on-site.<sup>422</sup> Products include suspension PVC resin, hydrogen cyanide, and chlorinated paraffins.<sup>423</sup>
  - OxyVinyl suspension PVC resins are used in a wide variety of products, including pipes, flooring, siding and windows, top coats, wire and cable, and medical tubing.<sup>424</sup>
  - In 2017, at least 24,395 tons of OxyVinyl suspension PVC resins were shipped around the world. The leading destination was Belgium; other ports of entry were located in Algeria, Cameroon, Dominican Republic, Ecuador, Egypt, India, Israel, Jordan, Libya, Nigeria, Oman, Portugal, Saudi Arabia, Spain, Turkey, and the United Arab Emirates.<sup>425</sup> Most of the exported resin grades are used to manufacture PVC pipes.
- **Pollution:**
  - EDC and VCM distillation can generate PCB-contaminated bottoms, as Costner et al. (1995) found in government filings. A “hazardous waste management activity” document for Occidental’s

EDC/VCM facility in Deer Park describes the generation of 10,000 pounds per year of “PCB Contaminated Liquids” during “VCM Production.”<sup>426</sup>

- Prior to removing its mercury cells in 2008, the Deer Park plant released substantial amounts of mercury into the air, water, and in landfills. In 2001, it ranked as the “#1 source of total mercury pollution in Texas,” according to Oceana.<sup>427</sup>
- In 2008, KTRK-TV Houston reported on a fire that “started around 7:15 am inside a furnace at the Oxy Vinyl plant on Tidal Road near Highway 225. Plant officials say as a precaution, they called for a shelter-in-place in nearby communities. It has since been lifted. We’re told the fire was quickly contained and posed no threat to anyone.”<sup>428</sup> The company told the Texas Commission on Environmental Quality (TCEQ) that EDC, hydrogen chloride, and VCM ignited after being accidentally vented from a cracking furnace.<sup>429</sup>
- Occidental Chemical imports asbestos from Brazil for several chlor-alkali plants. It imported at least 408 tons of asbestos from Brazil between 2013 and 2016, and another 131 tons in 2017.<sup>430</sup> The government of Brazil outlawed asbestos mining in late 2017.
- Between 2012 and 2015, OxyChem reported disposing of 123,049 pounds of asbestos waste in Allied Waste/BFI McCarty Road Landfill in Houston.<sup>431</sup>
- For more pollutant release information, see Appendix.

## INVENTORY CODE: AMUSA06

- **Plant Name:** *OxyVinyls - Battleground (La Porte)*
- **Owner:** Occidental Petroleum (through OxyVinyls subsidiary). Chlor-alkali plant was originally developed by Diamond Shamrock in 1986.<sup>432</sup> The VCM plant was originally developed by BF Goodrich, which later spun its VCM assets off into a company called Geon (now PolyOne). In 1998, Geon and Occidental entered into a joint venture called OxyVinyl. OxyVinyl combined Geon’s VCM and PVC mass/suspension resin plants with Occidental’s PVC mass/suspension resin and VCM assets and related chlor-alkali facilities. Geon contributed its VCM plant - in La Porte - to the joint venture. OxyVinyl is now a wholly-owned subsidiary of Occidental Petroleum.<sup>433</sup>
- **Location:** La Porte, Texas, USA.
- **Process:** Asbestos diaphragm.<sup>434</sup>
- **Year Opened:** 1974.<sup>435</sup>
- **Capacities** (tons per year): 525,000 ton chlorine, 589,000 tons caustic soda (1999).<sup>436</sup> 1.77 million tons EDC (2009).<sup>437</sup> 1.25 million tons VCM (2015).<sup>438</sup> Nearby OxyVinyls Pasadena PVC plant had 898,000 tons capacity in 1999. Reported PVC capacity exceeds known on-site chlorine capacity to provide sufficient feedstock.
- **Technology Conversions:** None announced.
- **Markets:**
  - A short rail line connects this plant to the OxyVinyls PVC plant in Pasadena, Texas. In 1999, this plant had the capacity to produce 1,980,000 pounds (898,000 metric tons) of PVC.<sup>439</sup> See Deer Park inventory entry for further details of OxyVinyls PVC markets.
- **Pollution:**
  - March 27, 2008: Two vent gas incinerators at the La Porte VCM plant “were tripped offline,” leading to the release of 750 pounds of ethylene dichloride, 500 pounds of carbon monoxide, 340 pounds of gaseous ethylene, and 39 pounds of vinyl chloride monomer, according to OxyVinyls filing with Texas state regulators.<sup>440</sup>
  - June 25, 2015: Platts energy and commodities analysts reported that “OxyChem has suffered a production upset at its vinyl production facility in La Porte.”<sup>441</sup>
  - From 2012 to 2015, the La Porte plant transferred 11,010 pounds of asbestos to landfills.<sup>442</sup>
  - On a per capacity basis, this plant’s reported dioxin emissions were the highest among chlorine and PVC producers in the US and Canada from 2012 to 2016. It also reported above average

release rates for carbon tetrachloride, chloroform, and EDC. For more pollutant release information, see Appendix.

## INVENTORY CODE: AMUSA07

- **Plant Name:** *OxyChem - Ingleside*
- **Owners:** Occidental Petroleum (through OxyChem subsidiary), operator. Mexichem is part-owner through ethylene cracker joint venture. Occidental purchased chlor-alkali plant from DuPont in 1987.<sup>443</sup>
- **Location:** Ingleside / Gregory / Corpus Christi, Texas, USA.
- **Process:** Asbestos Diaphragm.<sup>444</sup>
- **Year Opened:** 1974.<sup>445</sup>
- **Capacities** (tons per year): 570,000 tons chlorine (2011).<sup>446</sup> 2,450,000 tons EDC (2003).<sup>447</sup> 907,000 tons VCM (2000).<sup>448</sup>
- **Capacity Rank** (Western Hemisphere): 8th of 41 plants overall. 3rd of 15 asbestos diaphragm plants.
- **Technology Conversions:**
  - Opened in 1974 by DuPont, with 219,000 ton-per-year chlorine production capacity using Kelchlor process.<sup>449</sup>
  - 1977: Added Diamond MDC55 diaphragm technology with 365,000 ton chlorine production capacity.<sup>450</sup>
  - 1991: OxyMar, a joint venture of Occidental and Marubeni Corp. (Japan), opened VCM facility with 1.4 billion pounds VCM capacity.<sup>451</sup>
  - 2000: OxyMar's VCM annual capacity was 2 billion pounds.<sup>452</sup>
  - Feb. 2017: In an Oxychem/Mexichem joint venture, a \$1.5 billion, 544,000 ton-per-year ethylene cracker opened in the Ingleside plant.<sup>453</sup> OxyChem president Robert Peterson said, "We are pleased to announce the safe startup of the ethylene cracker at our plant in Ingleside. This is a significant milestone for both OxyChem and Mexichem, enabling us to capitalize on the advantages that shale gas development presents for the chemical industry. It also helps our companies better compete globally in our respective markets, and gives us an inherent advantage to manage the cost of ethylene."<sup>454</sup>
- **Markets:**
  - The primary product of this plant is VCM, and, ultimately, PVC.
  - In 1990, the *Journal of Commerce* described the arrangement for the new OxyMar joint venture between Occidental and Marubeni of Japan: "Eighty percent of the VCM produced at the new facility will be bought by Occidental for use in manufacturing polyvinyl chloride in its domestic operations. The remaining 20 percent will be bought by Marubeni to be sold in the Pacific Rim." It also reported that "additional terms of the agreement stipulate that Marubeni will purchase approximately 200 million pounds a year [90,718 metric tons] of PVC from Occidental to be sold in the Far East, according to Denny Mountz, business manager for Occidental's VCM business."<sup>455</sup>
  - Mexichem's 2013 annual report explained its investment in the \$1.5 billion new ethylene cracker, which opened in 2017. Occidental's "VCM facility will be fed by the ethylene cracker, and it, in turn, will supply VCM to Mexichem's PVC facilities in [Altamira,] Mexico, [Cartagena,] Colombia, and the United States."<sup>456</sup> The Altamira plant has a 876,000 tons-per-year PVC capacity; Cartagena, 500,000 tons. Mexico's two PVC facilities in the US (Pedricktown, New Jersey, and Henry, Illinois) have a combined capacity of 245,000 tons per year.<sup>457</sup>
  - In 2013, Mexichem added substantial capacity to consume this VCM when it acquired the PVC resin operations of PolyOne (formerly Geon and BF Goodrich). The arrangement was similar to Mexichem's ethylene/VCM joint venture with Pemex at the Pajaritos complex in Veracruz, Mexico. "The joint ventures with Pemex Petroquímica and OxyChem allow integration into the ethylene market – which is 79% of the cost of VCM and 56% of the cost of PVC piping," said Mexichem.<sup>458</sup>
  - Upon the startup of the ethylene cracker in 2017, OxyChem president Robert Peterson said,

“This is a significant milestone for both OxyChem and Mexichem, enabling us to capitalize on the advantages that shale gas development presents for the chemical industry. It also helps our companies better compete globally in our respective markets, and gives us an inherent advantage to manage the cost of ethylene.”<sup>459</sup>

- In 1987, the *Journal of the Electrochemical Society* explained that DuPont, the original developer of this plant, “primarily had used the unit for raw material for its perchloroethylene plant.” DuPont sold the plant in 1987 to Occidental, whose “output will be aimed at foreign markets.”
- **Pollution:**
  - Occidental reported to the EPA releasing 80 pounds of asbestos into the air between 2012 and 2015 from Ingleside, more than all other chlor-alkali plants in the US combined.<sup>460</sup>
  - From 2012 to 2016, the Ingleside plant accounted for nearly half (47%) of the hexachlorobutadiene (HCBd) released by the US chlor-alkali industry. HCBd, a persistent bioaccumulative toxicant, is on a short list of chemicals under EPA review for potential restrictions under the Toxic Substances Control Act.
  - The Ingleside plant ranked fifth for VCM releases by capacity from 2012 to 2016. It was the largest source of VCM releases among plants that do not produce PVC resins.
  - From 2012 to 2016, Mexichem’s Henry, Illinois, PVC plant (which receives VCM from Ingleside) released hydrochloric acid at the second highest rate among chlorine or PVC producers in North America.
  - For more pollutant release information, see Appendix.

## INVENTORY CODE: AMUSA08

- **Plant name:** *OxyChem - Geismar*
- **Owner:** Occidental Chemical. Purchased from Vulcan Chemical in 2005.<sup>461</sup>
- **Location:** Geismar, Louisiana, USA.
- **Processes:** Synthetic diaphragm and membrane.<sup>462</sup>
- **Year Opened:** 1968, as part of Vulcan Chemical’s new chlorinated organic chemical plant in Geismar, Louisiana.<sup>463</sup>
- **Capacities** (tons per year): 438,000 tons chlorine (218,000 tons membrane and 220,000 tons asbestos). 270,000 tons EDC.<sup>464</sup>
- **Capacity Rank** (Western Hemisphere): 10th of 41 plants overall. 3rd of 5 synthetic diaphragm and 12th of 24 membrane plants.
- **Technology Conversions:**
  - In 1993, according to the European Union, this plant fully converted from asbestos to synthetic diaphragm technology.<sup>465</sup>
  - In 1998, Vulcan formed a joint venture with Mitsui to add a second chlor-alkali plant (210,000 mt/y) and a ethylene dichloride plant to the Geismar site. “Most of the chlorine for the joint venture will be delivered by pipeline to customers within the Geismar area, who will return anhydrous hydrogen chloride (HCl) to the joint venture. Mitsui will buy all of the EDC output from the Geismar facility,” reported the *Journal of the Electrochemical Industry*.<sup>466</sup>
  - In 1999, a pipeline network connected the Olin (St. Gabriel) chlor-alkali plant with numerous plants in Geismar, including the Vulcan (now Occidental) chlor-alkali, BASF and Rubicon isocyanate, and Borden Chemical (now Westlake) PVC plants (which also is a chlor-alkali plant). The pipeline avoids rail transport of hazardous chemicals. Also, this “chlorine-isocyanate-EDC triangle” helps each plant be more competitive with “chlorine integrated firms,” explains a 1999 article in the *Journal of the Electrochemical Society*.<sup>467</sup>
  - In 2000, Vulcan began producing hydrochlorocarbon-240fa in Geismar. HCC-240fa is a feedstock for HFC-245fa, a blowing agent used mainly in spray polyurethane foam insulation.<sup>468</sup> Honeywell produces HFC-245fa in Geismar.<sup>469</sup>

- **Markets:**
  - Chlorine is used in on-site production of chemical feedstocks for blowing agents.
  - OxyChem produces chlorinated solvents (including carbon tetrachloride, chloroform, and perchloroethylene) in Geismar, Louisiana, and Wichita, Kansas.<sup>470</sup> In 2005, an Agency for Toxic Substances and Disease Registry (ATSDR) toxicological profile for carbon tetrachloride said these plants, then owned by Vulcan, had the capacity to produce 60,000 tons of chlorinated solvents. It described these two plants as the country's only producers of carbon tetrachloride.<sup>471</sup>
  - Chlorine from Geismar is also consumed in EDC, PVC, and isocyanate plants, locally and globally. During the Vulcan/Mitsui joint venture, for example, Mitsui purchased all of the EDC output. "Mitsui is the largest EDC trader in the world and holds equity positions in several Asian vinyl and PVC producers," noted a Vulcan press release.<sup>472</sup>
- **Pollution:**
  - A sample of residues from the distillation of EDC at this plant, gathered by Greenpeace in 1993, contained 200,750 parts per billion dioxin.<sup>473</sup>
  - From 2012 to 2016, the Geismar plant released hexachlorobutadiene (HCBd) at a higher rate (15 kg per 1,000 tons production) than any other source in the US. According to the EPA, "The primary source of hexachlorobutadiene found in the United States is inadvertent production as a waste by-product of the manufacture of certain chlorinated hydrocarbons, such as tetrachloroethylene, trichloroethylene, and carbon tetrachloride."<sup>474</sup>
  - The OxyChem Geismar plant's carbon tetrachloride release rate ranked second in the country from 2012 to 2016. These emissions are poised to increase. In 2017, a \$145 million expansion was underway to produce refrigerants.<sup>475</sup> A 2017 air permit for this facility cited an increase in estimated VOC emissions of 7.44 tons per year from the "Utilities Process Unit," which "includes an increase in carbon tetrachloride."<sup>476</sup> This may be related to a joint venture between Occidental and Dow Chemical to produce "the new chlorocarbon, known as HCC-1230xa," used in the production of HFO-1234yf.<sup>477</sup>
  - For more pollutant release information, see Appendix.

## INVENTORY CODE: AMUSA09

- **Plant Name:** *OxyChem - Convent*
- **Owner:** Occidental Petroleum. In 1985, Occidental bought this and other chlorine plants from BF Goodrich.<sup>478</sup>
- **Location:** Convent, Louisiana, USA.
- **Process:** Asbestos Diaphragm.<sup>479</sup>
- **Year Opened:** 1981. Opened under the name Convent Chemical Corporation, a joint venture of BF Goodrich and Bechtel Petroleum, producing chlorine, ethylene dichloride, and caustic soda.<sup>480</sup>
- **Capacities** (tons per year): 353,000 tons chlorine, 388,000 tons caustic soda, 680,000 tons EDC.<sup>481</sup> Reported EDC capacity exceeds known on-site chlorine capacity to provide sufficient feedstock. Likely consumes chlorine from other facilities as well as from its own.
- **Capacity Rank** (Western Hemisphere): 16th of 41 plants overall. 9th of 15 asbestos diaphragm plants.
- **Technology Conversions:**
  - Expanded chlorine capacity in 1995.<sup>482</sup>
- **Markets:**
  - Sells Finished Grade Ethylene Dichloride, some overseas.<sup>483</sup> When the plant opened in 1981, its main consumer was Goodrich, which used the EDC to make VCM at its plants in Calvert City, Kentucky, and La Porte, Texas.<sup>484</sup> The Calvert City plant, now owned by Westlake, appears to have more EDC capacity than can be served by its in-house chlorine.
  - Also produces food grade caustic soda 50%.<sup>485</sup>

- **Pollution:**

- In 1996, Shintech proposed to build a new chlor-alkali plant in Convent. Local citizens' groups petitioned the EPA to deny a permit for this plant, arguing that "permitting the Shintech facility in Convent would add too much additional air pollution to an area that Petitioners stress already bears a disproportionately high level of industrial pollution from existing facilities."<sup>486</sup> Shintech subsequently built its plant in nearby Plaquemine, Louisiana.
- Occidental in Convent (as in many other locations) regularly imports asbestos from the Eternit asbestos mine in Minaçu, Goiás, Brazil. See Inventory Code AMBRA05 above.
- From 2012 to 2015, the Convent plant reported releasing 3.01 pounds of air stack releases of asbestos, and transferring 38 pounds of asbestos to landfills.<sup>487</sup>
- From 2012 to 2016, it released EDC at rates over twice the industry median.
- For more pollutant release information, see Appendix.

## INVENTORY CODE: AMUSA10

- **Plant Name:** *OxyChem - Taft*
- **Owner:** Occidental Petroleum.
- **Location:** Taft (near Hahnville and Killona), Louisiana, USA.
- **Process:** Asbestos diaphragm<sup>488</sup> and membrane.<sup>489</sup>
- **Year Opened:** 1971.
- **Capacities** (tons per year): Estimated 650,000 tons (438,000 tons chlorine from asbestos diaphragm, 217,000 tons membrane), based on historical data.<sup>490</sup>
- **Capacity Rank** (Western Hemisphere): 7th of 41 plants overall. 5th of 15 asbestos diaphragm plants. 13th of 24 membrane plants.
- **Technology Conversions:**
  - In 1971, Hooker Chemical (Occidental Petroleum subsidiary) opened a 51,000 ton per year asbestos diaphragm chlor-alkali plant in Taft.<sup>491</sup>
  - In 1972, Hooker Chemical announced plans to add 328,000 tpy chlorine production capacity in Taft, using an H-4 (asbestos) diaphragm cell.<sup>492</sup>
  - In 1984, Occidental added a 146,000 ton-per-year membrane (Eltech Systems membrane-gap-cell) plant. It replaced some obsolete diaphragm cells.<sup>493</sup>
  - In 2006, OxyChem "announced that it will convert its membrane cell chlor-alkali plant in Taft, Louisiana, to produce potassium hydroxide (KOH)." Also known as potash, KOH is formed from the electrolysis of potassium chloride.<sup>494</sup>
- **Markets:**
  - PVC: In 1984, Occidental and Shell signed a supply agreement in which chlorine from the Taft plant was delivered to Shell's Norco petrochemical complex, which included an ethylene plant. In this tolling arrangement, Shell agreed to convert chlorine into at least 150 million pounds (68,038 metric tons) per year of VCM.<sup>495</sup> Inter-company correspondence indicated that Occidental expected to receive 300 million pounds of VCM from Shell in 1985.<sup>496</sup>
  - A similar agreement was in place between Hooker and Shell from 1978 to 1984. A substantial amount of the VCM converted by Shell was destined for former Firestone PVC plants that Hooker/Occidental acquired, especially one in Burlington, New Jersey (closed since 2009).<sup>497</sup>
  - Potash (KOH) is used in building materials such as wallboard, carpet, and adhesives. It is also used in the production of biocides, batteries, fertilizers, soaps, colorants, and rubber chemicals.<sup>498</sup> OxyChem is the world's largest caustic potash producer.<sup>499</sup>
- **Pollution:**
  - In sheer volume, this facility was the country's third largest generator of hazardous waste in 2007 (2.8 million pounds).<sup>500</sup>

- This plant imported 26 tons of white chrysotile asbestos from Brazil in 2017. See AMBRA05 above for further discussion.
- From 2012 to 2015, the Taft plant transferred 40,492 pounds of asbestos waste to landfills.<sup>501</sup>
- For more pollutant release information, see Appendix.

## INVENTORY CODE: AMUSA11

- **Plant name:** *OxyChem - Wichita*
- **Owner:** Occidental Petroleum. Occidental bought Vulcan Materials' chemical plants in 2005.<sup>502</sup>
- **Location:** Wichita, Kansas, USA.
- **Process:** Asbestos diaphragm and membrane.<sup>503</sup>
- **Year Opened:** 1952.<sup>504</sup>
- **Capacities** (tons per year): 248,000 tons chlorine (165,000 tons asbestos diaphragm, 83,000 tons membrane).<sup>505</sup> Capacity has remained nearly constant since the addition of membrane cells in 1983.<sup>506</sup>
- **Capacity Rank** (Western Hemisphere): 23rd of 41 plants overall. 13th of 15 asbestos diaphragm plants. 20th of 24 membrane plants.
- **Technology Conversions:**
  - 1975: 25% capacity expansion.<sup>507</sup>
  - 1983: Added membrane cell capacity (68,000 tons per year).<sup>508</sup> It was the first large-scale membrane cell installed in the United States, according to the *Journal of the Electrochemical Society*. It used DuPont's Nafion membranes.<sup>509</sup>
- **Markets:**
  - This was a "captive" plant in 1997, according to the EPA, meaning chlorine was primarily consumed on-site.<sup>510</sup>
  - OxyChem produces chlorinated solvents (including carbon tetrachloride, chloroform, and perchloroethylene) in Wichita, Kansas, and Geismar, Louisiana. It also produces methylene chloride in Wichita.<sup>511</sup> In 2005, an Agency for Toxic Substances and Disease Registry (ATSDR) toxicological profile for carbon tetrachloride said these plants, then owned by Vulcan, had the capacity to produce 60,000 tons of chlorinated solvents. It described these two chemical factories as the country's only producers of carbon tetrachloride.<sup>512</sup>
  - Plant also produces sodium chlorate, used in pulp and paper industry.<sup>513</sup>
- **Pollution:**
  - In 1990, contaminated groundwater was discovered beneath downtown Wichita. The city named Vulcan Materials as one of 28 companies responsible for the contamination. "During much of the 1990s, city officials have been looking at how to fix the problem and who is going to pay for it," reported the *Wichita Business-Journal*. "From the first, city officials and downtown real estate owners were afraid downtown Wichita would be declared a federal Superfund site."<sup>514</sup>
  - Among chlor-alkali producers, from 2012 to 2016, the OxyChem - Wichita plant released the most chlorine on a per capacity basis. It ranked third for rates of carbon tetrachloride and chloroform releases.
  - For more pollutant release information, see Appendix.

## INVENTORY CODE: AMUSA12

- **Plant Name:** *OxyChem - New Johnsonville*
- **Owner:** Occidental Petroleum. Plant is operated by its Occidental Chemical subsidiary.
- **Location:** New Johnsonville, Tennessee, USA.
- **Process:** Membrane.
- **Year Opened:** 2014.<sup>515</sup>

- **Capacities** (tons per year): 165,000 metric tons chlorine.<sup>516</sup>
- **Capacity Rank** (Western Hemisphere): 29th of 41 plants overall. 15th of 24 membrane plants.
- **Technology Conversions:** None.
- **Markets:**
  - Built adjacent to DuPont titanium dioxide (TiO<sub>2</sub>) plant, for which it provides chlorine and caustic soda.<sup>517</sup>
  - DuPont's titanium dioxide plant has been operating since the 1950s.<sup>518</sup> DuPont had previously received chlorine by barge.<sup>519</sup> The company is the largest TiO<sub>2</sub> producer in the world.<sup>520</sup>
- **Pollution:**
  - OxyChem's wastewater discharge permit allows the daily release of one pound of chlorine and three pounds of nickel. Nickel is a catalyst in the plant's air pollution system.<sup>521</sup>
  - For more pollutant release information, see Appendix.

## INVENTORY CODE: AMUSA13

- **Plant name:** *Olin - Charleston*
- **Owner:** Olin Corporation.
- **Location:** Charleston, Tennessee, USA.
- **Process:** Membrane. Converted from mercury in 2011.<sup>522</sup>
- **Year Opened:** 1962.<sup>523</sup>
- **Capacity** (tons per year): 200,000 tons chlorine.<sup>524</sup>
- **Capacity Rank** (Western Hemisphere): 27th of 41 plants overall. 14th of 24 membrane plants.
- **Technology Conversions:**
  - "On December 9, 2010, our board of directors approved a plan to convert the 260,000 tons of mercury cell capacity at our Charleston, Tennessee facility to 200,000 tons of membrane capacity capable of producing both potassium hydroxide and caustic soda," Olin announced.<sup>525</sup>
- **Markets:**
  - This was a merchant plant in 1997, according to the EPA.<sup>526</sup>
  - In addition to chlorine and caustic soda, this plant produces sodium hypochlorite (bleach), potassium hydroxide, and hydrogen.<sup>527</sup>
  - The plant has a fleet of 16 tank barges (one of which, as of 2013, is single rather than double hull) that delivers chlorine, caustic soda and potassium hydroxide to destinations in the Gulf Intra-coastal Waterway, and the Tenn-Tom, Mobile, Illinois, Mississippi, Ohio and Tennessee Rivers.<sup>528</sup>
  - Chlorine and caustic soda from Olin are used in pulp and paper processing, chemical manufacturing, water purification, vinyl chloride manufacture, bleach, swimming pool chemicals, and isocyanate-based chemicals. Potassium hydroxide is used in fertilizer manufacturing, soaps, detergents and cleaners, battery manufacturing, and food processing chemicals.<sup>529</sup>
- **Pollution:**
  - A pipe replacement led to a mercury spill in 1988. In 1994, Olin paid a \$1 million fine to the EPA.<sup>530</sup>
  - Before it converted to membrane cell, Olin's plant was traditionally Tennessee's "largest single source of mercury air emissions, according to the US EPA's Toxic Release Inventory. In 2005, NRDC tested the air near the Charleston plant and found mercury concentrations as high as 1,788 ng/m<sup>3</sup>. This was nearly six times higher than the EPA's "safe level" for chronic mercury exposure of 300 ng/m<sup>3</sup>.<sup>531</sup>
  - On average, each day the Olin plant released 499 grams of fugitive mercury emissions from the cell room into the air during the period of August to October 2006.<sup>532</sup> The mercury cells have since been decommissioned.

- On June 17, 2015, a chlorine leak forced the temporary closure of the Hiwassee River to boat traffic.<sup>533</sup>
- For more pollutant release information, see Appendix.

## INVENTORY CODE: AMUSA14

- **Plant Name:** *Olin - McIntosh*
- **Owner:** Olin Corporation. The SunBelt Chlor-Alkali Partnership owned the membrane plant until the end of 2010, when Olin bought out PolyOne's 50% share in their joint venture.<sup>534</sup> Originally owned by Mathieson Chemical, which became part of Olin in 1954.<sup>535</sup>
- **Location:** McIntosh, Alabama, USA.
- **Process:** Asbestos diaphragm and membrane.<sup>536</sup>
- **Year Opened:** 1952.<sup>537</sup>
- **Capacities** (tons per year): Estimated 685,000 tons chlorine (365,000 tons by diaphragm; 320,000 tons by membrane technology).<sup>538</sup>
- **Capacity Rank** (Western Hemisphere): 6th of 41 plants overall. 8th of 15 asbestos diaphragm plants. 6th of 24 membrane plants.
- **Technology Conversions:**
  - In 1952, Mathieson Chemical Corporation opened this plant in McIntosh with Mathieson mercury cells.<sup>539</sup>
  - Olin opened a new asbestos diaphragm cell plant in December 1977, and in 1978 doubled its capacity to 365,000 tons of chlorine per year.<sup>540</sup>
  - The mercury cell plant temporarily closed in November 1982 and permanently closed in 1985.<sup>541</sup>
  - The SunBelt Chlor-Alkali Partnership -- a joint venture of Olin and the PVC producer, PolyOne (then named Geon) -- opened a new membrane cell chlor-alkali plant on the McIntosh site in November 1997.<sup>542</sup> The partnership installed additional membrane capacity in 2004, 2006, and 2007.<sup>543</sup> SunBelt owned the membrane plant until the end of 2010, when Olin bought out PolyOne's 50% share.<sup>544</sup>
- **Markets:**
  - Chlorine is used off-site mainly for PVC production.
    - In 1995, the *Journal of the Electrochemical Society* reported that, under the new partnership, "Geon will consume all the chlorine for its polyvinyl chloride production, while Olin will market coproduct caustic soda."<sup>545</sup>
    - In 2008, OxyVinyls was the "sole chlorine customer" of chlorine from the membrane plant, according to ICIS, a leading petrochemical industry news source.<sup>546</sup>
    - Under the SunBelt agreement, Oxyvinyls purchased chlorine from McIntosh for use in its Louisville, Kentucky, Pedricktown, New Jersey, and Pasadena, Texas, PVC plants.<sup>547</sup> In 2006, Occidental's Pedricktown PVC plant (which is distinct from Mexichem's plant in the same town) had a reported capacity of 160,000 tons-per-year.<sup>548</sup> (The Louisville PVC plant closed in 2009.)
  - In addition to chlorine and caustic soda, the McIntosh plant produces sodium hypochlorite (bleach), hydrochloric acid, and hydrogen.<sup>549</sup>
  - Historically, the McIntosh plant produced chlorinated biocides.<sup>550</sup>
- **Pollution:**
  - Thirty years of mercury cell production spread contamination throughout the community of McIntosh, Alabama. The Natural Resources Defense Council (NRDC) describes McIntosh as "a town paved with mercury waste." In a 2005 report, the NRDC notes "a recent series of investigative reports by the *Mobile Register* about Olin Corporation's now defunct mercury process plant in McIntosh, Alabama, [which] reported mercury concentrations in soil more than a thousand times

higher than normal near roads, schools, parks, and churches in the community of McIntosh. The investigation attributed the widespread contamination to a distinctive waste material that was used as roadbed throughout the southwest Alabama town instead of being properly disposed as waste. When *Register* reporters had the road material tested by a mercury laboratory, ‘the air surrounding the material in the test jar was nearly saturated with mercury gases.’ The EPA now specifically lists such muds as hazardous, yet they literally pave the roads of McIntosh.”<sup>551</sup>

- The plant is a Superfund site. In 1984, two years after the mercury cells closed, the EPA placed Olin’s McIntosh property on the National Priority List. The listing was “primarily because of contaminated groundwater resulting from facility operations,” it said.<sup>552</sup> The primary contaminants in the groundwater were mercury and chloroform.<sup>553</sup>
- In 2002, Alabama environmental officials tested seven largemouth bass in the Olin Basin (which runs into the Tombigbee River) and found that all of them greatly exceeded the US Food and Drug Administration’s guidance level for mercury (1 part per million (ppm)). The average was 5.39 ppm; the highest levels of mercury in the specimens was 9.35 ppm. Officials fenced off the Olin Basin and recommended against eating fish caught from the Tombigbee River in that area.<sup>554</sup>
- “According to an incident report written by Olin, 738 pounds of chlorine gas leaked” from the plant on Feb. 15, 2017, reported Kati Weis of *Fox 10 News* (KAJA of Mobile). “Chemists say that would be almost enough to fill an entire tank car. That amount is also nearly four times as much as what the facility usually emits into the air over a year period, the EPA documents show. The company’s community notification system wasn’t working so local residents were not aware of the leak.”<sup>555</sup>

“Provided that the wind would have been coming out of the north, the chlorine would have killed us,” said a local resident.

At least two people, a local resident and a police officer who responded to Olin’s request for assistance, reported chronic breathing difficulties after the leak.<sup>556</sup> “It’s very alarming, I look at some of these [leaks], and it appears to be negligence. It is very alarming,” McIntosh police officer Lt. Charles Koger told FOX News 10. Lt. Koger was found to have respiratory problems after the leak.<sup>557</sup>

“I found the Olin facility in McIntosh has a track record,” reported Weis. “In 2014, the EPA fined the facility \$1,200 for not having proper procedures to prevent a chemical accident. In 2015, court records show an employee sued the company for being wrongfully exposed to chlorine gas. He ultimately got a settlement of \$75,000. Last summer, OSHA fined the facility \$9,900 for exposing contractors to a five-pound chlorine gas cloud release.”

She continued, “State and federal records show there have been at least nine chlorine leaks at the plant since 2010 and the one on February 15 was the largest.”<sup>558</sup>

- In April 2017, the Alabama Department of Environmental Management (ADEM) and Olin reached a settlement agreement for the company to pay a fine of \$80,000 for the leak.<sup>559</sup>
- For more pollutant release information, see Appendix.

## INVENTORY CODE: AMUSA15

- **Plant Name:** *Olin - Niagara Falls*
- **Owner:** Olin.
- **Location:** Niagara Falls, New York, USA.
- **Process:** Membrane.<sup>560</sup>
- **Year Opened:** In 1897, the Mathieson Alkali company opened the plant with mercury cell technology.<sup>561</sup> Mathieson and Olin merged in 1954.<sup>562</sup>
- **Capacities** (tons per year): 240,000 tons of chlorine (2016), reduced from 300,000 tons in 2016.<sup>563</sup>
- **Capacity Rank** (Western Hemisphere): 25th of 41 plants overall. 10th of 24 membrane plants.
- **Technology Conversions:**
  - In 1985, Olin and DuPont announced they would build a 240,000-ton-per-year plant on Olin’s Niagara Falls site. They formed a joint venture called Niaclor.<sup>564</sup>

- In 1990, with the launch of the Niachlor capacity, Olin converted from mercury cell to membrane cell technology.<sup>565</sup> In 1997, Olin bought out DuPont's 50% share in Niachlor.<sup>566</sup>
- In 2011, Olin received \$1.5 million in state grants and tax credits to expand its bleach production line.<sup>567</sup>
- **Markets:**
  - Olin says this plant produces chlorine, hydrochloric acid and industrial bleach.<sup>568</sup>
  - In 1996, the *Journal of the Electrochemical Industry* reported that Niachlor's primary customers were "the regional pulp and paper, titanium dioxide, bleach, and water purification industries."<sup>569</sup>
- **Pollution:**
  - In 1971, the International Joint Commission reported that Olin was discharging up to a half pound of mercury per day into city sewers. "Olin Chemicals is under a Federal Court Stipulation to reduce their discharge to less than one half pound of mercury per day and provide a schedule of proposed future reductions," said the IJC.<sup>570</sup>
  - In 1979, a US District Court jury convicted the Olin Corporation, and a former production manager and a former chemist, of seven misdemeanor counts of falsifying documents. It found another former manager guilty on three charges. Olin and the former employees were found guilty of lying about the amounts of mercury the plant had discharged into the Niagara River from 1975 to 1977.<sup>571</sup>
  - For more pollutant release information, see Appendix.

## INVENTORY CODE: AMUSA16

- **Plant Name:** *Olin - Freeport*
- **Owner:** Olin Corporation. (Purchased from Dow Chemical [now DowDuPont] in 2015.<sup>572</sup>)
- **Location:** Freeport, Texas, USA.
- **Processes:** Asbestos diaphragm<sup>573</sup> and membrane.<sup>574</sup>
- **Year Opened:** 1940.<sup>575</sup>
- **Capacities** (tons per year): 3,030,000 metric tons chlorine (1,580,000 diaphragm, 1,450,000 membrane).<sup>576</sup> In 2008, plant production capacity for EDC was 2,110,000 metric tons.<sup>577</sup>
- **Capacity Rank** (Western Hemisphere): Largest chlor-alkali plant in the Western Hemisphere (out of 41 plants), more than double the size of second largest. Olin - Freeport's asbestos diaphragm and membrane capacities also are largest in the Americas, out of 15 and 24 plants, respectively.
- **Technology Conversions:**
  - In 2002, Dow added capacity to the chlor-alkali plant in Freeport "to feed a 500 million lbs/yr VCM expansion at the same site," reported the *Journal of the Electrochemical Society*.<sup>578</sup>
  - In 2014, Dow and Mitsui & Co., Ltd., completed construction of a joint venture membrane chlor-alkali manufacturing facility with the capacity to produce 800,000 tons of chlorine per year. It eliminated an identical amount of asbestos diaphragm capacity.<sup>579</sup>
  - On October 5, 2015, Olin acquired all of Dow's chlor-alkali and vinyl business in the US, and globally, all of its chlorinated organics and epoxy business.<sup>580</sup>
  - On March 31, 2016, Olin eliminated 220,000 tons per year of asbestos diaphragm cell chlorine production capacity.<sup>581</sup>
  - From late August to mid-October 2017, Olin reduced production at Freeport due to Hurricane Harvey's impacts, such as raw material availability and power outages.<sup>582</sup>
- **Markets:**
  - Chlorine made in Freeport is consumed on-site in chlorinated products and epoxies, and off-site in Shintech's PVC plant in Freeport.
  - An Olin presentation in 2015 described its newly-acquired plants in Freeport, Texas, and Plaquemine, Louisiana, as "two of the world's lowest cost chlor-alkali facilities." Factors driving

the budget include electricity prices, integrated brine sources, and -- most significantly -- ethylene, which "will be supplied through a 20-year co-investor agreement with Dow that will provide Olin with co-producer integrated economics."<sup>583</sup>

- Since at least 1978, this plant has supplied VCM to the nearby Shintech PVC plant in Freeport. Shintech has the capacity to produce 1.45 million tons of PVC per year.<sup>584</sup> In 2008, Dow announced an extension of its agreement to supply Shintech vinyl chloride monomer for its PVC production.<sup>585</sup>
- Chlorinated products made by Olin in Freeport include EDC/VCM, chlorinated organics intermediates, chlorinated organics solvents, sodium hypochlorite, and hydrochloric acid.<sup>586</sup>
- Olin uses chlorine on-site in the production of epoxy resins and feedstock allylics (such as epichlorohydrin) and aromatics (such as bisphenol).<sup>587</sup> Olin described Freeport as "the lowest cost producer of epoxies globally."<sup>588</sup>
- Dow produces isocyanates -- for which chlorine is an essential feedstock -- on the Freeport site.<sup>589</sup>
- **Pollution:**
  - According to the Dow Chemical Company, "From the start of operations at the Freeport site in the 1940s until the mid-1970s manufacturing wastes were typically placed in on-site pits and landfills. The resulting soil and groundwater contamination is being assessed and remediated under the provisions of the Resource Conservation Recovery Act RCRA in concert with the state of Texas."<sup>590</sup>
  - In 1981, *The New York Times* reported on recent "studies by Federal epidemiologists and doctors (that) have revealed up to twice the expected number of brain cancer or brain tumor deaths in a variety of chemical and oil processing plants in the United States, most of them situated along the Gulf Coast of Texas and Louisiana." These cases included Dow's Freeport plant, which "had 25 brain tumor deaths... approximately twice the expected incidence."<sup>591</sup>
  - "High levels of dioxin have led to fish advisories in the Lower Brazos River, which flows by Dow Chemical's VCM plant in Freeport, Texas," Charlie Cray recounted in *New Solutions*, an environmental and occupational health journal, in 1997.<sup>592</sup>
  - Dow reported that "on October 19, 2009, the Company received an Administrative Complaint from the Texas Council of Environmental Quality (TCEQ) related to two alleged air emission events and failure to monitor some equipment for fugitive air emissions at the Company's Freeport, Texas, site seeking a civil penalty in the amount of \$146,917. This matter has tentatively been settled with the TCEQ staff for the assessed amount subject to approval by the TCEQ Commissioners."<sup>593</sup>
  - Dow reported that "the Company received an Administrative Complaint dated May 23, 2013 from the Texas Council of Environmental Quality ('TCEQ') alleging violations of various environmental requirements regulating air emissions from operations at its Freeport, Texas, manufacturing facility. The TCEQ sought a fine in excess of \$100,000 for a number of independent violations of air permits and regulations. This Administrative Complaint was combined with other alleged violations of environmental requirements at the Freeport, Texas, manufacturing facility, including allegations of violations related to the operation of the Company's wastewater treatment plant. The combined Administrative Complaint was settled on October 8, 2014 with the Company agreeing to pay a total of \$67,060, half of which provided funding for a Supplemental Environmental Project entitled Houston-Galveston AERCO's Clean Cities/Clean Vehicles."<sup>594</sup>
  - Phosgene production at Freeport places 129,515 people in a "vulnerability zone" for a worst-case release of this toxic chemical, according to a 2014 report by the Environmental Justice and Health Alliance for Chemical Policy Reform.<sup>595</sup> Phosgene, an essential feedstock for isocyanate production, is formed by the reaction of chlorine and carbon monoxide.
  - From 2015 to 2016, Olin-Freeport's release rates, per chlor-alkali capacity, were among the highest in the industry for dioxins and PCBs. By weight, its chlorine releases were the highest: over 100 tons per year, including 20 tons into the air and 13 tons in water.
  - For more pollutant release information, see Appendix.

**INVENTORY CODE: AMUSA17**

- **Plant name:** *Olin - St. Gabriel*
- **Owner:** Olin. Purchased Pioneer in 2007.<sup>596</sup>
- **Location:** St. Gabriel, Louisiana, USA.
- **Process:** Membrane (converted from mercury in 2009).<sup>597</sup>
- **Year Opened:** 1970.<sup>598</sup>
- **Capacities** (tons per year): 246,000 tons chlorine (2009).<sup>599</sup>
- **Capacity Rank** (Western Hemisphere): 24th of 41 plants overall. 9th of 24 membrane plants.
- **Technology Conversions:**
  - In 2009, Olin converted from mercury to membrane cell and expanded its capacity to 246,000 tons of chlorine per year.<sup>600</sup>
- **Markets:**
  - A seven-mile liquid-chlorine pipeline connects St. Gabriel to chemical plants in Geismar, Louisiana. (This pipeline also is connected to the former Vulcan, now Occidental, plant in Geismar.<sup>601</sup>) The “St. Gabriel facility is an outstanding asset which provides us with pipelining access to the largest non-integrated chlorine consuming complex in North America,” said Olin CEO/President/Chairman Joseph Rupp.<sup>602</sup>
  - The pipeline, explains a 1999 article in the *Journal of the Electrochemical Society*, connects the Olin (St. Gabriel) and Vulcan (Geismar) chlor-alkali plants with isocyanate (BASF and Rubicon in Geismar) and EDC (Vulcan/Mitsui [now Occidental] and Borden Chemicals and Plastics [now Westlake], both also in Geismar) producers. This avoids rail transport of these hazardous chemicals, and helps each plant be more competitive with “chlorine integrated firms.”<sup>603</sup>
- **Pollution:**
  - In 2005, the Natural Resources Defense Council (NRDC) tested air near the St. Gabriel plant and found mercury concentrations as high as 2,629 ng/m<sup>3</sup> (nanogram per square meter). It was nearly 10 times higher than the EPA’s “safe level” for chronic mercury exposure of 300 ng/m<sup>3</sup>.<sup>604</sup>
  - On December 29, 2014, WLOX-TV reported that “three people were taken to the hospital Monday morning for exposure to chlorine at a chemical plant in St. Gabriel. Officials with the Olin Chlor Alkali plant confirmed there was a chlorine release from a product storage tank. A yellow-colored cloud was seen over the plant at the time of the incident.”<sup>605</sup>
  - In July 2017, WBRZ-TV reported on a chlorine leak at the plant: “11 employees were treated for injuries on-site, but no one was taken to the hospital. Both Iberville Parish Sheriff’s officials and the St. Gabriel Police Department blocked traffic two miles from the plant. All residents on Hwy 75 from LSU Ag Road to Point Clair Road, Point Clair Rd to south of Maryland St, and Hwy 30 from Hwy 74 to 4250 Hwy 30, were ordered to shelter in place. Additionally, those residents were advised to stay indoors and shut all doors and windows, turn off air conditioning or heating units, and close windows and turn off attic fans.”<sup>606</sup>
  - For more pollutant release information, see Appendix.

**INVENTORY CODE: AMUSA18**

- **Plant name:** *Olin (Blue Cube) - Plaquemine.*
- **Owner:** Olin Corporation. Olin acquired the chlor-alkali plant from Dow in 2015.<sup>607</sup>
- **Location:** Plaquemine, Louisiana, USA (located within 1,500-acre DowDuPont chemical complex).
- **Process:** Asbestos diaphragm.<sup>608</sup>
- **Year Opened:** 1958.
- **Capacities** (tons per year): 971,000 tons of chlorine capacity in 2016.<sup>609</sup> In 2008, plant’s production capacity for EDC was 1,270,000 tons.<sup>610</sup>

- **Capacity Rank** (Western Hemisphere): 4th of 41 plants overall. 2nd of 15 asbestos diaphragm plants.
- **Technology Conversions:**
  - Mercury cell operated on-site from 1963 to 1973.<sup>611</sup>
  - In 2005, Dow shuttered 186,000 ton-per-year chlorine diaphragm cell capacity.<sup>612</sup>
  - In 2011, Dow closed its 680,000 ton-per-year VCM unit.<sup>613</sup>
- **Markets:**
  - Dow supplied neighboring Shintech with VCM for PVC production until it closed its VCM unit in 2011. “Shintech calculates it will need approximately 1.3 billion pounds (590,000 metric tons) of VCM per year to meet its production plans,” according to a 2000 court ruling. Dow “is the only merchant supplier of VCM in the United States that has the capacity to provide such a large amount of VCM. Shintech’s new facility will be built across the road from Dow’s Plaquemine facility, which will provide VCM via an underground pipeline.”<sup>614</sup>
  - Dow continued to supply Shintech with chlorine after 2011. In 2014, the European Commission noted, “Shin-Tech, the largest producer of PVC in the United States, does have an on-going chlorine purchase agreement with Dow...”<sup>615</sup>
  - An Olin presentation in 2015 described its newly-acquired plants in Plaquemine, Louisiana, and Freeport, Texas, as “two of the world’s lowest cost chlor-alkali facilities.”<sup>616</sup>
  - According to an Olin filing in 2015, most chlorine produced in Plaquemine was distributed to Dow’s epoxy and global chlorinated organics.<sup>617</sup> The plant is a merchant producer of EDC.<sup>618</sup>
  - The plant also produces perchloroethylene.<sup>619</sup>
  - Olin sells technical grade carbon tetrachloride for chemical processing and fluorocarbon feed-stock.<sup>620</sup>
- **Pollution:**
  - In 1989, Dow began buying out families living in the small community of Morrisonville, next to the plant. “Companies are reducing their problems by moving people instead of reducing accidents and pollution,” Mary Lee Orr, the executive director of the Louisiana Environment Action Network, a coalition of environmental groups based in Baton Rouge, told *The New York Times*.<sup>621</sup>
  - A sample obtained from a process waste tank gathered by Greenpeace in 1993 contained 1,248 parts per billion dioxin.<sup>622</sup>
  - In 2001, the Louisiana Department of Health and Hospitals (DHH) noted that private well water in a trailer park near the plant contained elevated levels of chemical contamination. In 2003, residents of the Myrtle Grove Trailer Park said “as many as 13 pregnancies ended in miscarriage in just the last few years, and say that their children burned and itched from bath water and wading pools,” reported *The New York Times*.<sup>623</sup> Subsequently, “people were forced to move out of their homes at Myrtle Grove Trailer Park, where it was determined the same water folks used to drink, bathe, and cook with was contaminated with high levels of the toxic chemical vinyl chloride,” reported WAFB in 2008.<sup>624</sup>
  - In its 2010 annual report, Dow said, “The Company received a written communication dated September 17, 2010, from the EPA, notifying the Company of the EPA’s intent to assess a civil penalty against the Company for alleged violations of various environmental rules and regulations at the Company’s Plaquemine, Louisiana site. The Company is negotiating with the EPA and expects that resolution of this matter will likely result in a civil penalty in excess of \$100,000.”<sup>625</sup>
  - In 2011, a district judge ruled that the Dow Plaquemine plant was at least one of the causes of vinyl chloride contamination of the Upper Plaquemine Aquifer. According to the plaintiffs, “Dow was responsible for four instances of contamination, including a spill of 761,000 pounds of perchlorethylene in 1993 and using unlined pits on two areas of its property to dump chemicals that contributed to the contamination of the aquifer,” reported the *Plaquemine Post South*.<sup>626</sup>
  - The Dow (later Olin) Plaquemine plant was the country’s third leading source of hexachlorobutadiene (HCBD) waste between 2014 and 2016. During this period, it produced 8.5 million pounds of HCBD waste. According to the EPA, “The primary source of hexachlorobutadiene found in the

- United States is inadvertent production as a waste by-product of the manufacture of certain chlorinated hydrocarbons, such as tetrachloroethylene, trichloroethylene, and carbon tetrachloride.”<sup>627</sup>
- In December 2016, a chlorine leak, which officials described as “small,” led to the evacuation of most workers from the plant and the temporary closure of Louisiana Route 1. “A thick cloud of black smoke -- identified by Iberville Parish Sheriff Brett Stassi as hydrocarbon -- billowed from the facility and hovered over La. 1 between the town limits of Addis and Plaquemine Friday afternoon and into early evening as the plant worked to restore the power needed to stop the leak,” reported the *Advocate*.<sup>628</sup> The sheriff urged nearby residents to shelter in place and to turn off their heaters and air conditioners.<sup>629</sup> Residents reported having burning sensations in their eyes, and breathing troubles.<sup>630</sup>
  - In September 2017, two “small” (up to two-pounds) chlorine leaks injured a contract worker.<sup>631</sup>
  - From 2012 to 2015, the plant received 1.3 million pounds of asbestos. In 2014 and 2016, the Blue Cube Plaquemine plant imported asbestos from Asbest, Russia; more frequently, it imported asbestos from Brazil (149 tons in 2017).<sup>632</sup>
  - Between 1987 and 2015, Dow dumped 9.2 million pounds of asbestos waste in an on-site landfill.<sup>633</sup> In 2017 alone, Olin imported 149 tons of asbestos from Sama of Brazil.
  - From 2012 to 2015, the Dow (now Olin) plant in Plaquemine transferred 1,256,692 pounds (570 metric tons) of asbestos to landfills.<sup>634</sup>
  - For more pollutant release information, see Appendix.

## INVENTORY CODE: AMUSA19

- **Plant Name:** *Shintech Plaquemine*
- **Owner:** Shin-Etsu Chemical Co. Ltd. (Japan; Shintech is its North American subsidiary).
- **Location:** Plaquemine, Louisiana, USA.
- **Process:** Membrane.
- **Year Opened:** 2008.
- **Capacities** (tons per year): 1,055,000 metric tons of chlorine, 800,000 tons VCM capacity, 635,000 tons of PVC.<sup>635</sup>
- **Capacity Rank** (Western Hemisphere): 3rd of 41 plants overall. 2nd of 24 membrane plants.
- **Technology Conversions:**
  - In 1999, Shintech announced it planned to build a PVC plant alongside Dow’s Plaquemine chemical complex. The plan included a VCM pipeline from Dow, similar to the companies’ arrangement in Freeport, Texas.<sup>636</sup>
  - The plant opened in 2008 with capacity to produce 300,000 tons per year of PVC resin.<sup>637</sup>
  - In 2011, Shin-Etsu doubled PVC production capacity and reduced its dependence upon VCM and chlorine from neighboring Dow. “While continuing to purchase raw material from Dow Chemical, Shintech will strengthen its competitiveness by establishing an integrated system that enables in-house VCM production whenever necessary,” the company reported in advance of the project.<sup>638</sup> The project added an estimated 800,000 tons of VCM capacity to the complex.<sup>639</sup>
  - In 2015, the company announced it would install an ethane cracker and connect the ethylene output to VCM and PVC production on-site. The *Advocate* reported that Shintech also was nearing “completion of an incremental expansion of its VCM, PVC and caustic soda capacity in Iberville Parish.”<sup>640</sup>
  - In 2017, Shintech filed a permit application with the U.S. Army Corps of Engineers to build a new EDC/VCM plant on this site. The proposed new plant would produce enough EDC and VCM to raise its PVC capacity from 635,000 tons per year to 1,005,000 tons per year.<sup>641</sup>
- **Markets:**
  - Captive plant. All VCM consumed in PVC production, either on-site or in its plant in Addis, Louisiana. Shintech’s 2012 annual report notes, “Shintech Plaquemine Plant-1 includes utilities, a

chlor-alkali unit, VCM unit and PVC unit, while Shintech Plaquemine Plant-2 produces chlorine, EDC and VCM for supply to Shintech's nearby Addis PVC facility. The facilities have certainly helped solidify Shin-Etsu's position as the world's largest producer of PVC.<sup>642</sup> The Addis plant, which also is located near the Dow plant, has a capacity of 600,000 tons.<sup>643</sup>

- *Chemical & Engineering News*, in 2011, reported that the plant's VCM investments "suggest that the relationship between Shintech and Dow Chemical in Louisiana is coming to an end. Dow has supplied vinyl chloride to Shintech's 1.5 million-ton-per-year PVC complex in Freeport, Texas, for more than 35 years."<sup>644</sup>
- Shintech is the largest PVC producer in the United States and exports PVC resins around the world.
- **Pollution:**
  - From 2012 to 2016, the Shintech Plaquemine plant released higher than median rates, by production capacity, of chlorine and hydrochloric acid.
  - On July 29, 2017, a pipe ruptured at the Plaquemine facility, resulting in the release of VCM, EDC, and hydrochloric acid. According to the company, "the release was contained in the plant."<sup>645</sup>
  - For more pollutant release information, see Appendix.

## INVENTORY CODE: AMUSA20

- **Plant Name:** *Westlake - Plaquemine*
- **Owner:** Westlake Chemical. In 2016, Westlake Chemical purchased Axiall, the prior owner.
- **Location:** Plaquemine, Louisiana, USA.
- **Process:** Asbestos diaphragm.<sup>646</sup>
- **Year Opened:** 1975. Georgia-Pacific (later named Georgia Gulf) began producing chemicals (phenol/acetone and methanol) on this site in 1971. It started making chlor-alkali and PVC in 1975.<sup>647</sup>
- **Capacities** (tons per year): 426,000 tons of chlorine, 453,000 tons of caustic soda, 725,000 tons of VCM, and 861,000 tons of PVC.<sup>648</sup> Reported PVC capacity exceeds known on-site chlorine capacity to provide sufficient feedstock. Likely consumes chlorine from nearby facilities (AMUSA18 and AMUSA19) as well as from its own.
- **Capacity Rank** (Western Hemisphere): 11th of 41 plants overall. 6th of 15 asbestos diaphragm plants.
- **Technology Conversions:**
  - In 1980, Georgia Pacific added a VCM plant.<sup>649</sup>
  - Closed for maintenance throughout December 2017.<sup>650</sup>
- **Markets:**
  - The chlorine is consumed in production of VCM, most of which is consumed on-site in the production of EDC, VCM, and PVC "or shipped to our other vinyl resins facilities," according to then-owner, Axiall, in 2014. These resins are sold globally.<sup>651</sup>
  - According to Axiall, PVC produced in Plaquemine "is shipped to a variety of Royal Building Products locations, including those in Columbus, Ohio, Bristol, Tenn., and Abbotsford, British Columbia, where it is used to create end products like pipe and vinyl siding."<sup>652</sup>
  - Per its ISO 9001:2008 certification, this plant produces "Phenol, Acetone, 50% Sodium Hydroxide, Chlorine, Isopropenylbenzene, and Vinyl Resins."<sup>653</sup>
  - Acetone and caustic soda from this plant are shipped by inland river barges.<sup>654</sup>
- **Pollution:**
  - In September 1996, according to Georgia Gulf, "workers were exposed to a chemical substance on our premises in Plaquemine, Louisiana. The substance was later identified to be a form of mustard agent, a chemical which is not manufactured as part of our ordinary operations but instead occurred as a result of an unforeseen chemical reaction."<sup>655</sup>

- In 1999, Georgia Gulf settled with hundreds of workers, and their families, for exposing them to mustard gas created accidentally while producing VCM.<sup>656</sup>
- Also in 1999, Georgia Gulf moved 50 families out of Reveilletown, “away from its vinyl chloride plant, turning a community founded by freed slaves into a six-acre grove of oaks and pecan trees,” reported the *New York Times*. “Edward A. Schmitt, the general manager, said Georgia Gulf began buying Reveilletown property in the mid-1970s, only a few years after the chemical plant was built in 1969. ‘We didn’t need the six acres for expansion, but it serves as buffer zone if there was a major release,’ he said.”<sup>657</sup>
- Westlake and Axiall reported significant ongoing releases of lead compounds in Plaquemine. From 2012 to 2016, they reported releasing an average of 214 pounds of lead in water, air, and solid waste.<sup>658</sup> In a material safety data sheet dated Jan. 28, 2013,<sup>659</sup> Axiall listed a “Category 1” flexible PVC resin as containing 3% to 10% “Organometallic compounds of lead” heat stabilizer.
- Also from 2012 to 2016, the plant had the second highest rate of VCM releases in the US and Canada and the second highest rate of EDC releases. It also released hydrochloric acid and dioxins at rates higher than industry medians.
- In 2017, former residents said the chemical company was not allowing them to access Reveilletown’s historic cemetery, reported WBRZ.<sup>660</sup>
- For more pollutant release information, see Appendix.

## INVENTORY CODE: AMUSA21

- **Plant Name:** *Westlake - Geismar*
- **Owner:** Westlake Chemical. (Acquired VCM assets from Borden Chemicals [now Hexion] in 2002.<sup>661</sup>)
- **Location:** Geismar, Louisiana, USA.
- **Process:** Membrane.<sup>662</sup>
- **Year Opened:** 2013 (chlor-alkali plant). VCM has been produced on this site since the early 1960s.
- **Capacities** (tons per year): 317,000 tons chlorine, 385,000 tons VCM, and 331,000 tons PVC.<sup>663</sup> Reported PVC capacity exceeds known on-site chlorine capacity to provide sufficient feedstock. Likely consumes chlorine from nearby (AMUSA08 and AMUSA17) plants as well as from its own.
- **Capacity Rank** (Western Hemisphere): 18th of 41 plants overall. 7th of 24 membrane plants.
- **Technology Conversions:**
  - Next to the future site of Borden’s chemical plant, BASF Wyandotte operated asbestos diaphragm and mercury cell chlor-alkali plants between 1959 and 1983.<sup>664</sup> BASF closed its chlorine plant in Geismar in late 1983, and exited from the chlor-alkali industry.<sup>665</sup>
  - Borden Chemicals began operations in the Geismar chemical complex when it installed an acetylene-VCM plant in the early 1960s.<sup>666</sup>
  - In the mid-1970s, a new ethylene-based VCM plant started operations; acetylene-based VCM production continued.<sup>667</sup> “In 1976 Borden started selling acetylene to BASF Wyandotte for use in its plant next door in Geismar. Six years later, in its first condo deal, Borden sold a piece of the acetylene plant to BASF Wyandotte,” reported *Fortune* magazine.<sup>668</sup>
  - In 1983, Borden opened a new PVC resin plant on the site.<sup>669</sup> It relied upon outside sources of chlorine for its VCM and PVC operations, which it received by rail car from “various suppliers.”<sup>670</sup>
  - The *Journal of the Electrochemical Society* reported that “by 2000, an intricate web of pipelines will be laid down in Geismar, LA involving Vulcan/Mitsui and Pioneer, St. Gabriel, LA as chlorine suppliers, BASF and Rubicon as isocyanate producers and anhydrous HCl [hydrochloric acid] suppliers and Borden Chemicals & Plastics and Vulcan/Mitsui as EDC producers.” It described the arrangement as a “chlorine-isocyanate-EDC triangle.”<sup>671</sup>
  - Borden idled the acetylene VCM plant in December 2000.<sup>672</sup>
  - Borden closed the Plaquemine plant’s remaining operations (ethylene-VCM and PVC resins) in 2002. A bankruptcy court approved its sale to Westlake.<sup>673</sup>

- In November 2003, Westlake restarted the EDC portion of the plant.<sup>674</sup>
- Westlake Chemical restarted production of the VCM and PVC facilities in December 2004.<sup>675</sup>
- Westlake Chemical opened a new membrane cell chlor-alkali plant in 2013.<sup>676</sup>
- **Markets:**
  - Chlorine produced by the chlor-alkali plant is consumed on-site in VCM and PVC manufacturing.<sup>677</sup>
  - Recently added PVC capacity also “will be used in part to meet merchant PVC demand as well as internal demand for PVC resin as a result of the company’s recent acquisition of three PVC pipe plants from Bristolpipe Corporation,” according to Westlake.<sup>678</sup>
  - The Geismar plant produces PVC suspension resins used in pipes, siding, windows, doors, blow-molded bottles, and injection-molded fittings.<sup>679</sup>
  - “For its downstream building products companies, Westlake provides PVC resin that becomes PVC pipe for water and sewer applications, PVC siding, windows, fencing and other building products in the marketplace. The new facility will allow Westlake to be more fully integrated through a streamlined production model, as the company will be able to use internally produced chlorine to support its vinyl manufacturing operations,” reported *Trade and Industry Development* in 2014.
- **Pollution:**
  - Due to its past use of acetylene to produce VCM and mercury cells to produce chlorine, this facility has a history of mercury pollution that spans the globe.
  - In 1995, it was the only plant in the US still using acetylene to produce VCM, which was consumed on-site and in Illiopolis, Illinois, in PVC manufacturing. BASF held a 50% stake in the acetylene plant in Plaquemine.<sup>680</sup> Acetylene production of VCM uses mercuric chloride as a catalyst.
  - “During the early 1990s, the Company shipped partially depleted mercuric chloride catalyst [used in acetylene-VCM production] to the facility of Thor Chemicals S.A. (PTY) Limited (‘Thor’) in Cato Ridge, South Africa, for recovery of mercury,” reads Borden’s 1995 annual report.<sup>681</sup>
  - Borden shipped 2,900 drums of depleted mercuric chloride catalyst that were never recycled. Two Thor employees died of mercury poisoning. Thor Chemical claimed it was “recycling” mercury waste from around the world. Instead, it burned a portion of it, stored and dumped the bulk of it, and in the process poisoned its workers and the surrounding environment with some of the worst mercury contamination documented in the world.<sup>682</sup>
  - In 1994, the U.S. Department of Justice charged Borden with illegal exports of toxic waste. “Borden shipped over 300,000 pounds of hazardous waste to a Thor Chemicals facility located in South Africa without notifying EPA as required by RCRA,” asserted the DOJ. “The Borden shipments went to the Thor Chemicals facility purportedly for recycling, but little or none of the waste was actually recycled. Borden has already publicly acknowledged that approximately 2,500 barrels containing mercury and vinyl chloride wastes were found at the Thor facility with Borden labels.”<sup>683</sup>
  - “It was about 5 o’clock on Thursday afternoon in August 1996, when a dense gray cloud descended over Route 73, a two-lane road near Geismar, La., cutting visibility to zero and triggering a rear-end collision,” recounted a *Time* article. “As State Trooper Ross Johnson... drove toward the accident, he noted that every car headed his way had headlights on and windshield wipers flapping. When Johnson got out of his patrol car, he suddenly got hit by the heavy smell of ammonia. He ushered the drivers of the two cars out of the cloud and into a guard shack at an entrance to the Borden Chemicals and Plastics plant. ‘The fog was so dense I couldn’t see the road,’ one driver told him. A plant safety officer had notified authorities about the chemical release, but had assured them ‘there was no off-site impact.’ By then, Johnson recalled, ‘there was a fog as far as the eye could [see].’ After Johnson left the scene, his ‘throat was really starting to clench, [his] eyes were starting to burn, and [his] skin was really starting to itch.’ Johnson later learned that the cloud was a witches’ brew of toxic chemicals: ethylene dichloride, vinyl-chloride monomer and hydrogen chloride.”<sup>684</sup>

- In July 1997, VCM and ammonia again “escaped from the plant and forced the closing of Route 73,” according to *Time*. “In July 1998, a cloud of hydrochloric acid spewed out, shutting down roads in the area for about 20 minutes.”<sup>685</sup>
- In 1998, Borden agreed to pay \$3.6 million in civil penalties issued by the EPA, and to spend another \$3.4 million in remediation and other costs. It agreed to decommission two deep underground wells where it had been storing hazardous waste.<sup>686</sup> “The fine was described by a U.S. Attorney as ‘the largest ever for hazardous-waste law violations in Louisiana,’” explained Mike Schade of the Center for Health, Environment & Justice (CHEJ). “The settlement ended a case in which the U.S. EPA claimed Borden failed to investigate and clean up contamination at its site, failed to report toxic spills, and ran an incinerator without the proper license. Borden said in a news release that the penalty is ‘less than 1 percent of the \$800 million judgment sought by the government.’”<sup>687</sup>
- In 2008, according to EPA Toxics Release Inventory data, Westlake’s Geismar plant released more VCM than any other in the USA.<sup>688</sup>
- “On July 8, 2010, over 900 pounds of vinyl chloride as well as other chemicals were released during another accident,” according to CHEJ.<sup>689</sup>
- In 2012, an explosion occurred during a restart of the VCM unit.<sup>690</sup> Westlake Chemicals estimated that it released 2,645 pounds of hydrochloric acid, 632 pounds of chlorine, 239 pounds of vinyl chloride monomer, and many other chemicals.<sup>691</sup>
- In 2012, OSHA announced that it had “cited Westlake Vinyls Co. LP in Geismar for 10 serious safety and health violations, primarily related to OSHA’s process safety management standards. Proposed penalties total \$67,000.... A serious violation occurs when there is substantial probability that death or serious physical harm could result from a hazard about which the employer knew or should have known.”<sup>692</sup>
- From 2012 to 2016, by capacity, the plant had the second highest rate of chloroform and dioxin releases in the US and Canada. It also released higher than industry median rates of EDC, VCM, carbon tetrachloride and hydrochloric acid pollution.
- For more pollutant release information, see Appendix.

## INVENTORY CODE: AMUSA22

- **Plant Name:** *Westlake - Lake Charles*
- **Owner:** Westlake Chemical. Formerly owned by Conde Vista, Georgia Gulf, and PPG and Axiall. Westlake purchased Axiall in 2016.
- **Location:** Westlake, Louisiana, USA.
- **Processes:** Membrane and synthetic diaphragm.<sup>693</sup>
- **Year Opened:** 1947.
- **Capacities** (tons per year): 1.27 million tons chlorine (of which an estimated 250,000 tons are from synthetic diaphragm; and 1,020,000 tons are from membrane cells), 952,000 tons VCM, and 324,000 tons chlorinated derivatives. According to Westlake Chemicals, the Lake Charles site “consists of two tracts of land making up approximately 1,690 acres, each within three miles of the other. The site operates a diverse portfolio of manufacturing plants, including three chlor-alkali plants, two VCM plants, a chlorinated derivative products plant and cogeneration assets.”<sup>694</sup>
- **Capacity Rank** (Western Hemisphere): 2nd of 41 plants overall. 3rd of 24 membrane plants. 2nd of 5 synthetic diaphragm plants.
- **Technology Conversions:**
  - PPG closed a mercury cell chlor-alkali plant in Westlake in 2005.<sup>695</sup>
  - By 2010, all of this plant’s asbestos diaphragms were converted to synthetic diaphragms.<sup>696</sup>
  - A \$1.9 billion ethane cracker complex is under construction and due to start operations in 2019.<sup>697</sup> The “cracker complex and an associated \$1.1 billion monoethylene glycol (MEG) plant intend

to take advantage of access to competitive US shale feedstock resources as well as existing ethylene-distribution infrastructure,” according to *Oil & Gas Journal*.<sup>698</sup>

- **Markets:**

- According to prior owner Axiall, “vinyl-chloride monomer produced at Axiall’s Lake Charles North and South plants is sent to the Aberdeen, Miss., facility for PVC production. In turn, some PVC resins produced at the Aberdeen (plant) are shipped to a variety of Royal Building Products locations, including those in Columbus, Ohio, Bristol, Tenn., and Abbotsford, British Columbia, where it is used to create end products like pipe and siding.”<sup>699</sup> Aberdeen had a PVC production capacity of 455,000 tons per year in 2006.<sup>700</sup>
- An in-house fleet of 42 double-hull tank barges deliver liquid chlorine gas, liquid caustic soda, EDC, and chlorinated solvents to destinations in the Gulf Intracoastal Waterway and the Mississippi, Ohio, Missouri, Illinois, Arkansas, Tennessee, and Kanawha Rivers.<sup>701</sup>
- “A portion of VCM produced at the Lake Charles facilities is sold in domestic and exports markets,” Georgia Gulf reported in 1999.<sup>702</sup>
- VCM from Lake Charles supplied Georgia Gulf’s PVC plant in Oklahoma City,<sup>703</sup> which closed in 2008.<sup>704</sup>
- Co-located with Certainteed PVC siding plant, which had a reported capacity of 215,000 tons per year in 2006.<sup>705</sup>
- Manufactures chlorinated derivatives, including perchloroethylene, trichloroethylene, and methyl chloroform.<sup>706</sup>

- **Pollution:**

- In 1999, Georgia Gulf acquired the VCM plant from Conde Vista and noted “several serious environmental issues,” including:
  - On-site and offsite groundwater contamination, including in the Mossville community adjacent to the plant, first identified in 1981;
  - A \$42.1 million settlement with Mossville residents and the purchase of many homes.
  - Federal environmental investigations of VCM contamination of the Calcasieu Estuary.<sup>707</sup>
- Before it was closed in 2005, the mercury cell chlor-alkali plant in Westlake released an average of 997 pounds of mercury per year into the air, according to the EPA.<sup>708</sup>
- A fire in the VCM unit on Dec. 24, 2012, led then-owner PPG to declare a force majeure for VCM and other liquids.<sup>709</sup>
- In December 2013, after another fire broke out in the VCM area of the chemical complex, KATC-TV investigated the plant’s recent pollution track record. It reported:
 

“As a KATC investigation found, the company has a long track record of chemical spills and violating government regulations set by the Environmental Protection Agency, Louisiana Department of Environmental Quality and the Occupational Safety & Health Administration.

“The company was fined \$400,000 by LDEQ in September — one of the largest fines of the year — after years of chemical spills and environmental issues. Part of the settlement included a stipulation that the company install a \$190,000 leak detection and repair program.

“But chemical releases have continued. On Dec. 2 (2013), 104 pounds of vinyl chloride spilled after an equipment failure, and in November, a leak in a corroded pipe led to the release of 171 pounds of hydrogen chloride gas, according to LDEQ documents. A month earlier, another leak led to the release of 357 pounds of flammable liquid. The company also was fined \$6,000 last year for spilling 225 pounds of vinyl chloride after another equipment failure.

“These issues and others have led the facility to be in ‘significant violation’ of two Environmental Protection Agency regulations for years. It has had significant violations to the Clean Air Act for three years, and the Resource Conservation and Recovery Act for more than two years, according to the EPA. It has also been in noncompliance with the Clean Water Act for three years, according to the EPA. The facility sits near the Lake Charles lake.”<sup>710</sup>

- From 2012 to 2016, by capacity, the Lake Charles plant's rates of releases ranked fourth for EDC and VCM. It also released higher than industry median rates of dioxins, chloroform, chlorine, and hydrochloric acid.
- For more pollutant release information, see Appendix.

## INVENTORY CODE: AMUSA23

- **Plant Name:** *Westlake - Calvert City*
- **Owner:** Westlake Chemical. (Acquired VCM plant from B.F. Goodrich in 1990, and the rest of the facility by 1997.)<sup>711</sup>
- **Location:** Calvert City, Kentucky, USA.
- **Process:** Membrane.
- **Year Opened:** 1966. Original technology was mercury cell.<sup>712</sup>
- **Capacities** (tons per year): 250,000 tons chlorine, 680,000 tons VCM, and 680,000 tons PVC suspension resins. The Calvert City plant also includes an ethylene plant and produces olefins.<sup>713</sup> Some EDC for PVC production has been supplied by the OxyChem plant in Convent, Louisiana (see AMUSA09).
- **Capacity Rank** (Western Hemisphere): 21st of 41 plants overall. 8th of 24 membrane plants.
- **Technology Conversions:**
  - Converted from mercury to membrane cell in February 2002.<sup>714</sup>
  - Westlake expanded its ethane cracker capacity in Calvert City in 2017. Ethylene produced here is "primarily consumed by Westlake in the production of higher value-added chemicals including PVC."<sup>715</sup>
  - Westlake was "expanding its ethane cracker" in Calvert City in 2017.
- **Markets:**
  - The Calvert City plant produces PVC suspension resins used in pipes, siding, windows, doors, blow-molded bottles and injection-molded fittings.<sup>716</sup>
- **Pollution:**
  - "In January 1974, B.F. Goodrich informed federal officials that four employees of its PVC plant near Louisville, Kentucky, had been diagnosed with angiosarcoma since 1967," reported the Center for Public Integrity. "The tumor was so rare that only about 25 cases per year occurred in the U.S., according to the CDC. The Occupational Safety and Health Administration moved quickly to crack down on vinyl chloride, proposing a 500-fold reduction in the exposure limit in the space of a few months. Despite industry predictions of an economic cataclysm, PVC plants were able to achieve the reduction in short order, and the risk of angiosarcoma among workers was 'virtually eliminated,' the CDC found."<sup>717</sup>
  - Before it stopped running in 2002, each year the Westlake mercury cell chlor-alkali plant in Calvert City released an average of 983 pounds of mercury into the air, and transferred an average of 10,108 pounds of mercury offsite, according to the EPA.<sup>718</sup>
  - ICIS reported an explosion that followed a vinyl chloride leak on January 29, 2002. The heat from the fire ruptured a chlorine pipeline, which leaked chlorine gas. There were no reported injuries.<sup>719</sup>
  - In 2003, another explosion and fire in the VCM unit released a large vapor cloud that spread "over portions of Livingston County," according to the *Daily Kos*. The author also records the plant's releases of VCM and other toxic chemicals on August 16, 2005, and October 7, 2008.<sup>720</sup>
  - In 2010, Westlake Vinyls in Calvert City reported releasing (by mass) over 31 pounds of dioxins and dioxin-like compounds to surface waters, more than any company in the US that year.<sup>721</sup>
  - Also in 2010, Westlake Vinyls agreed to pay the state of Kentucky and the federal government \$800,000 and to take corrective actions after officials charged them with hundreds of violations of clean air and water laws.<sup>722</sup>
  - A chlorine gas leak occurred for 15 to 20 minutes on August 22, 2013.<sup>723</sup>

- An “unexpected shutdown” occurred on June 1, 2016, “as a result of a mechanical failure of its ethylene unit which resulted in a complete outage of the complex, which halted all production including EDC, VCM, Chlor-Alkali and PVC resin,” Westlake Chemical reported. The plant restarted more than six weeks later.<sup>724</sup>
- From 2012 to 2016, the Westlake-Calvert City plant released EDC and VCM at higher rates than any other plant in the US and Canada. It also ranked second for dioxin and chlorine releases.
- For more pollutant release information, see Appendix.

## INVENTORY CODE: AMUSA24

- **Plant Name:** *Westlake - Natrium*
- **Owner:** Westlake. In 2016, Westlake Chemical purchased Axiall, the prior owner.
- **Location:** Proctor (near New Martinsville), West Virginia, USA.
- **Process:** Mercury (Uhde 20, installed in 1958) and synthetic diaphragm (Tephram).<sup>725</sup>
- **Year Opened:** 1943.<sup>726</sup>
- **Capacities** (tons per year): 227,000 tons. Estimated 100,000 tons chlorine by mercury cell, and 127,000 tons chlorine by synthetic diaphragm.<sup>727</sup>
- **Capacity Rank** (Western Hemisphere): 22nd of 41 plants overall. 3rd of 8 mercury cell and 5th of 5 synthetic diaphragm plants.
- **Technology Conversions:**
  - In 2007, then-owner PPG announced it would “spend about \$3 million by the end of the year to reduce mercury discharges from the facility, which opened in 1943, with a mercury-free diaphragm operation that was upgraded in 1984,” the *Post-Gazette* reported. “Mercury cell process, which makes chlorine and caustic soda by pumping saltwater through mercury to produce a chemical reaction, was installed in 1957.”<sup>728</sup>
  - By 2015, all of this plant’s asbestos diaphragms were converted to synthetic (Tephram) diaphragms.<sup>729</sup>
  - In its 2017 annual report, Westlake noted that “in March 2011, the EPA proposed amendments to the emission standards for hazardous air pollutants for mercury emissions from mercury cell chlor-alkali plants. These proposed amendments would require improvements in work practices to reduce fugitive mercury emissions. We operate a mercury cell production unit at our Natrium facility. We cannot predict the timing or content of the final regulation, or its ultimate cost to, or impact on us.”<sup>730</sup>
- **Markets:**
  - Chlorine from this merchant plant is shipped by barge and rail.<sup>731</sup>
  - The plant also manufactures chlorinated derivatives.<sup>732</sup>
  - An in-house fleet of 17 double-hull tank barges deliver liquid chlorine and liquid caustic soda to destinations in the Gulf Intracoastal Waterway and the Calcasieu, Mississippi, Ohio, Missouri, Illinois, Arkansas, Tennessee, Monongahela, and Kanawha Rivers.<sup>733</sup>
- **Pollution:**
  - “PPG Industries’ chlorine production facility in Natrium, W.Va., which releases more than 400 pounds of mercury into the air and the Ohio River annually, is one of just five such plants in the United States still using an inefficient, polluting technology invented in 1894,” reported the *Pittsburgh Post-Gazette* in 2007.<sup>734</sup>
  - From 2012 to 2013, the ChemWaste landfill in Emelle, Alabama, received 103,060 pounds of liquid mercury from the Natrium plant.<sup>735</sup>
  - A chemical explosion killed a worker at the plant in October 2014.<sup>736</sup>
  - From 2012 to 2015, the Natrium plant transferred 77,472 pounds of asbestos to landfills.<sup>737</sup>
  - “On August 27, 2016, about 8:26 a.m., Eastern Daylight Time, a specification DOT 105J500W

tank car, AXLX1702, experienced a sudden crack in the tank shell shortly after being filled with liquefied compressed chlorine at the rail car loading rack,” according to a National Transportation Safety Board accident account.

“A peaceful, late-summer morning quickly descended into chaos for hundreds of area residents when more than 17,000 gallons of chlorine leaked from inside a railcar at the Axiall chemical plant,” reported *The Intelligencer*. “The leak resulted in a large chlorine cloud that covered areas on both sides of the Ohio River. This forced hundreds from their homes in the areas of Kent, Fish Creek, Proctor and New Martinsville, as well as locations in Monroe County. Portions of W.Va. 2 and Ohio 7 also were shut down for hours as the cloud dissipated. Although there were no immediately apparent injuries to the public, a pair of workers went to the hospital for their conditions. Moreover, residents and businesses within at least a 26-mile radius of the plant may have sustained property damage, in addition to suffering the inconvenience of their displacement.”<sup>738</sup>

- From 2012 to 2016, by weight, the relatively small Natrium plant released more hydrochloric acid (HCl) than any other US chlor-alkali or PVC plant. It reported releasing over 248 tons of HCl per year into the air. This is 158 tons per year more than released by the hemisphere’s largest plant, the Olin Freeport facility, which is 13 times larger. The Natrium chemical plant releases about 1.1 tons of HCl for each 1,000 tons of chlorine capacity. This rate of release is nearly twice as high as the next highest plant (Mexichem’s PVC resin factory in Henry, Illinois, and 188 times higher than the US industry’s median rate (5.8 kg per 1,000 tons chlorine throughput).
- This plant also released chlorine at a rate over 80 times higher than the industry median. This was largely due to fugitive emissions reported in 2016 that are likely related to the tank-car accident.
- For more pollutant release information, see Appendix.

## REGION: AFRICA

### EGYPT

#### INVENTORY CODE: AFEGY01

- **Plant Name:** *Misr - Alexandria*
- **Owner:** Misr Chemical Industries, “a subsidiary of Holding Company for Chemical Industries.”<sup>739</sup>
- **Location:** Alexandria, Egypt.
- **Process:** Membrane. Converted from mercury in mid-1990s.<sup>740</sup>
- **Year Opened:** 1961.<sup>741</sup>
- **Capacities** (tons per year): 68,250 tons chlorine (2018).
- **Capacity Rank** (Africa): Tied for 5th of 6 plants.
- **Technology Conversions:**
  - Switched from mercury in 1993. Increased capacity to 60,000 tons.<sup>742</sup>
  - Misr signed contract in 1994 for conversion from membrane to mercury and increased capacity to 50,000 tons.<sup>743</sup>
  - In 2014, the company’s chairman announced a strategic plan to increase production capacity, mainly to “cover the needs of water companies.”<sup>744</sup>
  - In 2017, the company announced completion of a project to increase capacity to 206 tons per day<sup>745</sup> (presumably caustic), which is the equivalent of 75,000 tons caustic soda and 68,000 tons chlorine per year.
- **Markets:**
  - According to the company’s website, the main destinations for the company’s chlorine are Syria, Libya, and Lebanon, and the main use for the chlorine is to purify drinking water.<sup>746</sup>
- **Pollution:**
  - This plant is located near tourist beaches in Alexandria. In 1973, researchers found mercury in the beach sands at levels between 8.02 and 15.5 parts per million. “The Chlorine-Alkali plant is obviously the major source of mercury pollution,” they found. The research team included an employee of Misr Chemical.<sup>747</sup> The plant converted from mercury to membrane cells in the 1990s.

#### INVENTORY CODE: AFEGY02

- **Plant Name:** *EPC - Alexandria*
- **Owner:** Egyptian Petrochemicals Company (EPC), a subsidiary of the Egyptian Petrochemicals Holding Company (ECHEM).<sup>748</sup>
- **Location:** Alexandria, Egypt.
- **Process:** Membrane (Asahi).<sup>749</sup>
- **Year Opened:** 1987.<sup>750</sup>
- **Capacities** (tons per year): 109,000 tons chlorine (in 2010<sup>751</sup>), 100,000 tons VCM,<sup>752</sup> 80,000 tons suspension-PVC resins and 30,000 tons “PVC compounds.”<sup>753</sup>
- **Capacity Rank** (Africa): 3rd of 6 plants.
- **Technology Conversions:**
  - In 2015, the company announced completion of an expansion that “raised production rates from 65,000 tons to 90,000 tons of PVC used in the manufacture of insulation materials and plastic pipes.”<sup>754</sup>
  - In June 2017, EPC hired Nuberg, an engineering firm based in India, to build a 228,000 ton-per-year chlor-alkali membrane plant (Ineos Bi-Chlor process) in Alexandria.<sup>755</sup>

- **Markets:**

- PVC. Uses chlorine for in-house PVC resin production.<sup>756</sup>
- After the plant opened in 1988, customers for this plant's PVC included Esilon Egypt (pipe manufacturer), Bata Shoe Co. (shoe soles), and the Egyptian government-owned National Plastics Co. (pipe for cables).<sup>757</sup>
- Egypt ranked as the world's 25th leading source of PVC resins from 2013-2016, averaging 76,320 tons per year.<sup>758</sup>

## INVENTORY CODE: AFEGY03

- **Plant Name:** *TCI Sanmar - Port Said*

- **Owner:** Sanmar Holdings (India), through its TCI Sanmar (formerly Trust Chemical) subsidiary.<sup>759</sup>

- **Location:** Port Said, Egypt.

- **Process:** Membrane.

- **Year Opened:** pre-2007.

- **Capacities** (tons per year): 250,000 tons chlorine, 400,000 tons VCM, 200,000 tons PVC, 60,000 tons ethylene.<sup>760</sup> Chlorine requirements for VCM production are greater than on-site capacity provides. VCM production may be supplemented by EDC imports, including shipments from the United States. Egypt was the sixth largest destination for US EDC exports from 2012 to 2016 (43,519 tons per year, average).<sup>761</sup> Egypt also imports EDC from Dow in Europe.<sup>762</sup>

- **Capacity Rank** (Africa): Largest chlor-alkali plant in Africa.

- **Technology Conversions:**

- When Sanmar acquired this plant in 2007, it had a production capacity of 180,000 tons chlorine, but was operating at only 40% capacity due to a lack of markets for the chlorine. Sanmar planned to turn this excess chlorine into PVC through the addition of EDC, VCM and PVC capacity.<sup>763</sup>
- In 2007, Sanmar contracted with Protech, an India-based engineering firm, to add over 93,000 tons per year chlorine capacity in Port Said.<sup>764</sup>
- In 2012, the Sanmar Group completed a PVC plant with a 200,000-ton capacity, and planned to double this to 400,000 tons by April 2018.<sup>765</sup>
- In 2016, the Oxford Business Group reported that Sanmar "is looking to extend the Trust Chemical Industries plant in Port Said, with ambitions to turn it into the largest producer of PVC and caustic soda in the Middle East and North Africa region. Sanmar will invest \$350 million to this end, bringing its total investments in the country to \$1.45 billion, according to the Egyptian daily *Al Ahram*."<sup>766</sup>

- **Markets:**

- In 2007, the company said that its planned VCM capacity would feed both on-site PVC production and production at its new PVC plant in Tamil Nadu, India. "About 200,000 tonnes/year of VCM will be captively utilised by the PVC plant at Port Said," reported industry experts ICIS. "The remaining 200,000 tonnes/year of VCM will be shipped to India to feed the 200,000 tonne/year PVC project which Chemplast Sanmar, a Sanmar Group subsidiary, will start up in Cuddalore, in Tamil Nadu, in July 2008," the source added.<sup>767</sup>
- Egypt ranked as the world's 25th leading source of PVC resins from 2013-2016, averaging 76,320 tons of exports per year.<sup>768</sup>

- **Pollution:**

- In 2010, Reporters Without Borders for Press Freedom highlighted the case of an Egyptian blogger who reported on pollution from this plant. "In Egypt, Trust Chemical Industries has for years been dumping unrecycled water into Lake Manzalah and the Suez Canal, near Port Said, while the government, out of fear or as a result of corruption, refused to intervene. Tamer Mabrouk, an ordinary blogger, investigated the issue and then took the risk of posting the results of his enquiries online. He was sued for libel in June 2008," wrote the rights group. "I brought a law-

suit against the company myself, requesting its closure as a source of pollution,' Mabrouk said. 'The court ruled that it was not competent to hear the case. At the same time, Trust Chemical Industries asked me to withdraw my suit in return for a sum of money. When I refused outright, they demanded that I issue a retraction.' A Port Said court fined Mabrouk 6,000 euros on 26 May 2009 - a fairly dissuasive message for someone who takes more than a year to earn that kind of money. He was then fired from his job.<sup>769</sup>

- In June 2017, a report by Alaraby Aljadeed claimed that TCI Sanmar Chemicals' operations in Port Said, Egypt, have been linked to explosions and lethal gas leaks that allegedly caused the death of one worker and injured about 10 others. The report also claims that 150 factory workers have suffered from various life-threatening illnesses after being exposed to toxic gases during the production process. According to Alaraby Aljadeed, the company's workers' union submitted a formal complaint to the Office of the Deputy Minister of Interior for National Security. The complaint documents 14 serious incidents, including dumping toxic waste into Lake Manzala and the Suez Canal.<sup>770</sup>

## MOROCCO

### INVENTORY CODE: AFMOR01

- **Plant Name:** SNEP - Mohammedia
- **Owner:** Ynna Holding (Morocco), through National Society of Electrolysis and Petrochemicals (SNEP) subsidiary.<sup>771</sup>
- **Location:** Mohammedia, Morocco.
- **Process:** Membrane. Replaced mercury cells in 2003.
- **Year Opened:** 1977.<sup>772</sup>
- **Capacities** (tons per year): At least 68,000 tons chlorine, 120,000 tons EDC (2011), 85,000 tons PVC (2017).<sup>773</sup>
- **Capacity Rank** (Africa): Tied for 5th of 6 plants.
- **Technology Conversions:**
  - In 1977, SNEP started chlor-alkali production using mercury cells.<sup>774</sup> Opening capacities were 22,000 tons chlorine and 28,000 tons PVC.<sup>775</sup>
  - In 1991, production capacities were 29,000 tons chlorine and 36,000 tons PVC.
  - In 1998, the first unit of membrane cells (16,000-ton capacity) were installed. Production capacities increased to 40,000 tons chlorine and 50,000 tons PVC.<sup>776</sup>
  - Also in 1997, Uhde De Nora supplied a membrane chlor-alkali unit with a 16,000-ton capacity.<sup>777</sup>
  - In 2003, SNEP replaced its mercury cells with a second membrane unit (21,300 ton capacity) and increased PVC production capacity to 55,000 tons.<sup>778</sup>
  - In 2009, SNEP purchased a new 85,000-ton-per-year suspension-PVC unit from Uhde (now ThyssenKrupp).<sup>779</sup>
  - In 2011, SNEP purchased a new EDC cracker and new fluidized bed oxychlorination reactor (120,000 ton EDC capacity).<sup>780</sup>
  - In 2018, SNEP planned to launch a plant expansion that would bring its production capacity to 140,000 tons per year of PVC.<sup>781</sup>
- **Markets:**
  - According to Ynna Holding, this is the only plastics manufacturing plant in Morocco. In addition to supplying 90% of the country's PVC, "SNEP also exports its products to England, Spain, Portugal, Egypt, Tunisia and sub-Saharan Africa."<sup>782</sup>
  - SNEP built a PVC pipe plant in Côte d'Ivoire in 1997.<sup>783</sup>
  - In 2006, PVC resins and compounds comprised over 75% of the company's sales.<sup>784</sup> The main uses for these resins are PVC tubes, profiles, and cabling.<sup>785</sup>

- In 2009, Morocco informed the World Trade Organization that it initiated “an investigation into the substantial increase in imports of PVC... which are causing or threatening to cause serious injury to domestic production... There has been a massive increase in PVC imports both in absolute terms and in relation to domestic production. Imports during the first quarter of 2009 increased by 434 per cent compared to the same period in 2008... This increase is due to an unexpected change in circumstances arising as a result of the international economic crisis which has caused the fall in global demand for PVC, especially in Europe and the United States of America.”<sup>786</sup>
- Morocco’s anti-dumping investigations into imports of PVC from the US, EU, and Mexico led to anti-dumping duties, lasting from 2016 to 2021, on PVC imported from these countries.<sup>787</sup>
- **Pollution:**
  - Tests of wastewater discharges in 1996 found mercury concentrations between 3.4 and 13.6 parts per million (ppm) from the chlor-alkali unit, up to 5.1 ppm from the VCM unit, and 1.1 and 9.0 ppm from the PVC unit. A Food and Agriculture Organization report noted there were also significant releases of VCM and EDC in the wastewater.<sup>788</sup> SNEP replaced mercury cells with membrane cells in 2003.

## INVENTORY CODE: AFSAF01

- **Plant Name:** *NCP Chlorchem - Chloorkop*
- **Owner:** SynChem, via NCP Chlorchem subsidiary. Formerly state-owned Klipfontein Organic Products (1940s to 1967), Sentrachem Group (1967-1997), and Dow Chemical (1997 to 2002).<sup>789</sup>
- **Location:** Chloorkop, Gauteng, South Africa.
- **Process:** Membrane.
- **Year Opened:** 1942.<sup>790</sup>
- **Capacities** (tons per year): 101,000 tons chlorine (2014).
- **Capacity Rank** (Africa): 4th of 6 plants.
- **Technology Conversions:**
  - From 1988 to 1996, Asahi Chemical supplied the plant with membrane cells.<sup>791</sup>
  - In 2008, NCP Chlorchem opened a new chlor-alkali plant with a 19,000-ton chlorine capacity.<sup>792</sup>
  - In September 2010, NCP Chlorchem stopped production at the newer of its two plants “due to manufacturing problems,” reported ICIS. This plant had the capacity to produce 19,000 tons of chlorine. “To compensate for the shutdown, the company is running the older plant at full capacity,” the source said. “The older plant has a production capacity of 85,000 tonnes/year of caustic soda and 82,000 tonnes/year of chlorine.”<sup>793</sup>
  - In November 2010, Company reopens newer chlor-alkali plant. ICIS reports the shutdown was due to an explosion.<sup>794</sup>
  - In 2013, two chlor-alkali plants were operating at Kempton Park.<sup>795</sup>
  - In 2016, NCP Chlorchem became part of the SynChem Group.<sup>796</sup>
- **Markets:**
  - Originally developed to produce phosgene and mustard gas at the request of the British government.<sup>797</sup>
  - After World War II, the factory produced benzene hexachloride and DDT.<sup>798</sup>
  - In 1997, Dow Chemical acquired Sentrachem, which according to *The New York Times*, “would allow Dow, which is based in Midland, Mich., to make a generic version of Roundup, the biggest-selling herbicide in the world, after Monsanto’s United States patent expires in 2000.”<sup>799</sup>
  - According to the owner, markets include “water treatment (potable and effluent); mining; pulp and paper; general trade and the chemical industries.”<sup>800</sup> It supplies over 90% of the chlorine used for water purification in the country.<sup>801</sup>

- In 1995, the company exported about half of its chloroparaffin products to countries including Indonesia, South Korea, Taiwan, and the United Arab Emirates.<sup>802</sup> NCP Chlorchem continued to produce and export chlorinated paraffins in 2016.<sup>803</sup>
- **Pollution:**
  - In July 2002, Greenpeace collected 11 wastewater samples from the plant. It noted that “the effluent channel (uncovered and broken at various points) runs across open land immediately after exiting the plant boundary fence... [Effluent] is then discharged to open evaporation ponds and that residual water from the site of these ponds is thereafter pumped to the Kaalspruit stream.” Tests found chloroform and carbon tetrachloride in the wastewater and that “the discharge of these chemicals to the evaporation ponds will inevitably result in substantial losses to the atmosphere, adding to the overall anthropogenic burden of atmospheric VOC [volatile organic compound] pollution.” Further, “once reaching groundwater, these VOCs can persist for many years, over which the contaminant plume can spread great distances down gradient from the initial point of contamination.”<sup>804</sup>
  - Explosions shut down portions of the operation in December 2008 and September 2010.<sup>805</sup>

## INVENTORY CODE: AFSAF02

- **Plant Name:** *Sasol - Midland*
- **Owner:** Sasol (formerly Polifin and AECI Chlor-Alkali & Plastics, which was part-owned by ICI of UK).
- **Location:** Midland, Sasolburg, South Africa.
- **Process:** Synthetic diaphragm and membrane. Converted from asbestos diaphragm in late 2000s.
- **Year Opened:** 1967.<sup>806</sup>
- **Capacities** (tons per year): 200,000 tons of VCM and PVC (2010).<sup>807</sup> At least 112,000 tons of chlorine, based on chlorine input needed to meet VCM and PVC capacities. In 2014, the company redacted all capacity information in an Atmospheric Emissions License filed with the Community Health and Environmental Services.<sup>808</sup> At least 92,000 tons of its capacity is from synthetic diaphragm technology. (See Conversions below).
- **Capacity Rank** (Africa): 2nd of 6 in Africa.
- **Technology Conversions:**
  - In 1972, the Midland plant had a PVC capacity of 29,029 tons.<sup>809</sup>
  - In 1978, CEC supplied 18,000-ton-capacity “DS” (asbestos) diaphragm cells.<sup>810</sup>
  - In 1988, Uhde supplied 23,000-ton-capacity membrane cells.<sup>811</sup>
  - In 1994, the plant had a chlorine production capacity of 145,000 tons.<sup>812</sup>
  - In 1993, AECI and Sasol formed a joint venture, Polifin, and closed the acetylene process of VCM production.<sup>813</sup>
  - In 1996, Uhde supplied BiTAC membrane cells with 22,410-ton capacity.<sup>814</sup>
  - In 1997, Uhde supplied membrane cells with 36,700-ton capacity.<sup>815</sup>
  - In March 2003, Sasol announced a strategy to phase out asbestos at its plants worldwide.<sup>816</sup>
  - In 2005, Uhde expanded the plant’s EDC capacity (168,000 tons via direct chlorination and 160,000 tons via oxychlorination), VCM capacity (205,000 tons).<sup>817</sup> PVC capacity increased by 35,000 tons to 200,000.<sup>818</sup>
  - In 2008, the South African government banned the use, manufacturing, and import and export of asbestos and asbestos-containing materials.<sup>819</sup>
  - In 2010, Sasol added a synthetic diaphragm cell (MDC-55) with a 92,000-ton chlorine production capacity.<sup>820</sup>
- **Markets:**
  - This captive PVC plant sells resins worldwide.<sup>821</sup>

- **Pollution:**

- Until 1995, Polifin had the capacity to produce up to 10,000 tons of chlorofluorocarbons and HCFC-22, which are substances that deplete Earth's protective ozone layer. The plant produced an estimated 18,750 tons of CFCs and 2,500 tons of HCFC-22 from 1986 to 1995.<sup>822</sup>
- In May 2000, a gas leak resulted in 213 people requiring medical treatment.<sup>823</sup>
- In September 2000, a gas leak led to the hospitalization of four people, and 23 others "received medical attention," according to a local news report. It was the third leak in five months.<sup>824</sup>

## REGION: EUROPE

### BELGIUM

#### INVENTORY CODE: EURBE01

- **Plant Name:** *Inovyn - Jemeppe-sur-Sambre*
- **Owner:** Ineos, via Inovyn subsidiary. Formerly Solvic. Ineos acquired Inovyn in July 2016.<sup>825</sup>
- **Location:** Jemeppe-sur-Sambre, Belgium.
- **Process:** Membrane.<sup>826</sup> Converted from mercury in 2001.
- **Year Opened:** 1897.
- **Capacities** (tons per year): 174,000 tons of chlorine (January 2017).<sup>827</sup> 480,000 tons of EDC (2017).<sup>828</sup> 450,000 tons of suspension PVC.<sup>829</sup> Capacities redacted from EU competition analysis in 2013.<sup>830</sup> EDC requirements are supplemented by Inovyn's Lillo plant.<sup>831</sup>
- **Capacity Rank** (Europe): 28th of 39 chlor-alkali plants.
- **Technology Conversions:**
  - Started operations using Castner-Kellner mercury cells in 1897.<sup>832</sup>
  - Added PVC production to plant operations in 1949.<sup>833</sup>
  - In 1970, the plant's PVC production capacity was 90,000 tons, fed by a 200,000-ton VCM plant.<sup>834</sup>
  - Replaced mercury with membrane technology (Krup Uhde) from 1992 to 2001.<sup>835</sup>
  - Added VCM and PVC capacity in 2010.<sup>836</sup>
- **Markets:**
  - Captive (on-site) production of suspension PVC resins, which supply building- and automotive-plastics manufacturers in Europe.
  - The plant coats and replaces coatings for chlor-alkali membrane cell anodes.<sup>837</sup>
  - The Jemeppe plant also produces and sells EDC.<sup>838</sup>
- **Pollution:**
  - In 1999, according to Yarime's analysis of OSPAR Convention data, the plant released mercury at the following rates (per ton of chlorine capacity): 0.05 grams into products, 0.28 grams into waste water, and 1.78 grams into the air. Its total releases of 2.11 grams ranked third of 46 chlor-alkali plants.<sup>839</sup> At the time, the plant had a mercury cell chlorine production capacity of 82,000 tons, meaning the plant released an estimated 173 kilograms (kg) of mercury in 1999.<sup>840</sup>
  - In 2001, the Jemeppe plant released 177.7 kg of mercury, including 88 kg into the air, and 89.7 kg into water.<sup>841</sup>
  - In 2006, the newspaper *Vers L'Avenir* reported that 21 out of 70 people who worked in the plant's mercury cell rooms "have died as a result of cancer." Then-owner Solvay disputed those figures, saying that 450 people had worked in the cells since the 1960s.<sup>842</sup>
  - On December 29, 2008, the site released a cloud of vinyl chloride monomer approximately 50 meters long and 100 meters wide, which dissipated above the plant, according to a fire chief.<sup>843</sup>
  - An issue brief on Iseos, by the global non-profit Food and Water Watch, reported that the Jemeppe plant "emitted into the air, water or both an estimated 89.4 tonnes of ammonia, 39.7 tonnes of [EDC], 74.4 tonnes of the carcinogen vinyl chloride, 38 kilograms of mercury and over 34 kilos of lead between 2011 and 2015."<sup>844</sup>
  - On October 26, 2016, the plant released a cloud of chlorine that spread through the Sambre valley into surrounding villages. There were no reported injuries.<sup>845</sup>
  - In 2016, according to the European Pollutant Release and Transfer Register (E-PRTR), the Jemeppe plant released 10.1 tons of EDC into the air and 79.8 kg into water, 17.1 tons of VCM

into the air and 95.6 kg into water, 0.102 grams (TEQ) dioxins and furans into water, and 34 kg of HCFCs into the air.<sup>846</sup>

- Inovyn (Ineos) reported releasing an average 1.8 kg per year of hexachlorobutadiene from its Jemeppe-sur-Sambre plant from 2012 to 2016. It was one of only two chlor-alkali plants in Europe to report HCBd releases.

## INVENTORY CODE: EURBE02

- **Plant Name:** *Inovyn - Lillo and Zandvliet (Antwerp)*
- **Owner:** Ineos, through Inovyn ChlorVinyls, Ltd. Ineos acquired Inovyn in July 2016.<sup>847</sup> Formerly SolVin (originally a 50/50 joint venture between Phillips Petroleum and BASF and later a 75/25 joint venture of Solvay and BASF).<sup>848</sup>
- **Location:** Port of Antwerp, Flanders, Belgium. Production occurs in two sections of the Port of Antwerp chemical cluster (Zandvliet and Lillo).<sup>849</sup>
- **Processes:** Mercury and membrane.
- **Year Opened:** 1966 (Zandvliet) and 1970 (Lillo).
- **Capacities** (tons per year): 458,000 tons of chlorine (Jan. 2017), of which 90,000 tons were from mercury (in the Zandvliet section of the chemical cluster [formerly BASF]), and 368,000 tons were from membrane cells (in the Lillo section of cluster [formerly Solvay]).<sup>850</sup> Added 100,000-ton chlorine capacity as co-product of new potassium hydroxide facility in October 2017.<sup>851</sup> Inovyn operates a 275,000-ton EDC unit in the Zandvliet section.<sup>852</sup> These plants no longer produce PVC resin on-site.<sup>853</sup>
- **Capacity Rank** (Europe): 4th of 39.
- **Technology Conversions:**
  - Lillo opened in 1970 with PVC capacity of 170 million pounds, using VCM supplied by BASF.<sup>854</sup>
  - In 1999, the Solvay/BASF joint venture decided to shut down Solvay's 250,000-ton EDC unit (located in the Lillo section of the chemical complex) and BASF's 170,000-ton VCM /120,000-ton PVC unit (in nearby Zandvliet) by 2001, and instead use hydrochloric acid from BASF's isocyanate plant at Zandvliet in the production of EDC by Solvin at Zandvliet.<sup>855</sup> The shutdowns were completed in April 2011. According to ICIS (the world's largest petrochemical-market information provider), "Solvin has expanded capacity at other plants, particularly Jemeppe in Belgium and Rheinberg in Germany to compensate for part of the capacity lost at Zandvliet."<sup>856</sup>
  - In 2007, Solvay constructed an oxychlorination unit at its EDC plant in Zandvliet.<sup>857</sup>
  - The Lillo plant's mercury cell capacity (180,000 tons per year) was converted to membrane cell in 2012.<sup>858</sup>
  - Since 2015, the company has been expanding membrane production in Lillo and been in the process of closing its mercury cell plant in Zandvliet.<sup>859</sup> In 2017, the listed capacity for production by mercury cell was 90,000 tons, down from 110,000 tons in 2012.<sup>860</sup> (As of May 2018, Ineos had not yet announced final closure of the mercury cell plants).
  - As of March 31, 2016, according to Moody's (the credit ratings and research company), Inovyn planned to spend about \$120 million (€100 million) over the subsequent 12 to 18 months on converting its Lillo and Stenungsung mercury cell plants.<sup>861</sup>
  - In October 2017, Inovyn opened a 160,000-ton potassium hydroxide production facility, with 100,000-ton chlorine co-product, in Lillo by the end of 2017.<sup>862</sup>
- **Markets:**
  - Primary products are chlorine and EDC (made in Zandvliet section).<sup>863</sup>
  - Inovyn's plant in Zandvliet supplies Inovyn's Jemeppe PVC plant with EDC.<sup>864</sup>
  - The Antwerp chemical cluster has many other potential users of this chlorine, including BASF and Covestro, which manufacture polyurethane, epoxy, and polycarbonate plastics.<sup>865</sup>
- **Pollution:**
  - In 2001, the plant released a reported 109 kg mercury into the air, and 4 kg into water.<sup>866</sup>

- In 2011, a thunderstorm triggered a “small” chlorine leak. Residents were not evacuated.<sup>867</sup>
- At the time of its conversion to membrane technology, as of December 2012, the Lillo plant was using 260.92 tons of mercury in cells, and stored another 9.87 tons on-site. Also in December 2012, the Zandvliet plant in the Antwerp cluster had 184.91 tons of mercury in its cells, and stored another 8.7 tons in the facility.<sup>868</sup>
- In 2016, the plants reported releasing 54.2 kg of mercury into water.<sup>869</sup>

## INVENTORY CODE: EURBE03

- **Plant Name:** *Vynova - Tessenderlo*
- **Owner:** International Chemical Investors Group, via Vynova. The investment group acquired this and other plants from Inovyn in 2015 in an EU-mandated “remedy package” for the merger of Solvay and INEOS.<sup>870</sup>
- **Location:** Tessenderlo, Limburg, Belgium.
- **Processes:** Mercury and membrane. Note: Mercury cells were scheduled to be closed by the end of June 2018.
- **Year Opened:** 1969. Opened by Limburgse Vinylmaatschappij, a joint venture of DSM (Netherlands) and Produits Chimiques de Tessenderlo (Belgium), to produce VCM. Company renamed Tessenderlo Chemie in 1972.<sup>871</sup>
- **Capacities** (tons per year): 365,000 tons of chlorine in 2015 (of which an estimated 90,000 tons were derived from mercury cell and 275,000 tons from membrane technology). 1,180,000 tons EDC capacity.<sup>872</sup> 550,000 tons VCM capacity.<sup>873</sup>
- **Capacity Rank** (Europe): 8th of 39.
- **Technology Conversions:**
  - The plant opened with a 45,000-ton mercury cell unit in 1969.
  - As of 2001, the plant’s mercury cell capacity was 250,000 tons.<sup>874</sup>
  - In 2001, Tessenderlo announced plans to add a new membrane unit with a 91,000-ton chlorine capacity by 2004.<sup>875</sup> Uhde added more capacity in 2006.<sup>876</sup>
  - In 2015, plant owners started work on a new membrane plant (100,000-ton chlorine capacity with 150,000-ton potassium hydroxide coproduct), replacing its mercury cells and adding to its existing membrane capacity of 270,000 tons.<sup>877</sup> The company planned to convert Tessenderlo to “completely membrane-based production by the end of 2017,” reported industry experts ICIS in October 2015.<sup>878</sup>
- **Markets:**
  - Sells liquid chlorine, potassium hydroxide, potassium carbonate, hydrochloric acid, sodium hypochlorite, and caustic soda liquid.<sup>879</sup>
  - Supplies VCM to Vynova’s suspension PVC plants in Mazingarbe, France, and Beek Geleen, Netherlands.<sup>880</sup> The Mazingarbe plant had a production capacity of 255,000 tons of PVC in 2016.<sup>881</sup> The Beek plant had a capacity of 225,000 tons of PVC in 2011.<sup>882</sup> According to a 2011 EU review, this production chain, as with “all PVC producers” in the European Union, uses VCM mainly captively.<sup>883</sup> Its suspension PVC resins are used in packaging, profiles, pipes, bottles, floors, cable sheathings, and other products.<sup>884</sup>
  - Plant is linked with Tessenderlo Chemie (which makes water treatment chemicals, calcium chloride, and ferric chloride<sup>885</sup>), Ineos Chlorotoluenes, and Chevron Phillips Chemicals (which produces organosulfur specialty chemicals<sup>886</sup>).<sup>887</sup>
- **Pollution:**
  - In 2001, Tessenderlo Chemie released 172.6 kg mercury into the air, which ranked tenth among chlorine factories in Europe, and 2.6 kg into water.<sup>888</sup>
  - In 2016, the Tessenderlo plant released 97.6 kg mercury into the air, 16.4 tons of EDC (6.64 tons by accident), and 4 tons of VCM into the air (456 kg by accident). Vynova’s suspension PVC plant

in Mazingarbe, France, which consumes VCM from Tessenderlo, released 7.86 tons of VCM into the air in 2016. There is no pollution data for Vynova's plant in Beek Geleen, Netherlands, which also consumes VCM from Tessenderlo.<sup>889</sup>

- In October 2017, the Inspector General for Environment and Transport reviewed an application from Vynova for its Beek Geleen PVC plant and found deficiencies in its plans to minimize VCM emissions. The application stated that the plant would release 12.2 tons of VCM per year.<sup>890</sup>

## FRANCE

### INVENTORY CODE: EURFR01

- **Plant Name:** *Inovyn - Tavaux*
- **Owner:** Ineos, through its Inovyn subsidiary. Ineos acquired Inovyn in July 2016.<sup>891</sup> Formerly owned by Solvay.
- **Location:** Tavaux, France.
- **Process:** Membrane.
- **Year Opened:** 1930.<sup>892</sup> Converted from mercury in 2012.
- **Capacities** (tons per year): 360,000 tons of chlorine (2017).<sup>893</sup> 260,000 tons of PVC.<sup>894</sup> Some of this PVC capacity is supported by shipments of EDC by rail.<sup>895</sup>
- **Capacity Rank** (Europe): 10th of 39.
- **Technology Conversions:**
  - Started up membrane plant (100,000 tons) in 1992.<sup>896</sup>
  - Eliminated mercury cells by 2012.<sup>897</sup> According to a 2010 Solvay press release announcing this conversion, three chlorine plants were operating in Tavaux “each with output capability of 120,000 t/y. Only one uses the membrane process; the other two use the less environmentally friendly mercury process. Output will be consolidated into two production lines – a new facility with capacity of 240,000 t/y [tons/year] and a converted 120,000 t/y unit.”
- **Markets:**
  - Inovyn's plant in Tavaux produces suspension PVC and emulsion PVC resins.
  - It also sells EDC and VCM.<sup>898</sup>
  - It produces polyvinylidene chloride (PVDC)<sup>899</sup>, a plastic fiber known as Saran, formerly used as a plastic food wrap.
  - The Taveaux plant also produces polyvinylidene fluoride (PVDF), epichlorohydrin, caustic soda, chloromethanes, and allyl chloride.<sup>900</sup>
- **Pollution:**
  - In the 1990s, the plant produced up to 40,000 tons of HCFC-141b/142b, an ozone depleting substance.<sup>901</sup>
  - In 2001, according to Oceana, of seven chlor-alkali plants in France, Solvay's Tavaux plant was the leading source of mercury emissions (213.6 kg, 202 kg into the air, 11.6 kg into water).<sup>902</sup>
  - In 2008, according to Euro Chlor, the Tavaux plant had 298 tons of mercury in cells and another 43 tons of mercury stored on-site.<sup>903</sup>
  - At the time of its conversion to membrane technology, as of December 2012, the Tavaux plant had 107 tons of mercury in cells, and stored another 403 tons of mercury on-site.<sup>904</sup>
  - In 2016, the Tavaux plant released 9.78 tons EDC into the air, 23.9 tons VCM into the air and 19.5 to water, 2.6 kg mercury into water, and 168 kg HCBd into water.<sup>905</sup>
  - Inovyn (Ineos) reported releasing an average of 149.8 kg per year of hexachlorobutadiene from its Tavaux plant from 2012 to 2016. It was one of only two chlor-alkali plants in Europe to report HCBd releases.

**INVENTORY CODE: EURFR02**

- **Plant Name:** *Kem One - Lavéra*
- **Owner:** Kem One. Formerly Atochem.<sup>906</sup>
- **Location:** Fos-sur-Mer, Bouches-du-Rhône, France.
- **Processes:** Synthetic diaphragm and membrane.
- **Year Opened:** 1976.<sup>907</sup>
- **Capacities** (tons per year): 340,000 tons of chlorine, of which 179,000 tons are by synthetic diaphragm and 161,000 tons by membrane technology (2017).<sup>908</sup> 430,000 tons of VCM.<sup>909</sup>
- **Capacity Rank** (Europe): 11th of 39.
- **Technology Conversions:**
  - Opened in 1976 with asbestos process.
  - Doubled VCM capacity in 1991.
  - Added 100,000-ton chlorine production capacity in 1992 with Nora Technology membrane electrolyzers.<sup>910</sup>
  - Converted from asbestos to synthetic diaphragm technology (PMX® diaphragms) from 2000 to 2002.<sup>911</sup>
- **Markets:**
  - Most of the chlorine is used on-site. According to Kem One, “around half of the VCM produced is then delivered to the KEM ONE site at Berre-L’Etang (Bouches-du-Rhône) [formerly known as UCB - Usine Chimique de Berre]; the rest is sent by barge to the Saint-Fons site (Rhône) to be transformed into PVC.”<sup>912</sup> The Berre-L’Etang site has a production capacity of 290,000 tons of suspension PVC resins.<sup>913</sup> In 2000, Saint-Fons’ PVC capacity was 205,000 tons.<sup>914</sup> The Saint-Fons plant also has a 9,000-ton chlorinated PVC (CPVC) resin capacity.<sup>915</sup> Kem One’s 5 PVC resin plants (Berre, Balan, Saint-Auban, and Saint-Fons, France, and Hernani, Spain) have a combined PVC production capacity of 910,000 tons.<sup>916</sup>
  - Some chlorine is sold as water disinfectant.<sup>917</sup>
- **Pollution:**
  - Residents of the Fos-sur-Mer and Port-Saint-Louis area report “twice as many diseases as elsewhere in France,” according to a study published in 2017. Local residents and scientists formed Institut Écocitoyen pour la Connaissance des Pollutions, which has tested air quality since 2011. Institute director Philippe Chamaret, chemist and director of the Institute, said the chemical composition of air pollutants in the area is “extremely complex.”<sup>918</sup>
  - In 2016, the Fos-sur-Mer plant reported releasing 76.4 tons of EDC into the air and 22.5 kg to water, 7.96 tons of VCM into the air and 13.9 kg to water. The Saint-Fons PVC plant, which receives VCM from Fos-sur-Mer, released 80.7 tons of VCM into the air and 358 kg to water. Kem One’s plant in Berre-L’Etang (Bouches-du-Rhône), which also consumes VCM from Fos-sur-Mer, released 2.1 tons of VCM into the air.<sup>919</sup>

**INVENTORY CODE: EURFR03**

- **Plant Name:**
- **Owner:** Kem One. Formerly Arkema, Elf Aquitaine, and Rhone-Poulenc.
- **Location:** Lavéra, France.
- **Processes:** Synthetic diaphragm and membrane. Formerly asbestos diaphragm and mercury.
- **Year Opened:** 1968.<sup>920</sup>
- **Capacities** (tons per year): 363,000 tons of chlorine; 199,000 tons of chlorine by synthetic diaphragm (2017). The balance had been provided via mercury cells, which were replaced by membrane cells by June 2017.<sup>921</sup> 525,000 tons of VCM.<sup>922</sup>

- **Capacity Rank** (Europe): 9th of 39.
- **Technology Conversions:**
  - VCM capacity in 1972 was 440,000 tons.
  - Converted from asbestos diaphragm to synthetic diaphragms (PMX®) from 2000 to 2002.<sup>923</sup> The Fos and Lavera plants were the first in Europe to use asbestos-free diaphragms.<sup>924</sup>
  - Converted remaining mercury cells to membrane by June 29, 2017.<sup>925</sup>
- **Markets:**
  - The Lavéra VCM production capacity is 40% of all VCM capacity in France, and 8% of Europe's capacity, according to Kem One.<sup>926</sup>
  - According to a 2007 article by industry experts ICIS, "EDC and VCM at the site are used for the manufacture of PVC at the nearby Balan (Ain) plant."<sup>927</sup> The Balan plant also receives VCM from the Fos-sur-Mer plant.<sup>928</sup> It has capacity to produce 300,000 tons of suspension PVC resins.<sup>929</sup>
  - Kem One's Saint-Auban plant (70,000-ton-per-year paste-PVC capacity) receives VCM from Lavéra by rail.<sup>930</sup>
  - VCM is also used in Kem One's PVC plants in Hernani, Spain and Saint-Fons, Rhône, France.<sup>931</sup> The Hernani plant produces up to 45,000 tons of emulsion PVC resins per year. It also receives VCM from the Fos-sur-Mer plant.<sup>932</sup> See EURFR02 above for further information about the Saint-Fons plant.
  - This plant is the largest chloromethane producer in "Continental Europe," according to Kem One. It can produce 130,000 tons of chloromethane, one-fifth of Europe's overall capacity.<sup>933</sup> Products include methyl chloride, methylene chloride, chloroform (mainly used to produce PTFE), and carbon tetrachloride.<sup>934</sup>
  - On January 17, 2017, a ship landed in Houston carrying 1,042 tons of carbon tetrachloride to The Chemours Company. Chemours opened a new hydrofluoroolefin (HFO) factory in Corpus Christi, Texas, that likely uses carbon tetrachloride as a feedstock.<sup>935</sup>
  - The Lavéra plant also has a 32,000-ton ferric chloride capacity.<sup>936</sup>
- **Pollution:**
  - On May 23, 2007, VCM production stopped due to a large fire that lasted about three hours. According to ICIS, "No-one was seriously injured but a few employees were referred to hospital. Environmental authorities were informed and measures put in place to restrict the potential impact on surrounding areas."<sup>937</sup>
  - "On Monday August 18th [2008] around 1.45 p.m, a small explosion on an electrolysis cell of one of our three chlorine units (which produce chlorine, hydrogen and caustic soda) of our Lavéra plant started a fire," reported then-owner Arkema.<sup>938</sup>
  - In 2016, the Lavéra plant released 292 kg of mercury into the air and 11.5 kg to water, 139 tons of EDC into the air, and 86.4 tons of VCM into the air. Kem One's Balan PVC plant released 9.9 tons of VCM into the air and 56.8 kg into water. Its PVC plant in Hernani, Spain, released 12.1 tons of VCM into the air. The Kem One PVC plant in Saint-Fons, Rhône, France, released 80.7 tons of VCM into the air, 3 tons of which was considered accidental, and 358 kg to water.<sup>939</sup>
  - From 2012 to 2016, the Lavéra plant's annual average reported VCM releases (90.1 tons per year) were the highest of all chlor-alkali, VCM, and PVC plants in the European Union. The Kem One Saint Auban plant, which receives VCM from Lavéra, reported the third highest average VCM releases (41.1 tons per year), and the highest average VCM releases per ton PVC capacity (601.4 grams).

## INVENTORY CODE: EURFR04

- **Plant Name:** *Vencorex - Pont-de-Claix*
- **Owner:** Vencorex, a 50/50 joint venture formed in 2012 between PTT Global Chemical (Thailand) and Perstorp Group (Sweden).<sup>940</sup> Chloralp, a subsidiary of LaRoche, sold the chlorine plant to Rhodia in

2004.<sup>941</sup> Rhône-Poulenc owned the isocyanates plant from 1975 to 1995, then Rhodia / Lyondell owned it until Perstorp took control in 2008.<sup>942</sup>

- **Location:** Le Pont-de-Claix, south of Grenoble, France.
- **Process:** Synthetic diaphragm.
- **Year Opened:** 1916.<sup>943</sup>
- **Capacities** (tons per year): 170,000 tons of chlorine (2017).<sup>944</sup> 125,000 tons of toluene diisocyanates (TDI).<sup>945</sup>
- **Capacity Rank** (Europe): 29th of 39.
- **Technology Conversions:**
  - In 1962, the chemical complex began producing TDI.<sup>946</sup>
  - In 1978, it began producing hexamethylene diisocyanate (HDI).
  - From 1998 to 2001, ChlorAlp installed “patented microporous asbestos free diaphragms,” reported a European Commission paper on chlor-alkali production. “In 1998 10% of the Hooker S3B cells in the industrial cell room were converted with this material; in 1999 30% were to have been converted; at the end of 2000 60% of the S3B and H4 cells were to have been converted and in 2001 the site will be fully equipped with Asbestos Free Diaphragms.”<sup>947</sup>
  - Also in 2001, the plant added a new TDI unit.
  - In 2008, Perstorp took over the isocyanates plant from Rhodia / Lyondell and announced the completion of a project to replace asbestos with synthetic diaphragms.<sup>948</sup>
  - In 2014, Vencorex said it would install a new membrane cell unit with a 110,000- ton capacity by 2016.<sup>949</sup> In January 2017, Vencorex said the project would be completed “in the coming months.”<sup>950</sup>
- **Markets:**
  - Ships liquid chlorine by rail throughout Western Europe. Customers, according to Vencorex, include “fine chemistry, pharmaceuticals, lubricants and agro-chemistry.”<sup>951</sup>
  - Manufactures aromatic (TDI) and aliphatic (IPDI, HDI and derivatives) isocyanates.<sup>952</sup> Exports isocyanates to Mexico and the US.<sup>953</sup>
- **Pollution:**
  - In 2016, the plant released 1.9 kg hexachlorobenzene, 143 kg trichlorobenzenes, 12.3 kg tetrachloroethylene, 28.6 kg 1,2,3,4,5,6-hexachlorocyclohexane, 1.3 kg pentachlorobenzene, 119 kg trichloromethane, and 40.4 kg dichloromethane to water.<sup>954</sup>

## GERMANY

### INVENTORY CODE: EURDE01

- **Plant Name:** *AkzoNobel - Frankfurt*
- **Owner:** AkzoNobel (purchased from LaRoche in 2009, which bought the plant from Celanese in 1997<sup>955</sup>).
- **Location:** Frankfurt, Germany.
- **Process:** Membrane (converted from mercury in 2014).<sup>956</sup>
- **Year Opened:** 1956.
- **Capacities** (tons per year): 250,000 tons of chlorine (2017).<sup>957</sup>
- **Capacity Rank** (Europe): 16th (tie) of 39.
- **Technology Conversions:**
  - In May 2014, AkzoNobel replaced the mercury cells with membrane technology and increased its capacity by 50%, to 250,000 tons per year.<sup>958</sup>
  - In October 2017, the company said it was designing for expanded chloromethane capacity.<sup>959</sup>

- **Markets:**
  - Produces chloromethanes (120,000-ton capacity), mostly methyl chloride (100,000-ton capacity), chloroform, and carbon tetrachloride,<sup>960</sup> some of which it exports to the US.<sup>961</sup>
- **Pollution:**
  - In 2001, the plant released 142 kg of mercury into the air.<sup>962</sup>
  - In December 2012, AkzoNobel's factory contained 238 tons of mercury in its mercury cells and stored another 33 tons on site.<sup>963</sup>
  - AkzoNobel reported releasing 63.9 kg mercury into the air in 2014, 31.9 kg into the air in 2015, and 2.1 kg to wastewater in 2016.<sup>964</sup>

## INVENTORY CODE: EURDE02

- **Plant Name:** *AkzoNobel - Ibbenbüren*
- **Owner:** AkzoNobel. Formerly owned by ECI Electro-Chemie, which AkzoNobel acquired in 2002.<sup>965</sup>
- **Location:** Ibbenbüren, North Rhine-Westphalia, Germany.
- **Process:** Membrane (KOH). Converted from mercury cells in 2017.<sup>966</sup>
- **Year Opened:** 1963.<sup>967</sup>
- **Capacities** (tons per year): 75,000 tons of chlorine, 130,000 tons of potassium hydroxide.<sup>968</sup>
- **Capacity Rank** (Europe): 39th of 39.
- **Technology Conversions:**
  - In November 2017, the plant's mercury cell operations closed.<sup>969</sup>
  - In February 2018, AkzoNobel and Evonik Industries opened a new (75,000-ton chlorine capacity) membrane electrolysis plant to produce potassium hydroxide solution and chlorine.<sup>970</sup>
- **Markets:**
  - AkzoNobel uses the chlorine from Ibbenbüren to produce chloromethanes.<sup>971</sup>
  - Evonik uses potassium hydroxide from Ibbenbüren at its Lülldorf plant to produce potassium carbonate, potassium bicarbonate, and potassium formate.<sup>972</sup>
- **Pollution:**
  - In 2001, the plant released 63.6 kg of mercury into the air.<sup>973</sup>
  - In 2009, lightning struck the plant, and a mixture of chlorine and hydrogen exploded and injured two workers.<sup>974</sup>
  - In December 2012, the plant held 175 tons of mercury in its cells.<sup>975</sup>
  - AkzoNobel reported releases of 49.4 kg of mercury into the air in 2016.<sup>976</sup>

## INVENTORY CODE: EURDE03

- **Plant Name:** *BASF - Ludwigshafen*
- **Owner:** BASF.
- **Location:** Ludwigshafen, Rhineland-Palatinate, Germany.
- **Processes:** Mercury and membrane.
- **Year Opened:** 1931. Opened by IG Farben, which broke into three companies, including Badische Anilin & Soda-Fabrik (BASF), after the end of the Second World War.<sup>977</sup>
- **Capacities** (tons per year): 385,000 tons, including 170,000 tons by mercury cell and 215,000 tons from membrane technology (2017).<sup>978</sup>
- **Capacity Rank** (Europe): 7th of 39. 2nd largest of 8 mercury cell plants.
- **Technology Conversions:**
  - The mercury cell plant at Ludwigshafen began operating in 1958.<sup>979</sup> There are no current plans to stop using mercury at this plant.

- Converted diaphragm cells to membrane cells in 2003.<sup>980</sup>
- In 2010, the Bio Intelligence Service, in a European Commission-commissioned review of mercury policy noted that the Euro Chlor industry association's voluntary commitment to phase out use of mercury cells "does not cover plants producing chlorine and alkoxides (instead of or in addition to alkali) considered as 'specialty chemicals.' One of these specialty chemicals is sodium methylate, a chemical that is used in the production of biodiesel. This concerns two plants in Germany [Evonik in Lulsdorf and BASF in Ludwigshafen]. According to information provided by the Sodium Methylate Importers Consortium (GIMS), sodium methylate can be manufactured via three different industrial processes, one of which uses mercury amalgam in electrolytic cells. The types of environmental releases resulting from the mercury-based process are reportedly similar to those of the chlor-alkali industry. Alternative mercury-free manufacturing processes are available (using sodium metal or soda), which reportedly have lower environmental impacts but are more expensive to operate. In Europe, sodium methylate is only produced in the two above mentioned German plants operating mercury-based processes with a production of approximately 100,00 t/year of sodium methylate, while in the rest of the world only mercury-free processes are used."<sup>981</sup>
- The Euro Chlor mercury phase-out does not apply to the amalgam process for the production of alcoholates, including sodium methylate and potassium methylate, noted the INGENIEUR.de news site in 2011. "Evonik and BASF therefore hope [to] persuade environmentalists and, above all, the international community, not to ban this process."<sup>982</sup>
- In 2014, BASF said it would build a new toluene diisocyanate (TDI) complex by the end of 2015.<sup>983</sup> In 2017, S&P Global Platts reported, "Following a series of delays, the company eventually flicked the switch on the 300,000 mt/year plant in the fall of 2016. However, following technical problems relating to the Ludwigshafen explosion in October, BASF was forced to shut down the plant again in early December. The company aims to start the plant up again in the first quarter of this year."<sup>984</sup>
- In 2015, BASF announced it would expand membrane production at Ludwigshafen by 250,000 tons, to 465,000 tons per year.<sup>985</sup>
- In 2016, the European Environmental Bureau objected to an exemption contained in a draft of a European Commission regulation implementing the Minamata Convention. The draft did not include a phase-out provision for plants that produce alcoholates, of which there are two in Europe: this BASF plant in Ludwigshafen and Evonik's plant in Lulsdorf, Germany. "The current EC proposal appears not to meet the minimum requirements regarding this sector," wrote the EEB. "Mercury free technologies are also commercially available for the production of sodium methylate and sodium ethylate. Therefore the use of mercury for these substances should be phased out as soon as possible."<sup>986</sup>
- In March 2017, the EC implemented the Minamata Convention with a regulation that exempts plants that produce alcoholates.<sup>987</sup>
- **Markets:**
  - Alcoholates: These are used to catalyze the production of biodiesel, pharmaceuticals, fragrances, and pigments. Products include sodium methylate and potassium methylate, which BASF ships worldwide. According to an EC research document, "approximately 100,000 tons of sodium methylate in solution is produced and marketed in Europe every year because of biodiesel promotion."<sup>988</sup>
  - Isocyanates: New plant has the capacity to produce 300,000 tons of toluene diisocyanate used mainly in polyurethane foams.<sup>989</sup>
  - Produced trichloroethylene as of 2010.<sup>990</sup>
- **Pollution:**
  - In 1953, an explosion at the plant's 2,4,5-trichlorophenol unit injured 55 people. "One man got chloracne just by using his father's towel," according to a chemical safety handbook. Chloracne is an indicator of dioxin exposure. "Various attempts were made at Ludwigshafen to remove the dioxin from the plant building... but these were not effective. Eventually the whole building was demolished under controlled conditions and the debris buried."<sup>991</sup>

- In 2001, the plant released 163 kg of mercury into the air and 2 kg into the water.<sup>992</sup>
- In December 2012, BASF's Ludwigshafen plant held more mercury than any other site in Europe: 733.77 tons were used in cells, and 72.2 tons were stored in the facility. It also had the third highest proportion of mercury in cells: 2.72 kg per ton of chlorine capacity (after the PCC Rokita plant in Poland and the Ercros plant in Flix, Spain).<sup>993</sup>
- On February 26, 2013, excavation for the TDI plant detonated an unexploded World War II bomb, injuring a worker.<sup>994</sup>
- During the construction of the TDI plant, according to *The Handelsblatt* newspaper, "there were several leaks of poisonous phosgene gas in a safety chamber, halting production."<sup>995</sup>
- In 2016, BASF's Ludwigshafen plant released 0.135 grams (TEQ) of dioxins and furans into the air, 50.9 kg of mercury into the air, and 23.9 tons of halogenated organic compounds into water.<sup>996</sup>

## INVENTORY CODE: EURDE04

- **Plant Name:** Covestro - Brunsbüttel
- **Owner:** Covestro (formerly Bayer).
- **Location:** Brunsbüttel, Germany.
- **Process:** Membrane (2012).
- **Year Opened:** 1977.
- **Capacities** (tons per year): 210,000 tons of chlorine, 200,000 tons of methylene diisocyanate (MDI) (2017).
- **Capacity Rank** (Europe): 23rd of 39.
- **Technology Conversions:**
  - 1977: The Brunsbüttel site opened, producing chlorine for on-site toluene diisocyanate (TDI) production.
  - 1988: Bayer started producing MDI at its site in Brunsbüttel.  
2003: TDI production capacity expanded.
  - 2004: Bayer started a new chlorine production unit using "Oxygen Depolarized Cathodes" to electrolyze hydrochloric acid.<sup>997</sup> This technology, developed by Uhde and De Nora, uses a fluoropolymer-coated cloth.<sup>998</sup> An electrolysis industry journal article says it "produces chlorine from hydrochloric acid using electrolysis with an oxygen depolarized cathode resulting in a decrease in the cell voltage for the process."<sup>999</sup>
  - 2014: The German government granted Covestro a permit to expand MDI production.<sup>1000</sup>
  - 2014: Covestro closed the TDI facility in favor of expanded capacity at its Dormagen site.<sup>1001</sup>
  - 2018: According to a February 2018 wood-products journal article, Covestro "is sticking to plans to expand its complex in Brunsbüttel. MDI capacity, which Covestro puts at about 200,000 tonnes per year, is to double to about 400,000 tonnes per year as a result of the rebuilding project on a closed TDI plant there. Commissioning is currently slated for the end of 2018."<sup>1002</sup>
- **Markets:**
  - Chlorine is used in on-site production of MDI. Covestro is a global supplier of isocyanates, which are used to make polyurethane and formaldehyde-free composite wood binders.
- **Pollution:**
  - In September 2013, three people were injured by a leak of carbon monoxide.<sup>1003</sup>
  - Covestro did not report any organochlorine pollutant releases for Brunsbüttel in 2016.<sup>1004</sup> However, a European Commission review of E-PRTR data found that reporting of chlorinated organic and heavy metal pollutants is "incomplete.... This is particularly the case for the energy and chemical sectors."<sup>1005</sup>

## INVENTORY CODE: EURDE05

- **Plant Name:** *Covestro - Dormagen*
- **Owner:** Covestro (transferred from Bayer in 2015).<sup>1006</sup>
- **Location:** Dormagen, North Rhine-Westphalia, Germany.
- **Process:** Membrane.
- **Year Opened:** 1967, with mercury cell technology.<sup>1007</sup>
- **Capacities** (tons per year): 480,000 tons of chlorine from membrane (including 80,000 tons from electrolysis of hydrochloric acid using “Oxygen Depolarized Cathodes” (2017)).<sup>1008</sup>
- **Capacity Rank** (Europe): 3rd of 39.
- **Technology Conversions:**
  - In 1999, Bayer converted its mercury cell plant to membrane technology.<sup>1009</sup>
  - In 2000, Bayer installed a “full-scale industrial electrolyser,” using ODC.<sup>1010</sup>
- **Markets:**
  - Produces isocyanates and polyurethane products, including coatings and adhesives. In 2016, Covestro ranked as the world’s largest producer of polyurethane dispersions, and of TDI, and the second largest producer of MDI.<sup>1011</sup>
  - The company replaced old TDI units with new and expanded TDI production capacity in 2015. According to Covestro, “During the ramp-up phase in 2015 and 2016 a maximum production capacity of 250 kt is expected. An additional investment in the low double-digit millions of Euros range may be needed to reach the expected nameplate production capacity of 300 kt sustainably.”<sup>1012</sup>
  - The Dormagen site also produces fungicides and hydrochloric acid.<sup>1013</sup>
- **Pollution:**
  - In 2015, Covestro reported, “As is typical for such businesses, soil and ground water contamination have occurred in the past at some sites such as those in Leverkusen, Dormagen and Uerdingen and may occur or be discovered at the [Covestro] Group’s sites in the future.”<sup>1014</sup>
  - Covestro did not report any chlorinated pollutant releases for Dormagen in 2016.<sup>1015</sup> However, a European Commission review of E-PRTR data found that reporting of chlorinated organic and heavy metal pollutants is “incomplete.... This is particularly the case for the energy and chemical sectors.”<sup>1016</sup>

## INVENTORY CODE: EURDE06

- **Plant Name:** *Covestro - Leverkusen*
- **Owner:** Covestro.
- **Location:** Leverkusen, North Rhine-Westphalia, Germany.
- **Process:** Membrane. Converted from mercury in 2002.
- **Year Opened:** 1912.<sup>1017</sup>
- **Capacity** (tons per year): 390,000 tons of chlorine.<sup>1018</sup>
- **Capacity Rank** (Europe): 6th of 39.
- **Technology Conversions:**
  - Production started in 1912 (1,000-ton-per-year chlorine capacity from mercury cells).<sup>1019</sup>
  - Converted from mercury to membrane process in 2002.<sup>1020</sup>
- **Markets:**
  - All chlorine produced in Leverkusen is consumed internally.<sup>1021</sup>
  - The plant is a global source of isocyanates used in polyurethane, coatings, adhesives, and specialty chemicals. In 2013, Covestro expanded its production of hexamethylene diisocyanate (HDI) and isophorone diisocyanate (IPDI), which are mainly used to make polyurethane

automobile coatings.<sup>1022</sup> Bayer began producing HDI in Leverkusen in 1958.<sup>1023</sup> No published figures on capacity, new or old, are available.

- The plant also supplies chlorine to other chemical companies in the Leverkusen Chempark.<sup>1024</sup> Relevant products in the complex include benzyl chloride, chlorobenzene, chlorotoluene mixture, methyl chloride, chloroaniline, chloronitrobenzene, dichlorobenzene, titanium dioxide, and toluene.<sup>1025</sup>
- **Pollution:**
  - In 1987, *The New York Times* profiled the Rhine River economy, and its “long flat stretches, like the run that passes Leverkusen and the immense chemical works of Bayer, where nature gives way to industry. And there is growing concern that some of the industries that depend so heavily on the Rhine may be wearing out the river.”<sup>1026</sup>
  - In 2001, shortly before Bayer stopped using mercury cells, the plant released 130 kg of mercury into the air and 16 kg into the water. Its mercury releases to water were the highest of ten plants in Germany.<sup>1027</sup>
  - In 2015, Covestro reported, “As is typical for such businesses, soil and ground water contamination have occurred in the past at some sites such as those in Leverkusen, Dormagen and Uerdingen and may occur or be discovered at the Group’s sites in the future.”<sup>1028</sup>
  - Covestro did not report any chlorinated pollutant releases in 2016.<sup>1029</sup> However, a European Commission review of E-PRTR data found that reporting of chlorinated organic and heavy metal pollutants is “incomplete.... This is particularly the case for the energy and chemical sectors.”<sup>1030</sup>

## INVENTORY CODE: EURDE07

- **Plant Name:** Covestro - Uerdingen
- **Owner:** Covestro (formerly Bayer).
- **Location:** Uerdingen-Krefeld, North Rhine Westphalia, Germany.
- **Process:** Membrane. Converted from mercury in 2012.
- **Year Opened:** 1955, with mercury cell technology.<sup>1031</sup>
- **Capacities** (tons per year): 280,000 tons of chlorine from membrane cells.<sup>1032</sup> 200,000 tons of methylene diisocyanate (MDI). 300,000 tons of polycarbonate. (2015 data.)<sup>1033</sup>
- **Capacity Rank** (Europe): 13th (tie) of 39.
- **Technology Conversions:**
  - In 1997, the plant began a gradual transition to membrane cells.<sup>1034</sup>
  - In 2000, the plant’s chlorine production capacities were 130,000 tons of mercury and 90,000 tons of membrane cell. A European Commission report noted that these newer cells were built “close to existing (mercury) cell rooms. This allows the erection of a new cell room building whilst reusing other plant systems in situ. Some companies, because they have plenty of space, succeed in having the two technologies in the same cell-room, mercury and membrane, without any problem of contamination of membranes or products.”<sup>1035</sup>
  - In 2011, Bayer established a 20,000-metric-ton pilot plant for producing chlorine from hydrochloric acid using oxygen depleted cathodes at the Krefeld-Uerdingen site.<sup>1036</sup>
  - Completed phase-out of mercury in 2012.<sup>1037</sup>
  - Demonstration HCl/ODC plant, with 20,000-ton capacity, started operations in 2011.<sup>1038</sup>
- **Markets:**
  - The plant has been producing polycarbonate since 1958 and is the largest producer of this plastic in Western Europe.<sup>1039</sup>
  - This site also produces methylene diisocyanate (MDI).<sup>1040</sup>

- **Pollution:**

- In 2001, while converting to all-membrane cell technology, the plant released 127 kgs of mercury into the air and 6.4 kgs into water.<sup>1041</sup>
- A European Commission report noted, “A gradual conversion was carried out at the Bayer site in Uerdingen (Germany) taking advantage of an increased demand for chlorine. The same building could be used and no concentration plant or gas treatment facilities were needed. The production from the membrane cell unit was increased progressively, switching off mercury cells and balancing the demand between the two techniques when it was possible. However, industry reports that generally a step by step conversion is not economically attractive compared to a complete conversion, mainly because of cross-contamination of mercury into new equipment and the probable need for adaptations to the power supply.”<sup>1042</sup>
- The plant continued to hold 67.8 tons of mercury on-site in 2012, 10 years after it converted to membrane cells.<sup>1043</sup>
- In 2015, Covestro reported, “As is typical for such businesses, soil and groundwater contamination have occurred in the past at some sites such as those in Leverkusen, Dormagen, and Uerdingen and may occur or be discovered at the Group’s sites in the future.”<sup>1044</sup>
- Bayer built a pipeline to transport carbon monoxide between its Dormagen and Krefeld plants. Deutsche Welle reported in 2017, “Highly disputed, it’s still not in operation years later. New public safety concerns include fear of terror attacks... The 67 km-long carbon monoxide [CO] pipeline connecting plants in Dormagen and Krefeld (both in NRW) was completed in 2011. It runs below ground through populated areas on the right side of the River Rhine, and twice crosses under the river to and from the factories situated to the left of the river. Bayer maintained it needed to transport excess CO, which is used in the production of hard plastics. But the German chemical company never received an operating permit for the pipeline due to various lawsuits and disputes surrounding CO and whether it should be transported in the first place, and whether the legislation allowing construction of the pipeline to go ahead was even constitutional.”<sup>1045</sup>
- Covestro did not report any chlorinated pollutant releases in 2016. However, a European Commission review of E-PRTR data found that reporting of chlorinated organic and heavy metal pollutants is “incomplete.... This is particularly the case for the energy and chemical sectors.”

## INVENTORY CODE: EURDE08

- **Plant Name:** *Dow - Schkopau*
- **Owner:** DowDuPont, through subsidiary, Dow Olefinverbund GmbH. Previously known as Buna Sow Leuna Olefinverbund GmbH, BSL Werk Schkopau, and Werke Buna factory.<sup>1046</sup> Dow acquired the plant during the privatization of former East German companies in 1995.<sup>1047</sup>
- **Location:** Schkopau, Saxony-Anhalt, Germany. Plant is located within the “Dow Central Germany ValuePark®,” a complex of 10 chemical companies in Schkopau and Böhlen.<sup>1048</sup>
- **Process:** Membrane (2017). Converted from mercury in 1999.
- **Year Opened:** 1936, with mercury cell technology, under the name, Buna-Werke GmbH Schkopau.
- **Capacities** (tons per year): 250,000 tons of chlorine (2017).<sup>1049</sup> 255,000 tons of EDC (2017).<sup>1050</sup> 330,000 tons of VCM (2006).<sup>1051</sup>
- **Capacity Rank** (Europe): 16th (tie) of 39.
- **Technology Conversions:**
  - In 1998, chlorine production capacity was all mercury (200,000 tons).<sup>1052</sup>
  - Converted to membrane in 1999.<sup>1053</sup>
  - Expanded VCM production, from 150,000 to 330,000 tons in 1999, to feed its recently spun-off PVC plant nearby, then owned by European Vinyls Corporation.
  - Capacity was 220,000 tons of chlorine (all membrane) in 2000.<sup>1054</sup>
  - This plant was the site of an attempt to use PVC waste as feedstock for new VCM production.

It has been the only such attempt to be “commercially applied,” according to *Plastics and the Environment*. “Tests showed that this robust process, operating since 1999 to recycle chlorinated waste, can handle large quantities of PVC waste. Large-scale trials proved the concept. In total, 1027 t of PVC waste were processed and the recovered chlorine used on-site for producing VCM. Unfortunately the high costs of logistics and treatment limit its application.”<sup>1055</sup>

- **Markets:**

- Since the 1970s, VCM from this plant has been a feedstock for PVC production in the Schkopau complex. East Germany’s VEB Chemische Werke Buna factory produced PVC in the Schkopau complex in the 1970s and exported PVC resins.<sup>1056</sup> In 1998, European Vinyls Corporation (EVC) bought the PVC plants from Dow. EVC boosted PVC production capacity to 330,000 tons per year by 2000, and continued to consume VCM from Dow.<sup>1057</sup> Ineos took over EVC in 2001.<sup>1058</sup>
- In 2007, Vinnolit took over Ineos’ paste PVC plant (but not the suspension PVC plant) in Schkopau. It had a 100,000-ton resin production capacity.<sup>1059</sup> Westlake Chemical (USA) acquired the former European Vinyls Corporation (EVC) plant, from Vinnolit, in July 2014.<sup>1060</sup> Vinnolit (Westlake) continues to obtain VCM from Dow.<sup>1061</sup>
- In 2015, Inovyn (a joint venture of Solvay and Ineos Group) permanently closed its 310,000-ton suspension PVC production plant in Schkopau because it was unable to reach a long-term VCM supply contract with Dow.<sup>1062</sup>
- In January 2018, ICIS reported that “with some spare capacity in the [European] market due to Dow’s plant in Schkopau, Germany, lacking an accompanying PVC plant, there is some room to stretch additional capacity.”<sup>1063</sup>

- **Pollution:**

- Mercury vapors reportedly poisoned many workers when the plant was under East German government control. The full toll is unknown, as the medical records of many former employees vanished. A 2015 *Mitteldeutsche Zeitung* article called conditions under the East German government “murderous.” It said there were at least 21 cases of chronic mercury poisoning by 1983. A Stasi (state security) inspection found that the plant’s pipes were leaking mercury vapors and the control technology was “malfunctioning.” A company official at the time claimed, “The mercury used in our company is not so toxic because of its composition.”<sup>1064</sup>
- In 1985, an explosion killed three workers.<sup>1065</sup>
- The plant badly polluted the air, ground, and water during its decades of East German government operation “with almost no regard to environmental concerns,” according to a *Lausitzer Rundschau* newspaper article in 2004. After reunification, “around 145 million euros have been invested in the refurbishment of the Dow site for the exemption from contaminated sites. One of the focal points was the renovation of the mercury contaminated production facilities. The main project is now the groundwater remediation,” which authorities estimated would require 50 years to complete.<sup>1066</sup>
- The Saxony-Anhalt government website describes this contamination as “massive.” From 2002 to 2015, remediation projects have removed and replaced about 450,000 tons of contaminated soil, and cleaned about 7.2 million cubic meters of groundwater.<sup>1067</sup>
- The Vinnolit (Westlake) PVC plant in Schkopau reported releasing 8.56 tons of VCM into the air in 2016. Dow did not report organochlorine pollutant releases for its Schkopau plant.<sup>1068</sup> However, a European Commission review of E-PRTR data found that reporting of chlorinated organic and heavy metal pollutants is “incomplete.... This is particularly the case for the energy and chemical sectors.”

## INVENTORY CODE: EURDE09

- **Plant Name:** *Dow - Stade*
- **Owner:** DowDuPont, through Dow Deutschland Anlagengesellschaft.
- **Location:** Stade, Lower Saxony, Germany.

- **Processes:** Asbestos diaphragm and membrane.
- **Year Opened:** 1972.<sup>1069</sup>
- **Capacities** (tons per year): 1,585,000 tons of chlorine, of which, 1,030,000 tons of diaphragm capacity and 555,000 tons of membrane capacity (2017).<sup>1070</sup> 260,000 tons of EDC capacity (2017).<sup>1071</sup>
- **Capacity Rank** (Europe): Largest of 39 plants. Asbestos diaphragm capacity is largest of 3 plants in Europe. Membrane capacity is 2nd largest of 33 plants in Europe.
- **Technology Conversions:**
  - Dow added membrane cell capacity in the 1990s, which raised its overall chlorine capacity to 1,240,000 tons.<sup>1072</sup>
  - In 2001, Dow planned to “boost capacity at the Stade plant by 15 percent” by 2003 using membrane cell technology.<sup>1073</sup> According to the Electrochemical Society’s review for the year 2001, “Dow said that it will be converting a chlorine plant at Stade, Germany from diaphragm-cell to membrane-cell process by 2002. The unit will produce 340,000 tpy of caustic and will increase membrane capacity to 470,000 tpy. This is part of the company’s plan of converting the whole 1.5 million tpy diaphragm-cell capacity to membrane cell in stages.”<sup>1074</sup>
  - In 2006, the European Commission granted Dow a “derogation” from an asbestos ban.<sup>1075</sup>
  - In 2011, Dow, using an exemption from Europe’s asbestos ban for chlor-alkali plants, informed the EU that “chlorine plants with current densities  $< 1.5 \text{ kA/m}^2$  are known to have problems when they operate with asbestos-free diaphragms because, among other things, the sodium hydroxide produced is of a very low concentration and cannot be put to further use, and operation on an industrial scale is not possible. This applies in particular to the technology used by Dow with its very low current density of  $0.6 \text{ kA/m}^2$  and specially designed electrolysis cells. ... As already mentioned, asbestos was substituted only in installations that could be operated at a higher current density ( $>1.5 \text{ kA/m}^2$ ). For technical reasons, installations with a lower current density have been unsuccessful in implementing the substitutes available to date. ... Most diaphragm installations operate with a current density several times higher than Dow’s installations in Stade ( $1.3$  to approx.  $2.7 \text{ kA/m}^2$ ). This important technical difference is the reason why none of the asbestos-free diaphragm materials developed to date could be used at Dow.”<sup>1076</sup>
  - The European Trade Union Institute replied that these technical differences are not sufficient reasons for the exemption. “Variations in current density are not determined by the use of a particular technology. Membrane cells at Solvay’s Rheinberg facility operate at the same current density as asbestos diaphragm installations at Dow’s Stade plant,” it wrote.<sup>1077</sup>
  - In 2012, Dow made an economic argument for continuing its use of asbestos diaphragms. “In the case of the Dow plant in Stade, the economics of conversion to asbestos-free diaphragms are less favourable,” according to a European Commission report. “Operating a plant at low current densities ( $0.55\text{--}0.7 \text{ kA/m}^2$ ) implies higher material costs due to larger electrode areas compared to a plant operating at high current densities with the same production rate.”<sup>1078</sup>
  - Dow imports electrolysis cells “from a Dow plant in the USA,” according to a German federal agency report in 2014. These diaphragms are a blend of asbestos fibers and PTFE. The Federal Institute for Occupational Safety and Health said “a stepwise substitution to asbestos-free diaphragms is envisaged in 2015 and 2025.”<sup>1079</sup>
  - On July 26, 2015, just before Dow transferred its US chlor-alkali assets to Olin, it shipped 3,459 parts of M-83 cells, including “reconditioned chlorine cells and parts,” weighing a total of 266 tons, from the US to Germany.<sup>1080</sup> M-83 is a diaphragm cell, which can use both asbestos and non-asbestos materials. The German occupational health agency report in 2014 described these imported cathodes as a “mixture of polytetrafluorethylene (PTFE) and chrysotile [asbestos].”<sup>1081</sup>
  - In 2015, Dow told a European Commission committee that it “had committed itself to no longer importing fibers as well as diaphragms after 2017.” Based on this information, the committee extended Dow’s permission to use diaphragms containing chrysotile asbestos until the end of 2025.<sup>1082</sup>

- **Markets:**
  - In 2001, ICIS reported that the plant was increasing its capacity “in response to rising global demand for chlorine derivatives.”<sup>1083</sup>
  - Dow’s Stade site covers 5.5 square kilometers and produces a wide variety of chemicals derived from chlorine, including EDC, polycarbonates, chlorinated polyethylene, epoxies, and chlorinated organics including perchloroethylene, trichloroethylene, and carbon tetrachloride. Dow also produces perfluorinated products such as Teflon and ion exchange resins.<sup>1084</sup>
  - A 2014 EC review noted, “the EDC market in Europe is an ad hoc market, as only Dow and Evonik in Germany are producing excess EDC regularly.”<sup>1085</sup>
- **Pollution:**
  - In 1993, an explosion at the plant killed a worker.<sup>1086</sup>
  - From 2006 to 2010, Dow imported an average of 50 tons of chrysotile asbestos fibers.<sup>1087</sup>
  - Dow is Germany’s second-largest consumer of electricity.<sup>1088</sup>
  - In 2016, the Stade plant released 2.76 tons of EDC into the air and 18.6 kg into water, 32 kg of hexachlorobenzene into the air, 808 kg of tetrachloromethane into the air, 25.3 tons of halogenated organic compounds into water, 12 kg of tetrachloroethylene into water, and 57.8 kg of trichloromethane into water.<sup>1089</sup>

## INVENTORY CODE: EURDE10

- **Plant Name:** *Evonik - Lülisdorf*
- **Owner:** Evonik. Formerly Degussa AG Werk.
- **Location:** Lülisdorf, Niederkassel, North Rhine-Westphalia, Germany.
- **Process:** Mercury.
- **Year Opened:** 1913.<sup>1090</sup>
- **Capacity** (tons per year): 137,000 tons of chlorine (2017).<sup>1091</sup>
- **Capacity Rank** (Europe): 32nd of 39. 3rd largest of 8 mercury cell plants.
- **Technology Conversions:**
  - In 1953, this plant began using mercury cells to produce alcoholates.<sup>1092</sup>
  - As of April 2018, Evonik had announced no plans to stop using mercury to produce alcoholates.
- **Markets:**
  - Alcoholates: Evonik’s Lülisdorf plant produces and exports alcoholates, including sodium methylate and sodium ethanolate.<sup>1093</sup> “Behind each of these [mercury] cells is a reactor in which the respective amalgam reacts with methanol or ethanol. Evonik thus produces four different alcoholates,” explains VDI Nachrichten.<sup>1094</sup> Alcoholates are used in the production of biodiesel, as well as pigments, fragrances, and pharmaceuticals.<sup>1095</sup> Combined, BASF and Evonik’s mercury-based plants produce 100,000 tons per year of sodium methylate. Alcoholates are produced without mercury in the rest of the world.<sup>1096</sup>
  - Chlorine from the plant is delivered by pipeline to Evonik’s plant in Wesseling, where it produces chemicals used in tires and other rubber products, pharmaceuticals, paper, paints, and coatings.<sup>1097</sup> Much of this chlorine is consumed in the production of cyanuric chloride.<sup>1098</sup> ICIS reported in 2014 that Evonik added two units to its Wesseling complex that “will increase the capacity the company has to produce triallyl cyanurate and triallyl isocyanurate, commonly used in the production of photovoltaic modules, plastics and rubbers. The company did not disclose the facilities’ production capacities.”<sup>1099</sup>
- **Pollution:**
  - According to Oceana, in 2000, “Of the 10 mercury-cell chlorine factories in Germany, Degussa AG Werk (Degussa-Huls) in Lülisdorf ranked first in mercury emissions with 312 (686 lbs).”<sup>1100</sup>

- In 2016, the European Environmental Bureau (EEB) objected to an exemption contained in a draft European Commission regulation implementing the Minamata Convention. The draft did not include a phase-out provision for plants that produce alcoholates, of which there are two in Europe: Evonik's plant in Lülldorf and BASF's plant in Ludwigshafen. "Mercury free technologies are also commercially available for the production of sodium methylate and sodium ethylate," wrote the EEB. "Therefore the use of mercury for these substances should be phased out as soon as possible."<sup>1101</sup>
- In 2016, Degussa / Evonik reported releasing 47.1 kg of mercury into the air, and 1.95 kg into water in Lülldorf. The Evonik Wesseling cyanurate chloride complex reported releasing 1.11 kg of mercury into water.<sup>1102</sup>
- In March 2017, the EC implemented the Minamata Convention with a regulation that exempts plants that produce alcoholates.<sup>1103</sup>
- In 2017, the Lülldorf plant contained 104 mercury cells. They held a combined 340 tons of mercury.<sup>1104</sup>

## INVENTORY CODE: EURDE11

- **Plant Name:** *Inovyn - Rheinberg*
- **Owner:** Ineos (formerly owned by Solvay, and then by Inovyn, a joint venture of Solvay and Ineos, until 2016).<sup>1105</sup>
- **Location:** Rheinberg, North Rhine-Westphalia, Germany.
- **Processes:** Synthetic diaphragm and membrane.<sup>1106</sup>
- **Year Opened:** 1906.<sup>1107</sup>
- **Capacities** (tons per year): 220,000 tons of chlorine overall, 110,000 tons through synthetic diaphragm and 110,000 tons through membrane technology (2017).<sup>1108</sup> VCM capacity is undisclosed (capacity was 200,000 tons in 1974).<sup>1109</sup> 320,000 tons of PVC capacity.<sup>1110</sup>
- **Capacity Rank** (Europe): 19th (tie) of 39.
- **Technology Conversions:**
  - In 1945, the plant had a chlorine production capacity of 100,000 tons.<sup>1111</sup>
  - Opened PVC unit in 1958, which Ineos said was "quickly followed by investments in an electrolysis cell room, a manufacturing unit for allyl products as well as a VCM plant."<sup>1112</sup>
  - Capacity in 2000 was 200,000 tons through asbestos diaphragms.<sup>1113</sup>
  - Half of the capacity switched to membrane technology "as early as 2004," according to a German government report.<sup>1114</sup>
  - Converted to asbestos-free PMX® diaphragms from 2011 to 2012.<sup>1115</sup>
- **Markets:**
  - According to Ineos, "Today, Rheinberg site has a fully integrated VCM-PVC chain and also a fully integrated chain from electrolysis to allyl products. The site manufactures more than 1.3 million tonnes of chemicals each year. Products are PVC, epichlorohydrin, allyl chloride, caustic soda and di-polyglycerin."<sup>1116</sup>
  - According to a European Commission review in 2004, "Rheinberg's VCM plant also includes a chlorination unit, which is connected to the on-site electrolysis unit which is used for the production of allyl chloride and epichlorohydrin. Exceptionally, the chlorination unit converts chlorine to EDC when small additional quantities of EDC are required for S-PVC production." The plant also sells VCM and produces E-PVC.<sup>1117</sup>
  - The Rheinberg plant exports PVC and allyl chloride to North America.<sup>1118</sup>
- **Pollution:**
  - In 2016, the plant reported releasing 2.9 tons of EDC into the air. It also released 32.8 tons of VCM into the air and 31 kgs into water, and 4.2 tons of halogenated organic compounds into water.<sup>1119</sup>

## INVENTORY CODE: EURDE12

- **Plant Name:** *Mexichem (Vestolit) - Marl*
- **Owner:** Mexichem, through Vestolit subsidiary, which it acquired in 2014.<sup>1120</sup> Vestolit was a subsidiary of Huls.<sup>1121</sup>
- **Location:** Marl, North Rhine-Westphalia, Germany.
- **Process:** Membrane.<sup>1122</sup> Converted from mercury in 2007.
- **Age:** 1939.
- **Capacities** (tons per year): 265,000 tons of chlorine, 630,000 tons of EDC, 400,000 tons of VCM, and 416,000 tons of PVC, including: 207,000 tons of High-impact modified PVC, 117,000 tons of Emulsion-PVC, and 92,000 tons of Microsuspension PVC (B-PVC). (2018 data.)<sup>1123</sup>
- **Capacity Rank** (Europe): 15th of 39.
- **Technology Conversions:**
  - In 1998, the plant's chlorine capacity was 180,000 tons from mercury cells.<sup>1124</sup>
  - In 1999, Vestolit began adding membrane cells.<sup>1125</sup>
  - In 2007, the plant converted from mercury cell to membrane technology.<sup>1126</sup>
  - In 2017, Vestolit/Mexichem increased specialty PVC production at its Marl plant, making it “one of the largest worldwide for specialty PVC.”<sup>1127</sup>
- **Markets:**
  - Chlorine is consumed in on-site PVC production. This is Vestolit's only production-site. According to the European Commission, “To balance its production, Vestolit from time to time buys both EDC and VCM on the merchant market.”<sup>1128</sup>
  - “Vestolit is Europe's sixth largest producer of PVC resin, its only producer of high-impact suspension PVC resin (HIS-PVC), and its second largest producer of PVC paste,” according to BTG Pactual Global Research.<sup>1129</sup>
  - Mexichem is the world's second leading producer of specialty PVC resins.<sup>1130</sup>
  - Paste-PVC made in Marl is used in “hard-wearing floorings,” wall coverings, window frames, “and special grades for the use in profiles, films and specialty applications,” according to Mexichem.<sup>1131</sup>
  - High-impact modified PVC (called HIS-PVC) is used in the “production of light and weather resistant windows profiles,” according to Mexichem.<sup>1132</sup>
  - Vestolit resins are exported to flooring, siding, and other building-product manufacturers in the US.<sup>1133</sup>
  - Vestolit also markets Mexichem suspension PVC resins, made in Colombia and Mexico, to European customers.<sup>1134</sup>
- **Pollution:**
  - The Marl plant released 273 kgs of mercury in 2001, which ranked second among the 10 mercury cell plants then operating in Germany.<sup>1135</sup>
  - In 2016, the Marl plant reported releasing 43.3 tons of vinyl chloride into the air.<sup>1136</sup>
  - From 2012 to 2016, the Marl plant's annual average reported VCM releases (47.8 tons per year) were the second-highest among all chlor-alkali, VCM, and PVC plants in the European Union.

## INVENTORY CODE: EURDE13

- **Plant Name:** *Westlake (Vinnolit) - Gendorf*
- **Owner:** Westlake, through Vinnolit subsidiary, which it acquired in 2014. Vinnolit was a joint venture of Hoechst and Wacker and also included PVC plants in Burghausen, Köln-Merkenich, and Gendorf. Prior to Vinnolit, the plant was owned by Hoechst and operated by its subsidiary, Celanese.<sup>1137</sup>
- **Location:** Gendorf, Burgkirchen an der Alz, Germany.
- **Process:** Membrane. Converted from mercury in 2009.

- **Year Opened:** 1939. Opened by Wehrmacht to produce chlorine and war-related materials, operated by Allied Forces after the Second World War, then sold to Hoechst in 1955.<sup>1138</sup>
- **Capacities** (tons per year): 180,000 tons of chlorine (2017).<sup>1139</sup> 350,000 tons of EDC (2017).<sup>1140</sup> 300,000 tons of VCM, and 155,000 tons of PVC (2014).<sup>1141</sup>
- **Capacity Rank** (Europe): 26th (tie) of 39.
- **Technology Conversions:**
  - PVC production began in 1954.<sup>1142</sup>
  - In 1998, the plant's chlorine production capacity (by mercury cell) was 72,000 tons.<sup>1143</sup>
  - The plant converted from mercury (82,000 tons) in 2009.<sup>1144</sup>
  - Vinnolit plans to expand chlorine production by 25,000 tons (membrane technology), and increase VCM capacity by 2021.<sup>1145</sup>
- **Markets:**
  - Chlorine and VCM are produced and consumed on-site in PVC production (150,000-ton-per-year capacity).
  - The plant also supplies VCM to other Vinnolit PVC plants in Germany: Burghausen, Köln-Merkenich and Hürth-Knapsack [EURDE14].<sup>1146</sup>
    - In 2012, the Burghausen plant had a 100,000-ton paste-PVC capacity, more than any other plant in the world.<sup>1147</sup> It produces 110,000 tons of other PVC resins, for a total PVC capacity of 210,000 tons.<sup>1148</sup> The Burghausen chemical complex also has 50,000 tons of on-site chlorine capacity from membrane cell technology.<sup>1149</sup>
    - The Köln plant has a capacity of 160,000 tons of PVC and receives VCM from Hürth-Knapsack.<sup>1150</sup>
  - Combined, these plants produce 500,000 tons of specialty PVC and 280,000 tons of suspension PVC resins.<sup>1151</sup> Westlake is the world's leading producer of specialty PVC resins.<sup>1152</sup>
- **Pollution:**
  - In 2002, Det Norske Veritas (DNV), which monitored compliance with the European vinyl industry charter on toxic pollutants, found that Vinnolit's sampling frequency for hydrochloric acid emissions in Gendorf "does not meet the BAT [Best Available Technology] specification for combined liquid/vent incinerators, so compliance cannot be confirmed. However, samples taken for regulatory purposes were within the Charter limits." DNV also found that the plant's catalytic incinerator was not in compliance with the Charter's dioxin emissions threshold.<sup>1153</sup>
  - In 2001, the Gendorf plant released 107 kgs of mercury into the air.<sup>1154</sup>
  - In 2016, Vinnolit's Gendorf plant released 9.62 tons of vinyl chloride monomer into the air. The Burghausen PVC plant released 12.5 tons of VCM into the air. The Köln PVC plant released 6.07 tons VCM into the air.<sup>1155</sup>

## INVENTORY CODE: EURDE14

- **Plant Name:** *Westlake (Vinnolit) - Hürth-Knapsack*
- **Owner:** Westlake, through Vinnolit subsidiary, which it acquired in 2014.<sup>1156</sup>
- **Location:** Hürth-Knapsack, North Rhine-Westphalia, Germany.
- **Process:** Membrane. Completed conversion from mercury cells in 2009.<sup>1157</sup>
- **Year Opened:** 1962.<sup>1158</sup>
- **Capacities** (tons per year): 250,000 tons of chlorine.<sup>1159</sup> 160,000 tons of PVC (2016).<sup>1160</sup> 545,000 tons of EDC (2017).<sup>1161</sup> 370,000 tons of VCM (2015).<sup>1162</sup>
- **Capacity Rank** (Europe): 16th (tie) of 39.
- **Technology Conversions:**
  - In 1998, the plant's chlorine production capacity was 150,000 tons by mercury cell.<sup>1163</sup>

- In 2004, Vinnolit announced plans to expand production capacities of PVC (to 310,000 tons), and EDC and VCM (to 370,000 tons each).<sup>1164</sup>
- In 2009, Vinnolit completed converting its Knapsack plant from mercury cell to membrane technology, and contracted production capacity to 250,000 tons.<sup>1165</sup>
- **Markets:**
  - This is a vertically integrated plant that produces suspension PVC resins. It also supplies VCM to other Vinnolit plants, including the Köln-Merkenich suspension-PVC resin plant.<sup>1166</sup>
  - In 2004, Vinnolit said it would expand chlorine, EDC, and VCM capacities at Knapsack “to further reduce the need to buy in EDC and to support the planned measures to expand Paste-PVC production at the Burghausen plant.”<sup>1167</sup>
  - This plant receives chlorine or VCM from Vinnolit’s Gendorf plant.<sup>1168</sup>
  - Some Vinnolit PVC resins are exported to flooring, conveyor belt, and other manufacturers in the US.<sup>1169</sup>
- **Pollution:**
  - In 2001, the Knapsack plant released 186 kgs of mercury into the air, which ranked third among 10 mercury-cell chlorine plants then operating in Germany.
  - In 2002, Det Norske Veritas (DNV) found that the Hürth-Knapsack plant released VCM into water at levels in excess of the industry’s charter.<sup>1170</sup>
  - Vinnolit did not report any chlorinated pollutant releases from the Hürth-Knapsack plant in 2016.<sup>1171</sup> However, a European Commission review of E-PRTR data found that reporting of chlorinated organic and heavy metal pollutants is “incomplete.... This is particularly the case for the energy and chemical sectors.”

## HUNGARY

### INVENTORY CODE: EURHU01

- **Plant Name:** *Wanhua (BorsodChem) - Kazincbarcika*
- **Owner:** Wanhua Industrial Group, through its BorsodChem subsidiary, purchased in 2011.
- **Location:** Kazincbarcika, Borsod-Abaúj-Zemplén, Hungary.
- **Processes:** Mercury and membrane.
- **Year Opened:** 1963.
- **Capacities** (tons per year): 323,000 tons of chlorine overall, 131,000 tons by mercury and 192,000 tons by membrane technology (2017).<sup>1172</sup> 225,000 tons EDC (2017).<sup>1173</sup> 400,000 tons of PVC, 240,000 tons of MDI, and 250,000 tons of TDI (2017).<sup>1174</sup>
- **Capacity Rank** (Europe): 12th of 39. This is the largest chlorine, PVC, and isocyanates producer in Central and Eastern Europe.
- **Technology Conversions:**
  - The PVC plant in Kazincbarcika opened in 1963.<sup>1175</sup>
  - PVC capacity in 1973 was 25,000 tons, with a second plant planned to be built, by 1980, with a 120,000-ton capacity.<sup>1176</sup>
  - In 2000, the plant’s PVC capacity was 300,000 tons and its MDI capacity was 60,000 tons.<sup>1177</sup>
  - According to the Electrochemical Society review for the year 2000, “BorsodChem of Kazincbarcika, Hungary will expand its chlor-alkali plant in Kazincbarcika by adding a 60,000-80,000 mt/yr facility. BorsodChem are reported to be in talks with Krupp Uhde to provide their membrane technology for the facility. The new facility will raise chlorine capacity at the site to the 200,000 mt/yr level. BorsodChem may also convert its 120,000 mt/yr mercury cell capacity to membrane technology in the near future.”<sup>1178</sup>

- In 2004, Uhde completed a 225,000-ton expansion of EDC production (by oxychlorination) at BorsodChem.<sup>1179</sup>
- In 2009, BorsodChem began building a new toluene diisocyanate (TDI) plant, with completion expected by 2011.<sup>1180</sup>
- In 2014, BorsodChem said it would build a new hydrochloric acid conversion plant.<sup>1181</sup>
- Also in 2014, BorsodChem announced that it “has started preparations to replace its existing 125-kiloton/year-capacity mercury-based chlorine unit in Kazincbarcika, Hungary, with a more energy-efficient and environmentally friendly membrane plant. The project is expected to be completed by December 2017. The company already operates a 195 kt/year [thousand-ton-per-year] membrane unit, and with the replacement of the mercury plant, BorsodChem will maintain its position as the leading producer of chlorine and caustic soda in the region.”<sup>1182</sup> As of June 13, 2018, the company has not announced completion of the conversion from mercury to membrane technology.
- BorsodChem plans to double toluene diisocyanate (TDI) production capacity, from 250,000 tons to 500,000 tons, by late 2018.<sup>1183</sup>
- According to a European Commission report, “The deadline for chlorine cellrooms conversion is the end of 2019.”<sup>1184</sup>
- **Markets:**
  - BorsodChem consumes the chlorine on-site to produce suspension-PVC resins and isocyanates.
  - The main markets for its PVC resins are Romania, Hungary, Poland, Italy, Germany, and the Czech Republic.<sup>1185</sup>
  - “It sells more than half of its output on Western European markets, with customers in Central and Eastern Europe accounting for the bulk of remaining sales, though the Budapest-based company is expanding into markets further afield, like Asia,” reported Česká pozice magazine.<sup>1186</sup>
  - BorsodChem also exports isocyanates to the Americas.<sup>1187</sup>
- **Pollution:**
  - In 1995, Hungarian scientists described this as “an area where extreme and uncommon mercury pollution has occurred. During hydrochloric acid production, hundreds of tons of mercury has leaked out, contaminating the upper 4-5 meters of sediments.”<sup>1188</sup>
  - In 2001, according to Oceana, BorsodChem accounted for 52% of all mercury air emissions in Hungary. The plant released a reported 94 kg of mercury into the air and 3 kg to water.<sup>1189</sup>
  - After BorsodChem installed membrane cell technology for part of its production in 2008, “the wastes generated by chlorine production decreased by 40%.” However, EDC continued to contaminate groundwater through 2011, according to a November 2017 Greenpeace profile of Kazincbarcika.<sup>1190</sup>
  - In 2010, there were two accidents involving the production of isocyanates; in one accident, phosgene entered the airspace and hospitalized a worker with phosgene poisoning for several weeks.<sup>1191</sup>
  - As of December 2012, the plant held 214 tons of mercury in cells and stored another 13 tons on-site.<sup>1192</sup>
  - According to BorsodChem, 29,586 tons of EDC were recovered from groundwater through September 2013.<sup>1193</sup>
  - In 2016, the Kazincbarcika plant released 97 kg of mercury into the air and 4.85 kg into water, 8.72 tons of VCM into the air and 346 kg into water, 159 kg EDC into water, and 3.53 tons of halogenated organic compounds into water.<sup>1194</sup>
  - In 2018, Greenpeace estimates that an estimated 500 tons of mercury have contaminated the soil, and that the pollution reaches 20 meters deep.<sup>1195</sup>
  - According to a company report, 750 people live in a housing estate “in the immediate vicinity”; many others live or spend time in a school and lodgings nearby.<sup>1196</sup>

- Mercury waste from the plant has been dumped in a hazardous-waste landfill in Berente, where members of the Romani community live. “According to local reporters the incidence of cancers is very high,” says Greenpeace.<sup>1197</sup>
- A February 2018 television documentary in Hungary investigated mercury poisoning of workers at the plant.<sup>1198</sup>

## ITALY

### INVENTORY CODE: EURIT01

- **Plant Name:** *Inovyn - Rosignano Solvay*
- **Owner:** Ineos via Inovyn subsidiary (formerly Solvay). Ineos acquired Inovyn in July 2016.<sup>1199</sup>
- **Location:** Rosignano Solvay, Tuscany, Livorno, Italy.
- **Process:** Membrane. Converted from mercury in 2007.
- **Year Opened:** 1914.
- **Capacities** (tons per year): 150,000 tons of chlorine (2017).<sup>1200</sup> 30,000 tons of chloromethanes (2015).<sup>1201</sup>
- **Capacity Rank** (Europe): 30th of 39.
- **Technology Conversions:**
  - In 1914, Solvay opened this chemical plant in Rosignano Marittimo.<sup>1202</sup>
  - In 2007, the plant was converted from mercury to membrane technology and increased chlorine capacity from 127,000 to 150,000 tons.<sup>1203</sup>
- **Markets:**
  - Chloromethanes, including methylene chloride.<sup>1204</sup>
- **Pollution:**
  - In 2001, the Rosignano Solvay plant released 71 kg of mercury into water, and 84 kg into the air. Its water releases were the highest among seven reporting plants in Italy.<sup>1205</sup>
  - The Rosignano Solvay plant released an average 0.67 grams of mercury per ton of chlorine capacity in 2002 and 0.41 grams per ton in 2003.<sup>1206</sup>
  - In 2008, after the conversion to membrane technology was complete, the site held 13 tons of mercury on-site.
  - The Spiagge Bianche beach, comprised of solid waste from over a century of chemical production at Rosignano Solvay, is popular despite its location and composition. A ditch carries waste from the complex to the sea.<sup>1207</sup> “The stunningly white sand here is not natural. It’s chemical waste, and its source stands right next to the beach—an enormous complex of towering chimneys and cooling towers spewing smoke and steam into the air. This is the Solvay chemical plant,” explains the website Amusing Planet. “Mixed with the calcium chloride and limestone waste are many toxic chemicals such as mercury, arsenic, cadmium, chromium, lead and ammonia, which are incredibly harmful to humans and animals.”<sup>1208</sup>
  - Sampling by environmental officials have found extensive mercury contamination of the beach and surrounding marine environment.<sup>1209</sup>
  - In 2016, the plant released 10.4 kg of dichloromethane to water, according to E-PRTR data.<sup>1210</sup>

## NETHERLANDS

### INVENTORY CODE: EURNE01

- **Plant Name:** *AkzoNobel - Botlek*
- **Owner:** AkzoNobel.
- **Location:** Botlek-Rotterdam, Netherlands.
- **Process:** Membrane. Converted from mercury by 1984.

- **Year Opened:** 1961.<sup>1211</sup>
- **Capacity** (tons per year): 637,000 tons of chlorine (2017).<sup>1212</sup>
- **Capacity Rank** (Europe): 2nd of 39. Membrane cell capacity is largest in Europe.
- **Technology Conversions:**
  - Zoutchemie Botlek opened in 1961 with 60,000 tons of chlorine capacity by mercury cell.<sup>1213</sup>
  - Chlorine capacity in 1970 was 70,000 tons.<sup>1214</sup>
  - Mercury cells converted to membrane by 1984.<sup>1215</sup>
  - Chlorine capacity in 1998 was 250,000 tons.<sup>1216</sup>
  - Chlorine capacity in 2000 was 350,000 tons.<sup>1217</sup>
  - In 2001, AkzoNobel applied for a permit to increase production capacity to 500,000 tons.<sup>1218</sup>
  - According to the European Commission, “The use of carbon tetrachloride stopped during the first decade of the 21st century in parallel with the installation of new membrane cell units” at the AkzoNobel plants in Delfzijl and Rotterdam-Botlek.<sup>1219</sup>
- **Markets:**
  - This plant is central to the “Pernis-Botlek-Europoort” chemical complex, one of the largest in the world.<sup>1220</sup> The Botlek chlor-alkali plant supplies chlorine for the production of PVC, isocyanates used in polyurethane, and epichlorohydrin used in epoxy resins.
  - It is co-located with the VCM plant owned by Shin-Etsu, which supports PVC production in Pernis, Netherlands, and Estarreja, Spain.
    - In 1973, the Botlek plant provided VCM to a 160,000-ton PVC plant in Pernis, then owned by Shell (now owned by Shin-Etsu), about seven kilometers away.
    - In 1982, Akzo sold the Botlek VCM plant to Shell.<sup>1221</sup>
    - In 2001, Shin-Etsu acquired the VCM and PVC operations.<sup>1222</sup>
    - The Shin-Etsu VCM plant in Botlek, expanded capacity to 620,000 tons in 2003, which remained its capacity in 2016.<sup>1223</sup>
    - The Pernis PVC plant expanded to a production capacity of 450,000 tons in 2006.<sup>1224</sup>
    - According to Shin-Etsu, PVC resins from Pernis are used in flooring, pipes, windows, cables, and automobiles.
    - The Shin-Etsu VCM plant also supplies a PVC resin plant in Estarreja, Portugal, owned by Shin-Etsu through its subsidiary, Companhia Industrial de Resinas Sintéticas (CIRES, Lda.).<sup>1225</sup> The plant’s capacity was 200,000 tons in 2008.<sup>1226</sup>
  - Since 1972, the plant has supplied chlorine to a methylene diisocyanate (MDI) plant also in the Botlek complex, now owned by Huntsman.<sup>1227</sup> In 2014, Huntsman’s Botlek MDI operations had a capacity of up to 400,000 tons per year.<sup>1228</sup>
  - AkzoNobel’s other major chlorine customer is Hexion, which uses chlorine to produce epichlorohydrin at its Pernis epoxy resin plant, which had a capacity of 100,000 tons of epichlorohydrin in 2006.<sup>1229</sup>
  - AkzoNobel also has produced chlorinated pesticides on-site, including:
    - 2-methyl-4-chlorophenoxyacetic acid (MCPA);
    - MCPP: 2-methyl-4-chlorophenoxypropionic acid (MCP);
    - D-MCPP: (+)-(R)-2-methyl-4-chlorophenoxypropionic acid (D-MCPP);
    - and, D-2,4 DP: (+)-(R)-2,4 dichlorophenoxypropionic acid (D-2,4).<sup>1230</sup>
  - The plant also produced trichloroethylene in 2010<sup>1231</sup> and shipped diazo- azo- or azoxy- compounds to Mexico in 2017.<sup>1232</sup>
- **Pollution:**
  - In the early 1970s, “EDC and VCM tars were incinerated at sea,” according to Nederlandse

Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (TNO). “This practice was stopped in 1975.”<sup>1233</sup>

- A 1987 study found an “unexpected presence” of organochlorine compounds, including chlorotoluenes, chlorophenols, and bromophenols. The study’s authors considered the plant’s production of EDC and chlorinated pesticides as potential sources. “Waste water treatment at AkzoNobel has improved considerably since that time,” reported TNO.<sup>1234</sup>
- According to a 1995 TNO report, the PVC plant (then run by the Rovin joint venture of Shell and AkzoNobel) released 140 tons of PVC powder in the air in 1990, as well as 200 tons of PVC in sewage sludge and 76 tons of “PVC coagulate.” The emissions came from washing-tower and ventilation systems.<sup>1235</sup>
- In 2005, chlorine gas leaked from the plant and a foul smell “hung over the Botlek district of Rotterdam Port,” reported Dutch News. “The leak caused a major alert before 10pm on Monday. The Fire Service managed to plug it within two hours by reducing the pressure in the pipes which contained the chlorine.... A spokesperson for the Fire Service said the contaminated air spread only about 200 to 300 metres due to the lack of wind. A strong odour was reported in residential areas nearby but the Fire Service said it was not dangerous to the public.”<sup>1236</sup>
- In 2016, the AkzoNobel Botlek chlor-alkali plant released 16.5 tons of chlorine and inorganic compounds (as HCl) into the air, 71.8 kg of EDC into water, and 13 kg of trichloromethane into water. The Shin-Etsu VCM and PVC plant in Botlek released 10.3 tons of EDC into the air, 7.58 tons of vinyl chloride into the air, and 555 kg of 1,1,2,2-tetrachloroethane into the air. Other downstream consumers of Botlek chlorine include the Shin-Etsu Pernis PVC plant in Vondelingenplaat Rotterdam, Netherlands, which released 2.03 tons of VCM into the air; and, the Shin-Etsu (Cires) PVC plant in Estarreja, Portugal, which released 5.17 tons of VCM into the air.<sup>1237</sup>

## INVENTORY CODE: EURNE02

- **Plant Name:** *AkzoNobel - Delfzijl*
- **Owner:** AkzoNobel.
- **Location:** Delfzijl, Netherlands.
- **Process:** Membrane.
- **Year Opened:** 1958, by Koninklijke Nederlandsche Zoutindustrie.
- **Capacity** (tons per year): 121,000 tons of chlorine (2017).
- **Capacity Rank** (Europe): 34th of 39.
- **Technology Conversions:**
  - Koninklijke Nederlandsche Zoutindustrie (KNZ, a predecessor of AkzoNobel) opened the chemical plant in 1958 with 40,000 tons of chlorine production capacity by mercury cell.<sup>1238</sup>
  - KNZ added 70,000-ton chlorine capacity by diaphragm in 1969.<sup>1239</sup>
  - According to the European Commission, “The use of carbon tetrachloride stopped during the first decade of the 21st century in parallel with the installation of new membrane cell units” at the AkzoNobel plants in Delfzijl and Rotterdam-Botlek.<sup>1240</sup>
  - In 2006, the plant completed its conversion from asbestos diaphragms and mercury cell to membrane technology.<sup>1241</sup>
  - Also in 2006, AkzoNobel opened a monochloroacetic acid plant to its chemical complex in Delfzijl, replacing one it had operated in Hengelo.<sup>1242</sup>
- **Markets:**
  - Chlorine from AkzoNobel’s plant supports other companies’ production at the Delfzijl chemical park. Related plants include:
    - A joint venture of AkzoNobel and Tosoh of Japan, Delamine, which produces ethylene amine from the conversion of dichloroethane with ammonia.<sup>1243</sup>
    - A plant run by Lubrizol (US), which produces chlorinated PVC.<sup>1244</sup>

- Teijin Aramid, which makes ultrastrong fibers from synthetic polyamides.<sup>1245</sup>
  - AkzoNobel produces monochloroacetic acid (MCA) at the Delfzijl plant. MCA is a thickening agent used in wallpaper adhesives, detergents, food, and personal care products.<sup>1246</sup>
  - In 2004, the Delfzijl plant supplied chlorine to VCM production in Botlek.<sup>1247</sup>
- **Pollution:**
  - AkzoNobel did not report any chlorinated pollutant releases from Delfzijl in 2016. However, a European Commission review of E-PRTR data found that reporting of chlorinated organic and heavy metal pollutants is “incomplete.... This is particularly the case for the energy and chemical sectors.”

## NORWAY

### INVENTORY CODE: EURNO01

- **Plant Name:** *Inovyn - Rafnes*
- **Owner:** Ineos, through Inovyn subsidiary, which Ineos acquired in July 2016.<sup>1248</sup> Ineos purchased this plant from Norsk Hydro in 2007.<sup>1249</sup>
- **Location:** Stathelle, Norway.
- **Process:** Membrane. Converted from asbestos diaphragm in 2006.
- **Year Opened:** 1978.<sup>1250</sup>
- **Capacities** (tons per year): 280,000 tons of chlorine (2017).<sup>1251</sup> 735,000 tons of EDC (2017).<sup>1252</sup> 517,000 tons of VCM (2011).<sup>1253</sup>
- **Capacity Rank** (Europe): 13th (tie) of 39.
- **Technology Conversions:**
  - In 1984, the Norwegian government banned the use of asbestos, but subsequently granted then-owner Norsk Hydro an exemption to continue its use in chlor-alkali production until 2006.<sup>1254</sup>
  - In 1998, then-owner Norsk Hydro announced plans to convert its diaphragm chlorine plant to membrane and boost capacity from 130,000 to 400,000 tons per year of chlorine and from 470,000 to 650,000 tons per year of VCM, “primarily through the debottlenecking of the cracking and oxychlorination sections,” according to the *Journal of the Electrochemical Society*.<sup>1255</sup> (Conversion and expansion occurred by 2006, but not to those anticipated levels.)
  - Norsk Hydro installed one new 130,000-ton membrane plant in 2005 and another 130,000-ton unit in 2006.<sup>1256</sup>
  - In March 2016, a shipment of ethane from US shale gas arrived in Norway to feed its gas cracker at Rafnes, which feeds EDC/VCM production. “Shale gas economics has revitalised US manufacturing, it has the potential to do the same for European manufacturing,” said INEOS chairman, Jim Ratcliffe.<sup>1257</sup>
  - In February 2018, Inovyn announced it would expand VCM capacity by “around 70,000 tons per year, which will be used in the production of vinyls at its Porsgrunn, Stenungsund [Sweden], and Newton Aycliffe sites.” It also plans to expand chlorine production capacity by 35,000 tons.<sup>1258</sup>
- **Markets:**
  - Some of the plant’s VCM is distributed to Inovyn’s PVC factory across the Frierfjord in Herøya (Porsgrunn), which produces S-PVC used in pipes and cables, and paste-PVC for use in products like flooring and wall coverings. Its capacity is 200,000 tons of PVC.<sup>1259</sup>
  - Some of the VCM is also consumed by Inovyn’s chlorine-to-PVC factory in Stenungsung, Sweden (EURSV01).
  - Since the 1980s, VCM also has been shipped across the North Sea to a PVC plant in Newton-Aycliffe, UK. This Ineos plant currently has the capacity to produce 440,000 tons of PVC.<sup>1260</sup>
  - Inovyn Rafnes exported PVC to Mexico in 2017.<sup>1261</sup>

- **Pollution:**
  - According to a November 2017 Food and Water Watch report, “in 2009, a compressor pump at the Rafnes plant leaked lubricating oil; 200 to 400 litres ultimately reached the fjord creating an oil film on the coast” and in 2010, “the Rafnes plant released powerfully smelling smoke.”<sup>1262</sup>
  - Food and Water Watch also noted the pollution record of the Newton-Aycliffe PVC plant that receives VCM from Rafnes. “The Ineos PVC facility in Newton Aycliffe released 50 tonnes of vinyl chloride into the air from 2011 and 2015. Ineos paid £16,000 in fines and costs for releasing 56 tonnes of particle-laden gases and steam into the air from the Aycliffe plant in 2010, which left white dust containing PVC and vinyl chloride on nearby homes and gardens.”
  - In 2016, the Rafnes plant released 11.7 tons of EDC into the air, and 2.14 tons of VCM into the air. The Porsgrunn (Herøya) PVC plant released 13.8 tons of VCM into the air and 160 kg to water. The Newton-Aycliffe plant released 7.87 tons of VCM into the air.<sup>1263</sup>

## POLAND

### INVENTORY CODE: EURPO01

- **Plant Name:** *PCC Rokita - Brzeg Dony*
- **Owner:** PCC Rokita.
- **Location:** Brzeg Dolny, Poland.
- **Process:** Membrane. Converted from mercury in 2015.
- **Year Opened:** Late 1930s.<sup>1264</sup>
- **Capacity** (tons per year): 150,000 tons of chlorine (2017).
- **Capacity Rank** (Europe): 30th of 39.
- **Technology Conversions:**
  - In 2010, PCC Rokita began converting from mercury cell to membrane technology.<sup>1265</sup>
  - In 2013, the plant’s capacity was a mix of mercury (48,000 tons) and membrane (77,000 tons) technology.<sup>1266</sup>
  - In April 2015, the company completed its elimination of mercury cell technology. “Overall, this will increase the annual production capacity of PCC Rokita from a current 120,000 metric tons of chlorine to 135,000 metric tons, and from 135,000 metric tons of caustic soda to 152,000 metric tons. Plans are also already in place for 2016 to further increase capacity through additional process optimisation, causing the annual capacity figures to then rise to 149,000 metric tons of chlorine and 168,000 metric tons of caustic soda,” according to a PCC-Rokita press release.<sup>1267</sup>
- **Markets:**
  - The Rokita plant consists of three units, including one that produces chlorine and its derivatives, among them hydrochloric acid, chlorobenzene, and trichloroethylene.<sup>1268</sup>
  - In the 1980s, the plant also produced biocides, including pentachlorophenol and 2,4-D.<sup>1269</sup>
- **Pollution:**
  - “The chemical works ‘Rokita’ in Brzeg Dolny (Zakłady Chemiczne “Rokita” S.A.) were built by Germans in late 1930s, for the sake of production of military gases – tabun and sarin,” according to Waste Prevention Association „3R” of Poland (WPA). After the Second World War, “the plant started to specialize in the production of pesticides and polyurethane.”<sup>1270</sup>
  - “In [the] 1980s, products of the Plant were analyzed for the presence of dioxin compounds,” reported the WPA. “It was found out that a pentachlorophenol (PCP) - based wood preservative contained 1200 milligrams of dioxins per kilogram of the product, which is an extremely high concentration.” The analysis also found dioxins at lower (but still significant) concentrations in herbicides. Dioxins were found at levels of 14.7 parts per million (ppm) in 2,4-D and 24.9 ppm in 2,4-DP. By 1992, the plant reportedly held “over 20,000 tonnes of chlorinated wastes from pesticide production.”<sup>1271</sup>

- In 2010, the plant reported releasing 0.82 grams of mercury into water per ton of chlorine production capacity, which was the highest rate in Europe.<sup>1272</sup>
- In December 2012, the plant held 280.74 tons of mercury in its cells. Its proportion of mercury in cells per chlorine production capacity (3.65 kg per ton capacity) was the highest reported in Europe.<sup>1273</sup>
- In 2016, the plant reported releasing 18 kg of mercury in air and 24.2 kg into water.<sup>1274</sup> PCC Rokita did not report any chlorinated pollutant releases from Brzeg Dolny in 2016. However, a European Commission review of E-PRTR data found that reporting of chlorinated organic and heavy metal pollutants is “incomplete.... This is particularly the case for the energy and chemical sectors.”

## INVENTORY CODE: EURPO02

- **Plant Name:** *Anwil - Włocławek*
- **Owner:** PKN Orlen, through its Anwil S.A. subsidiary, which it acquired in 2012.<sup>1275</sup> Formerly known as Zakłady Azotowe Włocławek and Zakłady Farb Włocławek.<sup>1276</sup>
- **Location:** Włocławek, Włocławskie, Poland.
- **Process:** Membrane. Converted from asbestos diaphragm in 2006.
- **Year Opened:** 1983.<sup>1277</sup>
- **Capacities** (tons per year): 214,000 tons of chlorine (2017). 300,000 tons of VCM (2007).<sup>1278</sup> 340,000 tons of PVC (2007 and 2014).<sup>1279</sup>
- **Capacity Rank** (Europe): 22nd of 39.
- **Technology Conversions:**
  - Anwil began producing PVC at this site in 1983. It produces suspension-PVC resins. According to a European Commission report, it is the only PVC plant in Europe that is fully integrated with ethylene supplies.<sup>1280</sup>
  - Prior to its conversion, the plant’s diaphragm capacity was 197,000 tons of chlorine.<sup>1281</sup>
  - In 2006, Anwil converted from asbestos diaphragm to membrane technology and increased its capacity to 195,000 tons of chlorine.<sup>1282</sup>
  - In 2007, a “modernization” project increased the PVC complex’s capacity from 300,000 tons to 340,000 tons.
- **Markets:**
  - Anwil supplies over 40% of the PVC sold in Poland under the brand name Polanvil.<sup>1283</sup> It markets PVC to the rest of the European Union “as well as in Turkey, Russia, Kazakhstan or Ukraine,” according to Anwil.<sup>1284</sup>
  - Anwil exports VCM to the Spolana export-oriented PVC plant in Neratovice, Czech Republic.<sup>1285</sup> Spolana’s Neratovice plant has a 135,000-ton PVC capacity. The Spolana plant in Neratovice included a mercury cell-based chlor-alkali operation from 1941 to 2017, but no longer produces chlorine.<sup>1286</sup> Spolana and Anwil are both controlled by Orlen S.A.
- **Pollution:**
  - The Spolana plant in Neratovice, Czech Republic, which receives VCM from Anwil, released substantial amounts of mercury before it closed the chlor-alkali portion of its plant in 2017. For example:
    - In 2002, Greenpeace tests found that the Neratovice chemical plant site “is polluted with enormous concentrations of mercury. The laboratory results show heavy contamination in a wide area around the main contaminated building, a former amalgam electrolysis unit, up to the bank of the Elbe River. The samples from Spolana contain grams to tens of grams of mercury per kilogram, which is up to 100,000 times more than normal for non-contaminated areas.” Greenpeace said the concentrations it found were “ten times higher than Spolana admitted publicly.”<sup>1287</sup>

- “Every year, more than 100 kg of mercury from Spolana contaminates water and air,” wrote the environmental organization, Arnika, in 2012. “Further hundreds of kg of this toxic metal are passed by Spolana into waste and an unknown amount of mercury is being stored on its dump site near the river Elbe, where the chemical plant is located.”<sup>1288</sup>
  - Arnika and IPEN have documented elevated levels of mercury in fish in the nearby River Labe.<sup>1289</sup>
- In 2016, the Anwil plant reported releasing 0.206 grams (TEQ) of dioxins and furans into the air, 6.8 tons EDC into the air and 573 kg into water, 1.8 tons of trichloromethane into the air, 11 tons of VCM into the air, and 4.03 tons of halogenated organic compounds into water. The Spolana plant reported releasing 30 kg of mercury into the air and 6.6 kg into water, 165 kg of HCFCs into the air, 2.99 tons of EDC into the air and 50 kg into water, 2.87 tons of VCM into the air, 32.1 tons of trichloroethylene into the air, 1.02 tons of halogenated organic compounds into the air, and 33 kg of trichloromethane into water.

## ROMANIA

### INVENTORY CODE: EURO01

- **Plant Name:** *Oltchim - Râmnicu Vâlcea*
- **Owner:** Oltchim S.A. Rm. Vâlcea.
- **Location:** Râmnicu Vâlcea, Romania.
- **Process:** Membrane. Formerly included asbestos diaphragm and mercury technology.
- **Year Opened:** 1968.<sup>1290</sup>
- **Capacity** (tons per year): 105,000 tons of chlorine (2017).
- **Capacity Rank** (Europe): 37th of 39.
- **Technology Conversions:**
  - According to IPEN, the original mercury cell plant opened in 1968 with a 91,000-ton chlorine capacity. A series of expansions and contractions have followed:
    - In 1974, Oltchim added mercury cells with a 190,000-ton chlorine capacity.
    - From 1984 to 1993, the plant ran a 90,900-ton-per-year chlorine unit using asbestos diaphragm technology.
    - The original mercury cell plant closed in 1999.
    - Oltchim added a 109,000-ton-per-year chlorine unit with membrane technology in 2000.<sup>1291</sup>
    - In November 2008, Oltchim permanently closed its VCM production.<sup>1292</sup>
    - In September 2011, Oltchim closed its PVC capacity, due to the shutdown of the Aprechim pyrolysis plant, its source of ethylene.<sup>1293</sup>
    - In 2012, Oltchim closed its remaining mercury cell electrolysis capacity, leaving chlorine production capacity of 105,000 tons by membrane cell, according to Euro Chlor.<sup>1294</sup>
- **Markets:**
  - Chlorinated products include chlorine, sodium hypochlorite, and hydrochloric acid. It also produces DOTP, a new type of plasticizer that is replacing orthophthalates.<sup>1295</sup>
  - Oltchim uses chlorine on-site in the production of propylene oxide. It planned to increase production by purchasing “about 12,500 tons of chlorine.”<sup>1296</sup>
- **Pollution:**
  - The plant was the second largest source of mercury releases among 27 reporting European countries in 2009. It was also the second leading source of non-methane volatile organic compounds of all reporting industries.<sup>1297</sup>
  - In a study published in 2010, scientists traced mercury contamination in the Babeni Reservoir to

the upstream Oltchim chlor-alkali plant. “Preliminary analyses (unpublished) showed high mercury concentrations in the surface sediment of the Babeni Reservoir,” they reported. “Whilst the chlor-alkali plant partly switched to a cleaner technology in 1999, no obvious decrease of mercury concentrations was observed in [the last] decade. Results from the sediment core reflected the historical trend of mercury release from the chlor-alkali plant, revealed important contamination episodes and confirmed a legacy of contamination of mercury in recent sediments even if the concentrations of mercury decreased toward the surface due to a more efficient emission control.”<sup>1298</sup> Further, they found high mercury concentrations in people who ate fish from the reservoir. “Hence the mercury contamination of the Babeni Reservoir and other parts of the River Olt poses a severe health risk to those consuming large amounts of fish from there,” reported IPEN, a global environmental and public health organization.<sup>1299</sup>

- In December 2013, the plant held 151 tons of mercury in its chlor-alkali production cells and stored another 4 tons on-site.<sup>1300</sup>
- Oltchim recently determined that “there are areas contaminated with mercury” and thus “the land of the site is suitable for industrial facilities and can no longer be used for agriculture.”<sup>1301</sup>
- In 2016, Oltchim’s plant released 21.9 kg of mercury into water. Oltchim did not report any chlorinated pollutant releases from Râmnicu Vâlcea in 2016.<sup>1302</sup> However, a European Commission review of E-PRTR data found that reporting of chlorinated organic and heavy metal pollutants is “incomplete.... This is particularly the case for the energy and chemical sectors.”

## RUSSIA

### INVENTORY CODE: EURRU01

- **Plant Name:** *HaloPolymer - Kirovo-Chepetsk*
- **Owner:** JSC HaloPolymer. Formed in June 2008 from the consolidation of Kirovo-Chepetsky Joint Stock Company / Polymer Plant of KCKK (which the Nuclear Power Ministry owned in part)<sup>1303</sup> and Perm Halogen (partly held by the Industry, Science and Technology Ministry and formerly known as Ural Industrial Union Halogen).<sup>1304</sup>
- **Location:** Kirovo-Chepetsk, Kirov Region, Russia.
- **Process:** Mercury.
- **Year Opened:** 1955.<sup>1305</sup>
- **Capacity** (tons per year): 182,000 tons chlorine capacity (2008).<sup>1306</sup>
- **Capacity Rank** (Europe): 25th of 39 plants overall. Largest mercury cell plant in Europe.
- **Technology Conversions:**
  - In 2005, the plant had a reported chlorine production capacity of 189,000 tons.<sup>1307</sup>
  - From 2000 to 2007, the plant produced an average of 64,000 tons of chlorine<sup>1308</sup> This was far below its reported capacity.
  - The plant capacity in 2008 was 182,000 tons of chlorine.<sup>1309</sup>
  - In 2008, the plant incorporated some membrane technology to produce chlorine as part of a “chloroform retrofit.”<sup>1310</sup>
  - In July 2009, according to the UNEP Global Mercury Partnership, “the Kirovo-Chepetsky Joint Stock Company ‘Zavod Polimerov’ began reconstruction and modernization of the brine conditioning unit. This unit is a major source of mercury losses in solid waste. Completion is scheduled for the end of [2010]. When the reconstruction and modernization is completed, the facility will achieve annual reductions of 10 tons of mercury.”<sup>1311</sup>
  - In December 2012, the company valued its mercury inventory at \$7.8 million, up from \$5.8 million in December 2011.<sup>1312</sup>
  - A Russian industry association submission to the UN in 2016 sought support for another brine unit that would further reduce but not eliminate mercury consumption and releases.<sup>1313</sup>

- **Markets:**

- The Kirovo-Chepetsk plant began producing chloroform and fluoropolymers in 1956.<sup>1314</sup> Chloroform produced in Kirovo-Chepetsk is used in the production of fluoropolymers on-site and in Perm. In 2008, HaloPolymer was the world's fourth largest producer of fluoropolymers.<sup>1315</sup> It produces them in two locations: HaloPolymer Kirovo-Chepetsk produces "FKM-rummers, R-218, and R-350." HaloPolymer Perm produces "PTFE compounds, R-14, R-318, R-125, R-blends and acid blends," according to a company presentation in November 2014.<sup>1316</sup>
- In 1995, the Kirovo-Chepetsk plant produced chlorofluorocarbons (CFC-113 and CFC-114) and hydrochlorofluorocarbons (HCFC-22).
- The Perm plant produced CFC-11, CFC-12, and CFC-113 in 1995.<sup>1317</sup>
- In 2002, the World Bank approved over \$5 million in grants to the Halogen plant in Perm, and the Kirovo-Chepetsk plant to stop producing ozone-depleting chemicals. The Halogen plant had capacities to produce 30,000 tons per year of CFC-11 and -12, and 1,400 tons per year of Halon 2402. Kirovo-Chepetsk could produce 5,800 tons of CFC-113 and 1,030 tons of Halon 2402. The goal was for the plants to "modernize so they produce other chemicals that do not harm the atmosphere," according to a bank official.<sup>1318</sup>
- In 2008, according to HaloPolymer, the Perm plant produced "freons-14, 22, 125, 318; chemical agents, hydrofluoric acids, [and] fluoroplastics."<sup>1319</sup> It produced 13,000 tons of PTFE.<sup>1320</sup>
- In 2010, the Kirovo-Chepetsk plant had capacity to produce up to 2,000 tons per year of HCFC-142b.<sup>1321</sup>
- In 2014, HaloPolymer was the second largest producer of PTFE in Europe.<sup>1322</sup> In 2015, according to HaloPolymer, it became the "exclusive Russian producer of fluorocarbons due to government regulation of the market."<sup>1323</sup>
- According to the company's website, in 2010, HaloPolymer produced over 7,000 tons of fluoropolymers, "10.2 tonnes of freons, (and) 286 thousand tonnes of inorganic chemistry products," which it supplies to over 30 countries.<sup>1324</sup>
- From May 26, 2015, to May 22, 2018, HaloPolymers exported, on average, over 71,000 tons of fluoropolymers and other chemicals to the US. The company has a Texas, US-based subsidiary, HaloPolymer Trading, which is its "exclusive distributor" of PTFE and other chemical products in the Americas, Europe, and Asia.<sup>1325</sup> In 2012, HaloPolymer issued a press release announcing that it "became the first Russian company to join the American Society of the Plastic Industry (SPI). This organization is one of the most influential in the US and represents the interests of participants in the plastics market."<sup>1326</sup> (SPI later renamed itself the Plastics Industry Association.<sup>1327</sup>)

- **Pollution:**

- From 1986 to 1995, Russia produced 887,570 tons of ozone-depleting substances, including 665,000 tons of chlorofluorocarbons, 190,000 tons of HCFC-22, 15,000 tons of HCFC 141b/142b, 1,335 tons of Halon 1301, and 980 tons of Halon 1211.<sup>1328</sup> The Halogen plant in Perm was the world's only producer of Halon 2402 (15,255 tons from 1986 to 1995) until production stopped in 2000.<sup>1329</sup> Halon 2402 is 13 to 16 times more destructive to the stratospheric ozone layer than CFC-11 is.<sup>1330</sup>
- In 1997, Russian experts reported to the Arctic Council that the Kirovo-Chepetsk plant released 12.4 tons of mercury in slurry generated during brine dissolution and cleaning, that these releases increased to 14.9 tons in 2002, and that near the plant, "there are temporary dumpsites and deep-burial dump fields which house 409,000 tonnes of mercury-containing waste."<sup>1331</sup>
- The Moscow-based International Science and Technology Center estimated in 2008 that the plant was consuming 300 grams of mercury for every ton of caustic soda it produced, and overall lost 1,600 tons of mercury.<sup>1332</sup>
- In October 2010, according to ICIS, the chemical plant was shut down after a chlorine leak. The company "has not commented on the incident, which municipal authorities said did not cause a health risk to the local population."<sup>1333</sup>

## INVENTORY CODE: EURRU02

- **Plant Name:** *EuroChem - Novomoskovsky Azot*
- **Owner:** EuroChem Group (Russia), through its Novomoskovsky Azot subsidiary, also known as Novomoskovsk Chlorine Company.<sup>1334</sup> EuroChem was formed in the year 2000. Andrey Melnichenko is the majority owner.<sup>1335</sup>
- **Location:** Novomoskovsk, Tula region, Russia.
- **Process:** Membrane. Converted from asbestos diaphragm in 2015.
- **Year Opened:** 1936. The chemical complex opened with a bleach plant.<sup>1336</sup>
- **Capacity** (tons per year): 91,000 tons of chlorine (2012).<sup>1337</sup>
- **Capacity Rank** (Europe): 38th of 39.
- **Technology Conversions:**
  - In 1971, there were reportedly plans to expand PVC resin production to 58,000 tons at Novomoskovsk.<sup>1338</sup>
  - In 2005, EuroChem listed PVC resins among this facility's chemical products, as well as "chlorine itself."<sup>1339</sup>
  - In 2007, the plant produced 43,100 tons of chlorine.<sup>1340</sup>
  - In 2009, the plant's VCM capacity (45,000 tons) was closed. It had used the acetylene hydrochlorination route of production, which is catalyzed by mercuric chloride.<sup>1341</sup>
  - In October 2013, Bluestar, a chemical machinery company based in China, signed a contract with Novomoskovsk Chlorine to build a 100,000-ton membrane chlor-alkali plant.<sup>1342</sup> According to the Russian chlorine trade association, RusChlor, "the Chinese companies help a lot in modernizing the already functioning Russian chlor-alkali plants including the projects that involve the plants' conversion into the membrane electrolysis technique."<sup>1343</sup>
  - In 2015, the plant converted from diaphragm to membrane technology.<sup>1344</sup>
  - The Novomoskovsk plant produced 70,300 tons of chlorine in 2016.<sup>1345</sup>
  - In June 2017, EuroChem signed a Memorandum of Intent with China National Chemical Corporation to jointly produce propylene oxide and isocyanates at Novomoskovsk. It would be the first isocyanates plant in Russia or any other country formerly part of the Soviet Union.<sup>1346</sup>
- **Markets:**
  - In the first quarter of 2004, the plant produced 10,700 tons of chlorine, 6,670 tons of "plastics and resins," 4,200 tons of sodium hypochlorite, 2,410 tons of tetrachloroethane, and 1,400 tons of calcium chloride.<sup>1347</sup>
  - Current chlorinated products include liquid chlorine, sodium hypochlorite, hydrochloric acid, and calcium chloride.<sup>1348</sup>
- **Pollution:**
  - The plant had three major releases of chlorine in 1987. A leak of chlorine killed one person in January 1987. In June 1987, chlorine leaked from two tankers, and the next month, the plant released 20 tons of chlorine.<sup>1349</sup>
  - In 2001 and 2002, the VCM operation consumed an average of 4.5 tons of mercury. At the end of 2002, the plant held about 12 tons of mercury in spent catalyst.<sup>1350</sup>
  - On June 18, 2002, an estimated ton of chlorine gas escaped from the plant "forming a 5 square kilometer cloud," according to a Russian news report. 71 workers were treated for poisoning; 14 people were hospitalized.<sup>1351</sup>
  - An environmental audit of the plant in 2012 led the Tula Environmental Prosecutor to charge operators with allegedly violating air pollution regulations.<sup>1352</sup>

## INVENTORY CODE: EURRU03

- **Plant Name:** *RusVinyl - Kstovo*
- **Owner:** RusVinyl, a joint venture of Sibur (Russia) and Solvay.<sup>1353</sup>
- **Location:** Kstovo, Nizhny Novgorod Oblast, Russia.
- **Process:** Membrane.
- **Year Opened:** 2014. A Solvay press release noted, “Vladimir Putin, the Russian President, attended the grand opening ceremony.”<sup>1354</sup>
- **Capacities** (tons per year): 205,000 tons of chlorine, 330,000 tons of PVC resins (of which 300,000 tons are suspension-PVC and 30,000 tons are emulsion PVC resins).
- **Capacity Rank** (Europe): 24th of 39.
- **Technology Conversions:**
  - None reported to date.
- **Markets:**
  - The plant produces chlorine and VCM for on-site PVC resin production.<sup>1355</sup>
  - RusVinyl offers PVC resins for “conveyor belts, fittings, pipes, sealants, fences and safety palisades, waterproof membranes, wires and cables, ducts, fuse boxes, plugs and accessories, ceilings, wall panels, flooring, furniture, inks, lacquers, adhesives, stair banisters, wallpaper, window profiles,”<sup>1356</sup> electrical equipment,<sup>1357</sup> car interiors, sound insulation and carpet backing,<sup>1358</sup> food and other product packaging,<sup>1359</sup> and medical equipment such as blood bags, oxygen masks, catheters, and gloves.<sup>1360</sup>
  - RusVinyl exported PVC to Mexico in 2016.<sup>1361</sup>
  - In March 2017, the government of Ukraine banned imports of PVC from RusVinyl and JSC Kaus-tik, the two leading PVC producers in Russia. *Plastics News Europe* reported, “This government move follows the recent sale by Russian oil group Lukoil of Karpatneftkhim, its idled Ukrainian petrochemicals plant, to Ukraine investors. It is planned to restart what is the country’s only PVC operation in April or May.”<sup>1362</sup>
- **Pollution:**
  - In 2013, the company was exploring ways of turning production waste sludge into construction blocks. “This material is safe,” and has a composition “similar to ordinary gypsum,” said RusVinyl.<sup>1363</sup>
  - The Federal Security Service of the Russian Federation (FSB) reportedly ordered RusVinyl and other industrial sites to curtail production leading up to and during the World Cup from May to July 2018.<sup>1364</sup>

## INVENTORY CODE: EURRU04

- **Plant Name:** *BSC - Sterlitamak*
- **Owner:** JSC Bashkirskaya Khimiya, through the Bashkir Soda Company (BSC).<sup>1365</sup>
- **Location:** Sterlitamak, Bashkortostan, Russia.
- **Processes:** Mercury cells and asbestos diaphragm.
- **Year Opened:** 1964.<sup>1366</sup>
- **Capacity** (tons per year): 218,000 tons of chlorine (2003).<sup>1367</sup> Based on 2013 production proportions (61% mercury, 39% diaphragm), the plant’s chlorine capacities are an estimated 134,000 tons by mercury and 84,000 tons by asbestos diaphragm technology. VCM capacity was 200,000 tons in 2009.<sup>1368</sup> In 2010, its PVC production capacity was 160,000 tons.<sup>1369</sup>
- **Capacity Rank** (Europe): 21st of 39.
- **Technology Conversions:**
  - In 1955, the USSR Council of Ministers decided to build this plant in Sterlitamak due to the

- “presence of Yar-Bishkadak deposit of salt... as well as rich oilfields, the processed product of which -- ethylene -- is utilized” in the production of VCM and PVC.<sup>1370</sup>
- In 1973, Soviet authorities planned to build a VCM and PVC plant (with a 60,000-ton capacity) in Sterlitamak.<sup>1371</sup>
  - In 1983, the government built a new mercury cell plant with a 145,000-ton capacity in Sterlitamak.<sup>1372</sup>
  - The original 80,000-ton-per-year chlorine capacity mercury cell plant in Sterlitamak City (the “CJSC “Kaustic” Krebs Plant) closed in 1988.<sup>1373</sup>
  - From 1997 to 2002, the plant produced an average of 93,000 tons of chlorine per year by mercury cell.<sup>1374</sup>
  - In 2003, the plant’s chlorine capacity was reported to be 218,000 tons.<sup>1375</sup>
  - In 2012, *Plastics News Europe* reported that “Sterlitamak Kaustik, Russia’s leading producer of PVC, is building a large complex for the production of VCM and PVC, the company has recently said. The project involves the construction of a new VCM plant with the capacity of 400,000 tonnes per year; a new facility for PVC production with the same capacity; and a new chlorine and caustic soda plant with the capacity of 360,000 tonnes per year.”<sup>1376</sup>
  - In January and February 2013, Sterlitamak Kaustic produced 19,000 tons of caustic soda by mercury cathode technique and 11,800 tons using diaphragm electrolysis.<sup>1377</sup>
- **Markets:**
    - Products include chlorine, EDC, PVC, and other organochlorines.
    - In the early 1990s, the Sterlitamak Kaustik plant exported 40,000 tons of EDC to Western Europe.<sup>1378</sup>
    - The plant has produced epichlorohydrin and perchloroethylene, although in 2011 this production was reported as being suspended.<sup>1379</sup>
  - **Pollution:**
    - In December 1968, 60 people were poisoned by a chlorine accident in Sterlitamak; 46 people were hospitalized.<sup>1380</sup>
    - “Sterlitamak’s problems became horrific in 1973, when the industries promoted a novel solution for storing their toxic wastes: They would bury them in deep underground cavities blasted out by deadly nuclear explosions,” wrote Kathleen Hunt in a 1993 *Los Angeles Times Magazine* article. She said that Albert Tukhvatullin, a local activist, “recalls hearing about the first local blast three days before it happened, but there was no evacuation. ‘We heard and felt the explosion 18 miles away. The ground trembled. It was something terrible.’ It was one of more than 100 nuclear explosions that have been carried out in the former Soviet Union for construction purposes.”<sup>1381</sup>
    - After the original mercury cell plant closed in 1988, according to the Almaty Institute of Power Engineering and Telecommunication, “mercury poured off the electrolyzers” and “about 140 tons of mercury was collected.” Mercury sludge and demolition debris “were sent to Nikitovka Mercury Combine in Ukraine.” “Dismantling of equipment of the old chlor-alkali production took place under the pressure of local mass media and NGOs [non-governmental organizations] requiring precaution measures to be taken because PO ‘Kaustik’ is located within the residential area.”<sup>1382</sup>
    - In December 1992, an explosion at the plant killed two workers.<sup>1383</sup>
    - A neighborhood in the midst of the plant was called “May 1st” and housed thousands of workers and their families. Hunt in 1993 described the housing as “squalid dormitories” and the surrounding plant “a nightmarish maze of corroding rails and vast crumbling ducts patched with strips of paper and fraying cloth rags. Discarded hardware litters the factory lots, and huge frozen pools of toxic wastes lie waiting for the spring thaw.... According to an official at Sterlitamak’s hygiene department, life expectancy for men here is only 45 years.”<sup>1384</sup>
    - In 2002, mercury levels in treated wastewater was more than a magnitude higher than the “current standard” of 0.001 mg/l, according to a Danish Environmental Protection Agency study. Wastewater contained 0.019 mg of mercury per liter. Effluent is released into the Belaya River.

The study also reported high levels of mercury in the ventilation and air of the electrolysis building. Overall, the plant lost over 9 tons of mercury in 1997 and 4.6 tons in 2002.<sup>1385</sup>

- In 2008, the plant consumed an estimated 400 to 450 grams of mercury per ton of caustic production.<sup>1386</sup>

## INVENTORY CODE: EURRU05

- **Plant Name:** *Nikochem “Kaustik” - Volgograd*
- **Owner:** Nikochem (also called Nikokhim, Nikos, and JSC “Kaustik”). Formerly called Plastkard or Plasti-card.
- **Location:** Volgograd, Russia (between Lake Sarpa and the Volga River).
- **Processes:** Mercury and asbestos diaphragm.
- **Year Opened:** 1968.<sup>1387</sup>
- **Capacities** (tons per year): 220,000 tons of chlorine and 100,000 tons of PVC (2012).<sup>1388</sup> Based on January-February 2013 chlorine production proportions (57% mercury, 43% diaphragm<sup>1389</sup>), HBN estimates the plant’s chlorine capacities are 125,000 tons of mercury and 95,000 tons by asbestos diaphragm technology. The plant also can produce up to 90,000 tons of VCM by acetylene route.
- **Capacity Rank** (Europe): 19th (tie) of 39.
- **Technology Conversions:**
  - The Volgograd “Kaustik” plant opened in 1968, using mercury cell electrolyzers.
  - Asbestos diaphragms were added to the plant in 1984.<sup>1390</sup>
  - From 1997 to 2002, the plant’s average chlorine output -- by mercury cell -- was 93,000 tons per year. This figure does not include output from asbestos diaphragm cells.<sup>1391</sup>
  - From 2000 to 2007, the plant’s average chlorine output, by all technologies, was 201,000 tons per year.<sup>1392</sup>
  - The US EPA launched a project in 2010 to recover 850-900 kg per year of mercury from wastewater at Volgograd “Kaustik” and reuse it in production. “After the treatment process the amount of mercury in the waste is reduced to 0.0002-0.0004 mg per liter,” according to EPA.<sup>1393</sup>
  - In the first two months of 2013, the Volgograd “Kaustik” plant produced 17,800 tons of chlorine from mercury cells and 13,600 tons from diaphragm electrolysis. This pace of production projects to over 106,000 tons of chlorine per year from mercury and 81,000 tons from diaphragm technology.<sup>1394</sup>
- **Markets:**
  - The company’s first products, made in 1967, were chlorinated biocides.<sup>1395</sup>
  - The chemical complex began producing chlorofluorocarbons in the 1970s.<sup>1396</sup>
  - Kaustik (Volgograd) had the capacity to produce 10,000 tons of methyl chloride in 2011.<sup>1397</sup>
  - Khimprom (also spelled as Chimprom or Chemprom) likely consumes chlorine from this plant. Khimprom in Volgograd had the capacity to produce 27,000 tons of VCM and PVC in 2013, but it does not produce chlorine.<sup>1398</sup> It uses carbide acetylene as the raw material for acetylene hydrochlorination of VCM. Chimprom also produced methyl chloride in the 1990s, HCFCs as of 2009, and trichloroethylene as of 2011.<sup>1399</sup>
  - In March 2017, the government of Ukraine banned imports of PVC from RusVinyl and JSC Kaustik. *Plastics News Europe* reported, “This government move follows the recent sale by Russian oil group Lukoil of Karpatneftkhim, its idled Ukrainian petrochemicals plant, to Ukraine investors. It is planned to restart what is the country’s only PVC operation in April or May.”<sup>1400</sup>
- **Pollution:**
  - In August 1969, a chlorine break during a fire in Volgograd injured 8 people, four of whom were no longer able to work. In January 1985, 7.5 tons of chlorine leaked from tankers and injured 27 people.<sup>1401</sup>

- A joint Danish-Russian study found that, in 2002, the plant released 389 kg of mercury into the air, 1.4 tons into sludge and effluent, 80 kg into products, 0.8 kg into water, and listed 4.51 tons of releases as “mechanical losses.” Further, the scientists said, “it should be acknowledged that mercury and its compounds can get into water basins and underground aquifers in the area adjacent to Kaustic OJSC. By assessment made by specialised geological organisations, there may be up to 500 tonnes of mercury inside the ground under the chlorine shop.”<sup>1402</sup>
- In 2013, the IPEN Mercury-Free Campaign released a detailed report on pollution from “Kaustik.” It reported:
  - There has been “long-term serious contamination of some parts of the Volga River and its sediments at such places as the sewage pond at the “Kaustik” plant.”
  - The plant’s 90,000-ton VCM capacity uses mercuric chloride as a catalyst in a “combined process involving conversion of dilute ethylene and acetylene obtained by the pyrolysis of the propane-butane fraction.”<sup>1403</sup>
  - In 2008, the facility released 689 kg of mercury.
  - “In 2009, there were barrels and drums completely filled with mercury-containing waste and sludge and stored on the bare ground without any protective covers or soil lining. As a result, in warm seasons, mercury vapour releases from the dump cause mercury pollution of the ambient air.”
  - It found high “levels of mercury in hair samples from two sites in the neighborhood of JSC “Kaustik” and summary of all samples taken in the vicinity of Volgograd, Russia... The average level of mercury in the hair of all 28 volunteers from Krasnarmeysky District and Raygorod was nearly two-times higher than the US EPA reference dose.”
  - And, the researchers found, “average mercury levels in catfish and perch samples were more than twice the US EPA reference dose, and average levels in carp also exceeded the reference dose.”<sup>1404</sup>
- According to Arnika, an environmental organization based in the Czech Republic, “About 4 tonnes of mercury is released at the hot spot into the environment with wastewaters, air emissions and products. About 1.6 tons out of these 4 tonnes is a mechanical loss. The landfill for vat residues of trichlorfon, polyvinyl chloride resin, lime slurry, caustic soda, spent catalysts and other substances of III-IV class of hazard is located in the Southern industrial hub of Volgograd.”<sup>1405</sup>

## INVENTORY CODE: EURRU06

- **Plant Name:** *Renova - Sayanskchemplast*
- **Owner:** Renova Group, through JSC “SayanskKhimPlast” (also spelled as Sayanskchemplast or Sayanskchimplast).<sup>1406</sup> Renova, and its owner, Viktor Vekselberg, are on the U.S. Department of Treasury’s Office of Foreign Assets Control sanctions list.<sup>1407</sup>
- **Location:** Sayansk, Irkutsk, Russia.
- **Process:** Membrane. Converted from mercury in 2006.<sup>1408</sup>
- **Year Opened:** 1976.<sup>1409</sup>
- **Capacities** (tons per year): 135,000 tons of chlorine (2010).<sup>1410</sup> 131,000 tons of EDC (2011).<sup>1411</sup> 350,000 tons of VCM (2016).<sup>1412</sup> 300,000 tons of PVC (2016).<sup>1413</sup>
- **Capacity Rank** (Europe): 33rd of 39.
- **Technology Conversions:**
  - Shut down 150,000-ton-per-year mercury cell production in 2006 and replaced with smaller membrane technology plant.<sup>1414</sup>
  - From 2000 to 2007, the plant’s average chlorine output was 110,000 tons per year.<sup>1415</sup>
  - In 2006, the plant’s PVC capacity was 250,000 tons of PVC.<sup>1416</sup>
  - In 2009 and 2010, suspension-PVC production capacity increased from 180,000 to 280,000 tons as it also increased EDC cracking and VCM capacity to 200,000 tons.<sup>1417</sup>

- In 2015, the Russian Ministry of Energy released a development plan for the country's gas and petrochemical industry through 2030. It includes plans to increase the volume of ethylene production in southern Irkutsk through a proposed alliance between Renova (owner of the Sayansk plant), Gazprom, and Sibur. The plans included increasing plant capacity in Sayank to 625,000 tons of ethylene and 450,000 tons of PVC.<sup>1418</sup>
- In 2016, Thyssen Uhde expanded the plant's VCM capacity to 350,000 tons.
- **Markets:**
  - According to *Bloomberg*, "SayanskKhimPlast manufactures and markets suspension-PVC, caustic soda, cable and footwear plasticized rubbers, corrugated pipes, wall panels, PVC-based cable channels, and [the] bleaching agent Belizna."<sup>1419</sup>
  - The plant was Russia's leading supplier of PVC profile extrusion in 2010 (188,000 tons).<sup>1420</sup> Its position among PVC producers in Russia fell to second after the startup of RusVinyl in 2014.<sup>1421</sup>
- **Pollution:**
  - "For the first few years of its operation, the high-end production collective SayanskKhimplast suffered continuous mishaps and accidents," according to a 2015 journal article.<sup>1422</sup>
  - Before they were replaced by membrane technology in 2006, the SayanskKhimplast mercury cells "released approximately 4 to 4.6 tons of mercury annually into the environment," according to the UNEP Global Mercury Partnership.<sup>1423</sup>
  - In 2007, an explosion and fire in the plant's EDC unit killed four people and injured four others.<sup>1424</sup>
  - In 2013, the plant ranked as the Irkutsk region's eighth leading source of air pollution, according to a Russian journal article. "The situation is aggravated by the fact that the company is located on the favorable territory for dispersion of impurities. The region's special features contribute to the accumulation of pollutant in the surface layer of the atmosphere, which is dangerous for living in the given territory," said the study's authors. The SayanskKhimplast plant released a reported 5,667 tons of air pollution per year, including EDC, trichloromethane, and carbon tetrachloride and 45 other pollutants.<sup>1425</sup>

## SPAIN

### INVENTORY CODE: EURES01

- **Plant Name:** *Ercros - Vila-seca*
- **Owner:** Ercros Industria. Formerly Aragonesas Industrias Y Energia, SA (EIASA), which Ercros acquired in 2005.<sup>1426</sup>
- **Location:** Vila-seca, Tarragona, Spain.
- **Process:** Membrane. Converted from mercury in 2017.
- **Year Opened:** 1952.<sup>1427</sup>
- **Capacities** (tons per year): 120,000 tons of chlorine (2018).<sup>1428</sup> 120,000 tons of suspension-PVC resins (2008).<sup>1429</sup>
- **Capacity Rank** (Europe): 35th of 39.
- **Technology Conversions:**
  - Aragonesas added mercury cell capacity in 1972.<sup>1430</sup>
  - It added membrane cell capacity in 1992 (35,000 tons) and 1997-1998 (10,600 tons).<sup>1431</sup>
  - In 2008, Ercros installed a 120,000-ton-per-year PVC plant.
  - The European Commission reported in 2014, "Ercros, a fully vertically integrated player, has recently decided to rely on EDC purchases [for PVC production], but only to a limited extent in addition to its internal production. That decision stems from a number of factors, among which a particularly favourable preexisting logistical arrangement, the economic condition of the Iberian Peninsula and the challenge posed by mercury conversion."<sup>1432</sup>

- In 2016, the company announced plans to close its mercury cells, expand membrane capacity, and “update” its PVC plant in Vila-Seca.<sup>1433</sup>
- At the start of 2017, the plant had the capacity to produce 135,000 tons per year of chlorine via mercury cell and 55,000 tons of chlorine by membrane technology.<sup>1434</sup>
- According to Ercros, “The chlorine production plant with mercury technology... stopped operating on December 4, [2017,] after 47 years of activity. As of this date, the tests for the commissioning of the chlorine plant with membrane technology expansion have started.” It expected the new membrane capacity to be operational by the end of 2017.<sup>1435</sup>
- The replacement and expansion in 2017 occurred during a country-wide transformation of chlor-alkali production. Mercury cell production was outlawed in Spain as of December 11, 2017. Ercros closed its plants in Flix, as did Elnosa in Lourizán-Pontevedra. Inovyn chose not to replace its 218,000-ton-capacity plant in Martorell and instead is importing EDC from an unnamed supplier for its PVC plant.<sup>1436</sup>
- **Markets:**
  - The Covestro MDI plant in Terragona, Spain, “is the largest consumer of chlorine from the Vila-seca plant,” according to CHEManager International.<sup>1437</sup> In 2017, according to *C&EN*, “Covestro signed a new contract with the Spanish firm Ercros for the chlorine it uses to produce MDI. Ercros says it will be able to meet Covestro’s requirements even though it is cutting chlorine capacity by 44% because of legislation requiring it to cease production based on mercury-cell technology by Dec. 11, 2017.”<sup>1438</sup>
  - Spain and neighboring countries are the main markets for the suspension-PVC resins made in Vila-Seca. According to the European Commission, “Ercros’ main focus is on its domestic market, Spain, where it is the number one player with a market share by sales volume of 30-40%. Spain accounts for 50-60% of Ercros’ production and is followed by France (10-20% of its production), Germany 5-10% of its production, and Italy and Portugal (both 5-10% of its production).”<sup>1439</sup>
  - Ercros also produces chloroisocyanurates on-site, some of which it ships to the United States.<sup>1440</sup> These chemicals are used as antimicrobials and disinfectants.<sup>1441</sup>
- **Pollution:**
  - In 2001, the plant released 154 kg of mercury into the air, and 8.4 kg into water. These releases ranked seventh highest source of mercury emissions in Spain.<sup>1442</sup>
  - In 2008, the plant had 347 tons of mercury on-site, second-most among European chlor-alkali plants on the Mediterranean coast.<sup>1443</sup>
  - A 2011 report by Centre d’Anàlisi i Programes Sanitaris (CAPS) of Barcelona noted the historical contamination from the chlorine plant in Vila-Seca, which “with obvious neglect or sometimes even connivance, have left a significant burden on subsoil, aquifers and the sea.” High concentrations of dioxins and toxic organochlorine pollutants leached into the aquifer. The plant discharged effluents directly to the ocean, contaminated with toxic substances like EDC, chloroform, trichloroethylene, tetrachloroethylene, bromodichloromethane, and 1,1,2-trichloroethane.<sup>1444</sup>
  - In December 2012, the plant’s chlor-alkali production cells held 208 tons of mercury.<sup>1445</sup>
  - In 2013, the plant released 4 kg of mercury into the air and 8 kg into water.<sup>1446</sup>
  - In 2016, Ercros reported releasing 58.4 kg of mercury into the air and 11.05 kg into water, 3.32 tons of EDC into the air and 320 kg into water, 6.6 tons of VCM into the air and 275 kg into water, 15.52 tons of halogenated organic compounds into water, 29.5 kg of trichlorobenzene into water, 850 grams of PCBs into water, 7.88 kg of tetrachloromethane into water, 312 kg of trichloromethane into water, 1.08 kg of pentachlorophenol into water, and 4.92 kg of chloroalkanes, C10-C13, into water.<sup>1447</sup>
  - Ercros in Vila-seca, Spain, reported PCB releases to the E-PRTR. It measured releases of PCBs into water at rates of 170 grams in 2014, 161 grams in 2015, and 310 grams in 2016.<sup>1448</sup>

## SWEDEN

### INVENTORY CODE: EURSV01

- **Plant Name:** *Inovyn - Stenungsund*
- **Owner:** Ineos, through Inovyn Sverige AB subsidiary, which Ineos acquired in July 2016.<sup>1449</sup> Inovyn acquired the plant from Norsk Hydro (Hydro Polymers) in 2008. Norsk Hydro owned it between 1984 and 2008. The original owner was KemaNord.<sup>1450</sup>
- **Location:** Stenungsund, Västra Götaland County, Sweden.
- **Process:** Membrane. Replaced mercury cells in May 2018.<sup>1451</sup>
- **Year Opened:** 1969.<sup>1452</sup>
- **Capacities** (tons per year): 120,000 tons of chlorine (2017).<sup>1453</sup> 240,000 tons of EDC (2017).<sup>1454</sup> 215,000 tons of PVC (2015).<sup>1455</sup>
- **Capacity Rank** (Europe): 35th (tie) of 39.
- **Technology Conversions:**
  - The plant's chlorine capacity in 1998 was 112,000 tons of chlorine per year by mercury cell.<sup>1456</sup>
  - In 1970, the plant's PVC capacity was 70,000 tons.<sup>1457</sup>
  - In 1984, the plant's PVC capacity was 110,000 tons.<sup>1458</sup>
  - In the 1990s, PVC capacity increased to 170,000 tons.<sup>1459</sup>
  - In 2000, Norsk Hydro abandoned the use of carbon tetrachloride for purification purposes.<sup>1460</sup> (See Glossary of Notes.)
  - In 2003, Hydro Polymers said it would end the use of mercury in Stenungsund by 2010.<sup>1461</sup>
  - In 2015, the plant's PVC capacity was 215,000 tons. Inovyn plans to increase capacity to 260,000 tons of PVC.<sup>1462</sup>
  - In April 2016, Inovyn announced that it would replace its mercury cells with a 123,000-ton-capacity membrane plant by December 2017.<sup>1463</sup>
  - In September 2017, Inovyn announced a "revised completion date of Q2 2018 for its Project to convert the mercury chlorine cell room at Stenungsund Site (Sweden) to membrane technology... As a result, the mercury cell room at Stenungsund Site will remain operational until May 2018 as covered by an exemption granted by the Swedish Chemical Agency."<sup>1464</sup>
  - On May 13, 2018, Inovyn confirmed that "it has ceased operation of its mercury chlorine cellroom at Stenungsund Site (Sweden)."<sup>1465</sup>
- **Markets:**
  - PVC resins, integrated with on-site production of chlorine, EDC, and VCM, are Inovyn's main product at Stenungsund. It produces suspension-PVC and emulsion PVC. It also imports some VCM and sells some EDC, according to the European Commission.<sup>1466</sup>
  - Inovyn Sverige shipped about 100 tons of PVC to the US per year in 2015 and 2016.<sup>1467</sup>
- **Pollution:**
  - According to Greenpeace, "In 1992, Norsk Hydro analyzed wastes from its VCM plant in Stenungsund, Sweden; dioxins were found in four waste streams, and total dioxin discharges into wastes were estimated at 321 grams TEQ/year.... (Also in) 2012, several Swedish universities found high levels of hexachlorobenzene, pentachlorobenzene and several congeners of dioxins and furans in sediments near Norsk Hydro's plant in Stenungsund."<sup>1468</sup>
  - In 2001, the Stenungsund plant released 16.6 kg of mercury into the air and 1.5 kg to water.<sup>1469</sup>
  - In December 2012, the plant's chlor-alkali cells contained 157 tons of mercury. Another 8.3 tons were stored on site.<sup>1470</sup>
  - In 2013, the Stenungsund plant released 16 kg of mercury into the air and 1.2 kg into products.<sup>1471</sup>
  - In 2016, it released 17 kg of mercury into the air, 18.2 tons of EDC into the air, 11 tons of trichloromethane into the air, and 52.2 tons of VCM into the air.<sup>1472</sup>

## UKRAINE

### INVENTORY CODE: EURUR01

- **Plant Name:** *Karpatneftekhim - Kalush*
- **Owner:** Xedrian Holding (Cyprus). Plastics News Europe reported that in February 2017, “according to Ukraine’s antitrust authority, AMCU, over 50% of Karpatneftekhim shares were bought by a former Lukoil-Ukraine chief executive, Ilkham Mamedov through his company Xedrian Holding of Limassol, Cyprus. A further capital share of more than 25% was acquired by the Kiev, Ukraine-based industrial engineering company Techinservice, it confirmed. Its owner is understood to be Ukrainian entrepreneur, Ivan Shchutsky.”<sup>1473</sup> According to MRC (a division of industry experts ICIS), “Techinservice Limited is associated with a major Ukrainian businessman Igor Kolomoisky and a deputy from the National Front Andrew Ivanchuk.”<sup>1474</sup> The plant was previously owned by Lukor, a subsidiary of Russian petrochemical company, Lukoil.<sup>1475</sup> In 2000, Lukoil acquired a majority stake from Oriana Concern when it was privatized.<sup>1476</sup> Oriana was formerly called P.O. Chlorvinyl, which commissioned the VCM plant in 1975.<sup>1477</sup>
- **Location:** Oriana complex, Kalush City, Ivano-Frankivsk region, Ukraine.
- **Process:** Membrane. Converted from diaphragm in 2010.
- **Year Opened:** 1975. Production suspended in 2012. Reopened in 2017.
- **Capacities** (tons per year): 180,000 tons of chlorine, 300,000 tons of PVC.<sup>1478</sup>
- **Capacity Rank** (Europe): 26th (tie) of 39.
- **Technology Conversions:**
  - In 1971, the Soviet government planned to build a 200,000- to 250,000-ton-per-year VCM plant in Kalush, accompanied by three 60,000-ton PVC plants.<sup>1479</sup>
  - The VCM plant opened in 1975.
  - In 1976, Chemical Week reported, “Now that its 250,000-metric-tons/yr Kalush in the Ukraine plant is on-stream, Russia has doubled its VCM capacity. Additional capacity is planned for 1978 when a \$40-million, 270,000-metric-ton/yr VCM plant on order from Germany will be ready.”<sup>1480</sup>
  - In 1996, Oriana retrofitted and expanded its VCM plant capacity from 250,000 tons to 370,000 tons.<sup>1481</sup>
  - In 2002, Lukoil planned to add 180,000 tons of PVC capacity to the plant.<sup>1482</sup>
  - In 2006, Lukoil said it would replace the Kalush plant’s asbestos diaphragms with membrane cell by 2008.<sup>1483</sup>
  - In 2008, Karpatneftekhim had a 370,000-ton-per-year VCM capacity and produced 104,000 tons of chlorine. It did not produce PVC at the time.<sup>1484</sup>
  - Lukoil completed the conversion of asbestos diaphragms to mercury cell technology in August 2010. It removed 191,000 tons of asbestos diaphragm capacity with financial support from Kyoto Protocol mechanisms.<sup>1485</sup>
  - Also in 2010, Lukoil installed 300,000 tons of PVC capacity in Kalush.<sup>1486</sup>
  - According to ICIS News, “Production at Karpatneftekhim was suspended in September 2012 after the plant repeatedly reported the problems due to the debts of the state for the reimbursement of export VAT and dumping of foreign, in particular American, producers of PVC.”<sup>1487</sup>
  - In June 2017, production at the plant resumed upon its sale to Ukrainian investors.<sup>1488</sup>
- **Markets:**
  - In March 2017, the government of Ukraine banned imports of PVC from RusVinyl and JSC “Kaus-tik.” Plastics News Europe reported, “This government move follows the recent sale by Russian oil group Lukoil of Karpatneftekhim, its idled Ukrainian petrochemicals plant, to Ukraine investors. It is planned to restart what is the country’s only PVC operation in April or May.”<sup>1489</sup>
  - There are numerous vinyl flooring manufacturers in Kalush.<sup>1490</sup>
  - In 2004 and 2005, the Kalush plant exported around 200,000 tons of VCM, mainly to Romania, Hungary, Greece, Poland, Slovakia, Turkey, and Portugal.<sup>1491</sup>

- **Pollution:**
  - In 2000, Ukraine declared the Kalush region as an environmental disaster zone, due in part to widespread hexachlorobenzene pollution caused by an Oriana chlorinated solvents plant (now closed).<sup>1492</sup>
  - In June 2017, as the plant readied for restarting after five years of being idled, residents complained of unpleasant odors. Igor Golavatchuk, a Kalush city official in charge of emergency situations, said it was a “normal occurrence” during plant start-ups, and because the weather was “gloomy” everything that left the pipe fell towards earth. He said that while “of course, it is better not to let children out into the street... there is nothing that could harm them.”<sup>1493</sup>

## UNITED KINGDOM

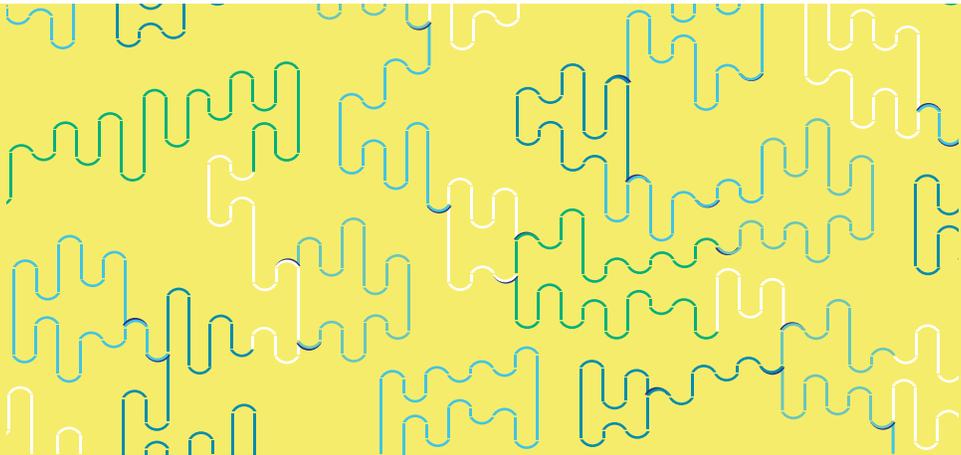
### INVENTORY CODE: EURUK01

- **Plant Name:** *Ineos/Vynova - Runcorn*
- **Owner:** International Chemical Investors Group, via Vynova subsidiary, and Ineos, via Inovyn subsidiary.<sup>1494</sup> In 2015, International Chemical Investors Group acquired the Runcorn EDC unit and a 50% share in the chlor-alkali plant in an EU-mandated “remedy package” for the merger of Solvay and Ineos.<sup>1495</sup> Ineos was formerly named European Vinyls Corporation. Previous owners of the plant, in reverse chronological order, included AkzoNobel, Imperial Chemical Industries (ICI), Brunner-Mond, and the Castner-Keller Alkali Company.
- **Location:** Runcorn, Cheshire, United Kingdom (UK).
- **Process:** Membrane. Closed mercury cell production in 2017.
- **Year Opened:** 1897.
- **Capacities** (tons per year): 430,000 tons of chlorine by membrane (2017).<sup>1496</sup> 300,000 tons of EDC (2017).<sup>1497</sup>
- **Capacity Rank** (Europe): 5th of 39.
- **Technology Conversions:**
  - In 1897, The Castner-Kellner Alkali Company began mercury cell production in Runcorn.<sup>1498</sup>
  - In 1900, the plant produced about 3,000 tons of chlorine.<sup>1499</sup>
  - In the 1930s, 1960s, and 1970s, the plant installed more mercury cells.<sup>1500</sup>
  - In 1961, ICI obtained its first patent for membrane-process chlor-alkali production.<sup>1501</sup>
  - In 1972, the plant was producing VCM, and had 200,000 tons of PVC capacity.<sup>1502</sup>
  - In 1989, ICI began producing chlorine by ion exchange membrane technology in Runcorn (37,500-ton capacity).<sup>1503</sup> It replaced a 75,000-ton mercury cell unit.<sup>1504</sup>
  - In 1992, the plant’s chlorine capacity was 600,000 tons.<sup>1505</sup>
  - In the 1990s, ICI used “heavies” (heavy ends from the distillation of EDC) from the VCM plant “as feedstock for the production of 100,000 metric tons per year of perchloroethylene and trichloroethylene,” according to Costner et al.<sup>1506</sup>
  - In 1997, the Runcorn operation produced 2-Chloro-5-(trifluoromethyl)pyridine for use as an intermediate in pesticides made by Zeneca.<sup>1507</sup>
  - In 2003, Ineos announced plans for a “phased replacement” of its mercury cells with membrane technology.<sup>1508</sup>
  - In 2009, Ineos stopped producing HCFC-22 at Runcorn.<sup>1509</sup> Mexichem acquired the fluorochemical plant in 2010. It currently produces HFC-125 and HFC-134a.<sup>1510</sup>
  - In 2010, the Ineos produced trichloroethylene, tetrachloroethylene, and tetrachloromethane.<sup>1511</sup>
  - In 2013, Ineos closed the Runcorn VCM and PVC plants (100,000-ton capacity), but continued to produce chlorine and EDC.<sup>1512</sup> “As demand for PVC in particular continues to be very weak, the Company needs to address its current over capacity in chlorine, VCM and PVC. As a result,

INEOS ChlorVinyls has decided to discontinue production from three of its plants,” the company announced. “The Company will focus all UK PVC production at its Newton Aycliffe Site [which imports VCM from Sweden, see EURSV01], which will facilitate closure of its small scale PVC unit at Runcorn Site. Also at Runcorn Site, the Company will reconfigure its VCM plant to produce EDC intermediate for internal use.”<sup>1513</sup>

- In February 2016, Inovyn closed its chloromethanes plant in Runcorn, consolidating its production in Tavaux, France, and Rosignano, Italy. Inovyn said that it would continue to produce carbon tetrachloride, chloroform, methylene chloride, and perchloroethylene in Runcorn.<sup>1514</sup>
- “Final closure [of the mercury cells] is expected to be complete by early 2017, followed by full decontamination and decommissioning activities,” announced Inovyn in December 2016, “and follows the earlier closure of two mercury units at the Site in 2006 and 2008 respectively.”<sup>1515</sup>
- In 2017, ICIS reported the plant’s EDC capacity as 300,000 tons, half its reported capacity in 2009.<sup>1516</sup>
- **Markets:**
  - The Runcorn plant sells bulk chlorine to third parties.<sup>1517</sup>
  - The Runcorn plant supplies EDC to Vynova’s VCM and PVC (370,000-ton) plant in Wilhelmshaven, Germany. According to the European Commission, Ineos has been supplying all of the Wilhelmshaven EDC requirements since 2013.<sup>1518</sup>
  - Vynova also exports EDC from Runcorn to worldwide consumers.<sup>1519</sup>
  - Ineos also produces carbon tetrachloride, chlorinated paraffins, chloroform, chlorotoluenes, and methylene chloride in Runcorn for the global market.<sup>1520</sup> Ineos says it is “one of the top three manufacturers of chlorinated toluene derivatives in the world.” It produces a total of “about 50,000 tons” of these products in Tesselrolo, Belgium, Maastricht, Netherlands, and Runcorn.<sup>1521</sup>
- **Pollution:**
  - In 1997, the UK Environment Agency reported that about 500 grams TEQ/year dioxin “in heavy organic residues... are sent to the Holford brine cavities for secure containment.... Major environmental improvements are being made on the site through the installation of three incinerators. Local air quality, the ozone layer and global warming will all benefit from a 90% reduction in the emission of chlorinated hydrocarbons into the air. Discharges to water will be cut by 80% and this will enable the Weston Canal to comply with water quality standards. The incinerators will also provide for the discontinuation of waste disposal at Weston Marsh Lagoons and Holford brine cavities.”<sup>1522</sup>
  - In 1998, Friends of the Earth called Runcorn “possibly Britain’s filthiest factory.” It said the local Weston canal “has been used as a drain” with the bottom covered by layers of mercury-contaminated brine and chlorinated solvents.<sup>1523</sup>
  - In 1999, ICI obtained a UK government exemption from a Climate Change Levy energy tax intended to reduce UK carbon dioxide emissions.<sup>1524</sup> According to the *Journal of the Electrochemical Society*, in 1992, the plant consumed 1% of all electricity in the UK.<sup>1525</sup>
  - In 1999, Greenpeace reported, “Most of the dioxins generated at Runcorn are contained in the organochlorine waste which is buried in salt caverns at Holford, in Cheshire. Most of the rest are in effluent discharged into Weston Marsh Lagoons. ICI admit that some of these dioxins escape from the lagoons into the Weston canal.”<sup>1526</sup>
  - In 2000, *The Independent* (UK) reported, “The village of Weston, Cheshire, is slowly disintegrating eight months after people there were told that a chemical dumped 25 years ago by the local ICI plant was seeping into the foundations of buildings. Only 21 of Weston’s 467 houses are affected by the toxic gas but fears over the safety of the whole community, and the level of compensation offered by ICI, have started an exodus. Soon, one-third of residents will have moved; the bus company is considering pulling out and the 100-year-old Scout hut is deserted... Now villagers are awaiting the fate of their shop. The chemical hexachlorobutadiene (HCBd) was found by chance when ICI, whose Castner Kellner plant is next to the village, did routine tests on possible effects of old chlorine production methods.... The chemical had been poured into pools

- in Weston's old north quarry in the Fifties and Sixties, only to seep out through the sandstone which had sustained the mining village for 100 years from 1820."<sup>1527</sup>
- In 2001, "Ineos Chlor took over the site from ICI at the beginning of the year and bosses claim the factory is suffering from 'years of neglect,'" reported the *Liverpool Echo*.<sup>1528</sup>
  - In 2001, the Runcorn plant released 1,050 kg of mercury into the air, and 101 kg into water. It was the leading source of mercury pollution in the UK, including over 25% of air and 40% of water emissions.<sup>1529</sup>
  - In 2002, the plant was in noncompliance with a number of industry standards for pollutant releases. According to Det Norske Veritas, it exceeded limits for VCM, EDC, hydrochloric acid, ethylene, and dioxin releases to the air. "The non-compliance by European Vinyls Corporation [now named Ineos] is to a large extent a consequence of a fire at the incinerator on their Runcorn VCM plant in April 2002."<sup>1530</sup> The incinerator, installed in the 1990s, burned chlorinated hazardous waste.<sup>1531</sup>
  - As of December 2012, the Runcorn plant used 357 tons of mercury in its cells and stored another 222 tons on-site.<sup>1532</sup>
  - In 2014, the Runcorn plant released "16.5 kg of mercury, 21.7 kg of lead and 134.1 kg of chloroform into the Weston Canal and Manchester Ship Canal," said Friends of the Earth. Over the previous two decades, the Runcorn plant released over 8.7 tons of mercury into the air.<sup>1533</sup>
  - Among the chlor-alkali plants reporting to the E-PRTR, the Runcorn plant released the second most EDC (199 tons per year average) between 2012 and 2016. The Vynova Wilhelmshaven plant, which receives EDC from Runcorn, reported the most emissions of EDC (206 tons per year average).
  - In 2016, the Runcorn plant released 372 tons of EDC into the air, 6.56 tons of VCM into the air, 21.2 kg of tetrachloroethylene into water, 2.4 kg of tetrachloromethane into water, 12.4 kg of trichloromethane into water, and 16 kg of trichloroethylene into water.<sup>1534</sup>



THE APPENDICES

## APPENDIX A.

## INDEX OF CHLOR-ALKALI PLANTS: THE AMERICAS, AFRICA, AND EUROPE

TABLE 13 . PRODUCTION CAPACITY: CHLOR-ALKALI PLANTS: THE AMERICAS, AFRICA, AND EUROPE

HBN INVENTORY CODE	PARENT COMPANY	LOCATION	COUNTRY	CURRENT TECHNOLOGY (AS OF MAY 2018)	ANNUAL CHLORINE CAPACITY (1,000 TONS, EST.)
AMARG01	Unipar Carbocloro	Bahia Blanca, Buenos Aires	Argentina	Mercury	163
AMBRA01	Braskem	Maceió, Alagoas	Brazil	Synthetic Diaphragm	409
AMBRA02	Braskem	Camaçari, Bahia	Brazil	Mercury	70
AMBRA03	Unipar Carbocloro	Cubatão, São Paulo	Brazil	Mercury+Synthetic Diaphragm+Membrane	355
AMBRA04	Unipar Carbocloro	Santo André, São Paulo	Brazil	Membrane	155
AMBRA05	DowDuPont Inc.	Candeias, Bahia	Brazil	Asbestos Diaphragm	415
AMCAN01	Chemtrade Logistics Income Fund	North Vancouver, B.C.	Canada	Membrane	231
AMCAN02	Westlake Chemical	Beauharnois, Quebec	Canada	Membrane	88
AMCAN03	Olin	Bécancour, Quebec	Canada	Asbestos Diaphragm+Membrane	175
AMMEX01	Mexichem and PEMEX	Coatzacoalcos, Veracruz	Mexico	Asbestos Diaphragm	260
AMMEX02	Cydsa	Allende, Veracruz	Mexico	Mercury	98
AMMEX03	Cydsa	Monterrey, Nuevo Leon	Mexico	Membrane	60
AMMEX04	Cydsa	Ecatepec de Morelos, Estado de México	Mexico	Membrane	39
AMMEX05	Mexichem	El Salto, Jalisco	Mexico	Asbestos Diaphragm	40
AMPER01	Quimpac	Callao, Callao	Peru	Mercury+Membrane	107
AMPER02	Quimpac	Paramonga, Lima	Peru	Mercury	27
AMUSA01	ASHTA	Ashtabula, Ohio	USA	Mercury	47
AMUSA02	Covestro	Baytown, Texas	USA	Membrane	363
AMUSA03	Formosa Plastics	Point Comfort, Texas	USA	Membrane	910
AMUSA04	Occidental Petroleum	Niagara Falls, New York	USA	Asbestos Diaphragm	336
AMUSA05	Occidental Petroleum	Deer Park, Texas	USA	Asbestos Diaphragm	295
AMUSA06	Occidental Petroleum	La Porte, Texas	USA	Asbestos Diaphragm	525
AMUSA07	Occidental Petroleum	Gregory, Texas	USA	Asbestos Diaphragm	570
AMUSA08	Occidental Petroleum	Geismar, Louisiana	USA	Membrane+Synthetic Diaphragm	438
AMUSA09	Occidental Petroleum	Convent, Louisiana	USA	Asbestos Diaphragm	353

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TABLE 13 . PRODUCTION CAPACITY: CHLOR-ALKALI PLANTS: THE AMERICAS, AFRICA, AND EUROPE

HBN INVENTORY CODE	PARENT COMPANY	LOCATION	COUNTRY	CURRENT TECHNOLOGY (AS OF MAY 2018)	ANNUAL CHLORINE CAPACITY (1,000 TONS, EST.)
AMUSA10	Occidental Petroleum	Hahnville/Taft, Louisiana	USA	Asbestos Diaphragm+Membrane	655
AMUSA11	Occidental Petroleum	Wichita, Kansas	USA	Asbestos Diaphragm+Membrane	248
AMUSA12	Occidental Petroleum	New Johnsonville, Tennessee	USA	Membrane	165
AMUSA13	Olin	Charleston, Tennessee	USA	Membrane	200
AMUSA14	Olin	McIntosh, Alabama	USA	Asbestos Diaphragm+Membrane	685
AMUSA15	Olin	Niagara Falls, New York	USA	Membrane	240
AMUSA16	Olin	Freeport, Texas	USA	Asbestos Diaphragm+Membrane	3030
AMUSA17	Olin	St. Gabriel, Louisiana	USA	Membrane	246
AMUSA18	Olin	Plaquemine, Louisiana	USA	Asbestos Diaphragm	971
AMUSA19	Shin-Etsu	Plaquemine, Louisiana	USA	Membrane	1055
AMUSA20	Westlake	Plaquemine, Louisiana	USA	Asbestos Diaphragm	426
AMUSA21	Westlake Chemical Corp	Geismar, Louisiana	USA	Membrane	317
AMUSA22	Westlake	Lake Charles / Westlake, Louisiana	USA	Membrane+Synthetic Diaphragm	1270
AMUSA23	Westlake Chemical Corp	Calvert City, Kentucky	USA	Membrane	250
AMUSA24	Westlake (ex PPG, Axiall)	Natrium (New Martinsville), West Virginia	USA	Mercury+Synthetic Diaphragm	227
AMVEN01	Pequiven	Los Puertos de Altigracia, Zulia	Venezuela	Membrane	120
AFEGY01	Misr Chemical Industries	Alexandria	Egypt	Membrane	68
AFEGY02	Egyptian Petrochemicals Company	Alexandria	Egypt	Membrane	109
AFEGY03	Sanmar Holdings	Port Said	Egypt	Membrane	250
AFMOR01	Ynna Holding	Mohammedia	Morocco	Membrane	68
AFSAF01	SynChem	Cloorkop, Gauteng	South Africa	Membrane	101
AFSAF02	Sasol	Midland, Sasolburg	South Africa	Membrane+Synthetic Diaphragm	112
EURBE01	Ineos	Jemeppe-sur-Sambre	Belgium	Membrane	174
EURBE02	Ineos	Port of Antwerp (Zandvliet and Lillo), Flanders	Belgium	Mercury+Membrane	458

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TABLE 13 . PRODUCTION CAPACITY: CHLOR-ALKALI PLANTS: THE AMERICAS, AFRICA, AND EUROPE

HBN INVENTORY CODE	PARENT COMPANY	LOCATION	COUNTRY	CURRENT TECHNOLOGY (AS OF MAY 2018)	ANNUAL CHLORINE CAPACITY (1,000 TONS, EST.)
EURBE03	International Chemical Investors Group	Tessenderlo, Limburg	Belgium	Mercury+Membrane	365
EURDE01	AkzoNobel	Frankfurt	Germany	Membrane	250
EURDE02	AkzoNobel	Ibbenbüren, North Rhine-Westphalia	Germany	Membrane	75
EURDE03	BASF	Ludwigshafen, Rheinland-Palantine	Germany	Mercury+Membrane	385
EURDE04	Covestro	Brunsbüttel	Germany	Membrane	210
EURDE05	Covestro	Dormagen, North Rhine-Westphalia	Germany	Membrane	480
EURDE06	Covestro	Leverkusen, North Rhine-Westphalia	Germany	Membrane	390
EURDE07	Covestro	Uerdingen-Krefeld, North Rhine-Westphalia	Germany	Membrane	280
EURDE08	DowDuPont	Schkopau, Saxony-Anhalt	Germany	Membrane	250
EURDE09	DowDuPont	Stade, Lower Saxony	Germany	Asbestos Diaphragm+Membrane	1585
EURDE10	Evoniik	Lülsdorf, North Rhine-Westphalia	Germany	Mercury	137
EURDE11	Ineos	Rheinberg, North Rhine-Westphalia	Germany	Membrane+Synthetic Diaphragm	220
EURDE12	Mexichem	Marl, North Rhine-Westphalia	Germany	Membrane	265
EURDE13	Westlake	Gendorf, Burgkirchen an der Alz	Germany	Membrane	180
EURDE14	Westlake	Hürth-Knapsack, North Rhine-Westphalia	Germany	Membrane	250
EURES01	Ercros Industria	Vila-seca, Tarragona	Spain	Membrane	120
EURFR01	Ineos	Tavaux	France	Membrane	360
EURFR02	Kem One	Fos-sur-Mer, Bouches-du-Rhône	France	Membrane+Synthetic Diaphragm	340
EURFR03	Kem One	Lavéra	France	Membrane+Synthetic Diaphragm	363
EURFR04	PTT Global Chemical and Perstorp Group (JV)	Le Pont-de-Claix	France	Synthetic Diaphragm	171
EURHU01	Wanhua Industrial Group	Kazincbarcika, Borsod-Abaúj-Zemplén	Hungary	Mercury+Membrane	323
EURIT01	Ineos	Rosignano Solvay, Tuscany	Italy	Membrane	150
EURNE01	AkzoNobel	Botlek-Rotterdam	Netherlands	Membrane	637

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TABLE 13 . PRODUCTION CAPACITY: CHLOR-ALKALI PLANTS: THE AMERICAS, AFRICA, AND EUROPE

HBN INVENTORY CODE	PARENT COMPANY	LOCATION	COUNTRY	CURRENT TECHNOLOGY (AS OF MAY 2018)	ANNUAL CHLORINE CAPACITY (1,000 TONS, EST.)
EURNE02	AkzoNobel	Delfzijl	Netherlands	Membrane	121
EURNO01	Ineos	Stathelle	Norway	Membrane	280
EURPO01	PCC Rokita	Brzeg Dolny	Poland	Membrane	150
EURPO02	PKN Orlen	Wloclawek, Wloclawskie	Poland	Membrane	214
EURRO01	Oltchim S.A.	Râmnicu Vâlcea	Romania	Membrane	105
EURRU01	JSC HaloPolymer	Kirovo-Chepetsk, Kirov region	Russia	Mercury	182
EURRU02	EuroChem Group	Novomoskovsk, Tula region	Russia	Membrane	91
EURRU03	Sibur and Solvay (JV)	Kstovo, Nizhny Novgorod	Russia	Membrane	205
EURRU04	JSC Bashkirskaya Khimiya	Steritamak, Bashkortostan	Russia	Mercury+Asbestos Diaphragm	218
EURRU05	Nikochem	Volgograd	Russia	Mercury+Asbestos Diaphragm	220
EURRU06	Renova Group	Sayansk, Irkutsk region	Russia	Membrane	135
EURSV01	Ineos	Stenungsund, Västra Götaland County	Sweden	Membrane	120
EURUK01	International Chemical Investors Group	Runcorn, Cheshire	United Kingdom	Membrane	430
EURUR01	Xedrian Holding	Kalush City, Ivano-Frankivsk	Ukraine	Membrane	180

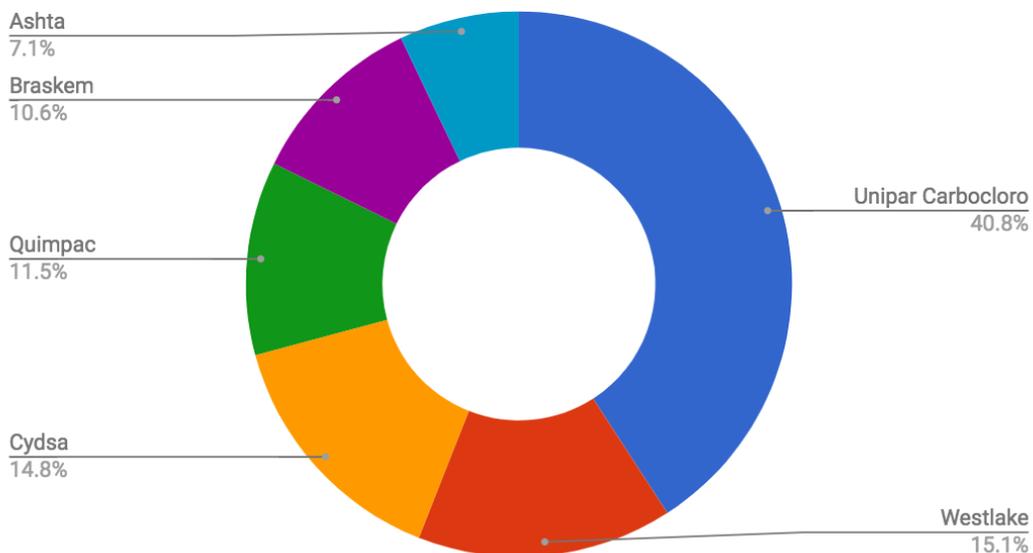
## APPENDIX B. CHLOR-ALKALI PLANTS USING MERCURY CELL AND ASBESTOS DIAPHRAGM

TABLE 14 . PRODUCTION CAPACITY: MERCURY CELL CHLORINE, THE AMERICAS AND EUROPE

PLANT	COUNTRY	1,000 tons/year (est.)		CONVERSION PLANS
		MERCURY CELL CHLORINE	RELATED PVC PRODUCTION	
HaloPolymer - Kirovo-Chepetsk	Russia	182		None
BASF - Ludwigshafen	Germany	170		None
Unipar Carbocloro - Bahia Blanca	Argentina	163	130	By 2020
Evonik - Lülisdorf	Germany	137		None
BSC - Sterlitamak	Russia	134	160	None
BorsodChem - Kazincbarcika	Hungary	131	400	None
Nikochem - Volgograd	Russia	125	110	None
Unipar Carbocloro - Cubatão	Brazil	107	48	By 2019
Westlake - Natrium, West Virginia	USA	100		None
Cydsa - IQUISA Coatzacoalcos	Mexico	98		By 2025 (*)
Inovyn (Ineos) - Zandvliet/Antwerp	Belgium	90		By 2018
Vynova (ICIG) - Tessenderlo	Belgium	90		By 2018
Braskem - Camaçari Petrochemical	Brazil	70	56	By 2025 (*)
Quimpac - Oquendo-Callao	Peru	49		By 2025 (*)
ASHTA - Ashtabula, Ohio	USA	47		By 2019
Quimpac - Paramonga	Peru	27		By 2025 (*)
	<b>TOTAL</b>	<b>1720</b>	<b>904</b>	

(\*) Per country's ratification of the Minamata Convention.  
Estimates by HBN Research, April 2018

### Mercury Cell Chlorine Producers - The Americas



### Mercury Cell Chlorine Producers - Europe

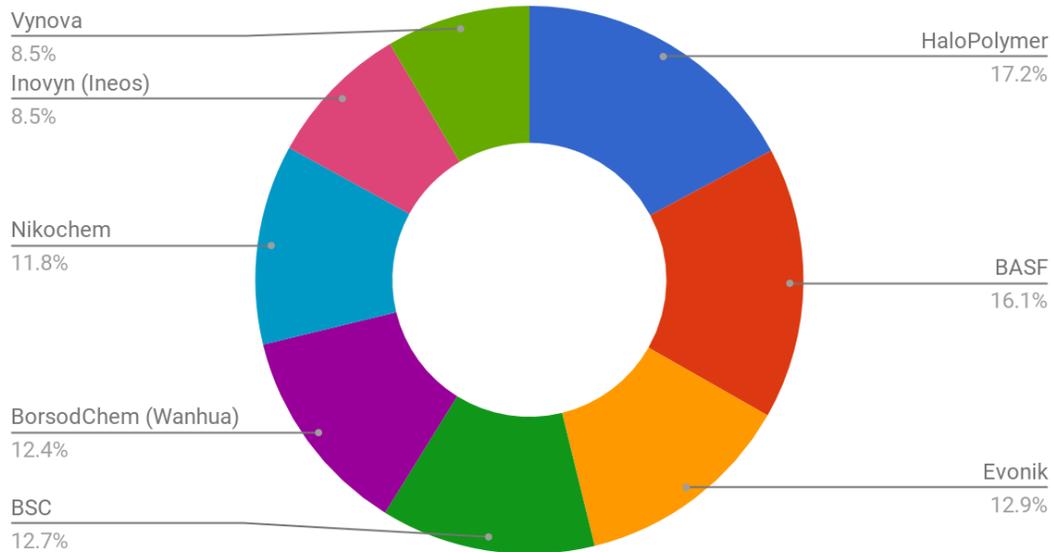


TABLE 15 . PRODUCTION CAPACITY: ASBESTOS DIAPHRAGM CHLORINE, THE AMERICAS and EUROPE

PLANT	COUNTRY	1,000 TONS PER YEAR (EST.)	
		ASBESTOS DIAPHRAGM CHLORINE	RELATED PVC PRODUCTION
Olin - Freeport	USA	1580	659
Dow - Stade	Germany	1030	
Olin - Plaquemine	USA	971	488
OxyChem - Ingleside	USA	570	455
OxyVinyls Battleground (LaPorte)	USA	525	420
OxyChem - Taft (Hahnville)	USA	438	350
Westlake - Plaquemine	USA	426	341
Dow - Aratu	Brazil	415	
Olin - McIntosh	USA	365	292
OxyChem - Convent	USA	353	282
OxyChem - Niagara Falls	USA	336	256
OxyChem - Deer Park	USA	295	236
Mexichem - Coatzacoalcos	Mexico	260	208
OxyChem - Wichita	USA	165	
Olin - Bécancour	Canada	110	
Nikochem "Kaustik" - Volgograd	Russia	95	160
BSC - Sterlitamak	Russia	84	110
Mexichem - El Salto	Mexico	40	
	<b>TOTAL</b>	<b>8058</b>	<b>4257</b>

Estimates by HBN Research, April 2018

## APPENDIX C. POLLUTION

### Excess Chlorinated Pollutant Release Ratings - Methodology

A supplemental table, “Excess Chlorinated Pollutant Release Ratings - (US and Canada),” is available online as a companion to this report. This table is based upon reported releases of nine chlorinated byproducts: carbon tetrachloride, chlorine, chloroform, dioxins, ethylene dichloride (EDC, also called 1,2-dichloroethane), hexachlorobutadiene (HCBd), hydrochloric acid, polychlorinated biphenyls (PCBs) and vinyl chloride monomer (VCM).

Release amounts and types are based on data in the EPA’s Toxics Release Inventory (TRI) and Environment and Climate Change Canada’s National Pollutant Release Inventory (ECCC NPRI).

The table covers a five-year period, 2012 to 2016.

The facilities in this analysis either produce chlorine or use it in the production of PVC feedstocks, including EDC, VCM, and PVC resins. In order to normalize release data among plants with different production configurations, we estimated the amount of chlorine required to sustain production capacities. We determined “chlorine throughputs” in this manner:

- If a plant produces only chlorine (and not EDC, VCM, and PVC), its chlorine throughput is 100% of its known or estimated chlorine production capacity.
- If a plant produces EDC, VCM, and/or PVC, its chlorine throughput is based on the highest chlorine throughput requirements of any given product. These requirements are based on the chlorine percentage of the chemical discussed in the Glossary of Notes.

Additional details are available in spreadsheets accompanying this report, as well as from government databases. TRI and NPRI codes for each plant listed in companion spreadsheets provide shortcuts to raw government data, which are available through numerous portals in US government websites.

The following is the link to our source for TRI data:

<https://www.epa.gov/toxics-release-inventory-tri-program/tri-data-and-tools>

For Canada’s National Pollutant Release Inventory, data are based on searches conducted from this site:

<https://pollution-waste.canada.ca/national-release-inventory/archives/index.cfm?lang=en>

TRI data are based on the sum of US TRI data reported in Sections 8.1 (which EPA defines as on- and off-site releases), 8.2 (on-site energy recovery), 8.3 (off-site energy recovery), 8.5 (recycling off-site), 8.7 (treatment off-site), and 8.8 (one-time direct releases or transfers off-site due to catastrophic events, remedial events, and “one-time events not associated with normal or routine production processes.” This table’s release calculations do not include on-site recycling and on-site waste treatment.

Some important caveats:

- TRI and NPRI data are self-reported; that is, companies releasing these pollutants are responsible for reporting them to government agencies.
- There are thresholds of releases below which companies are not obliged to report.

### Asbestos Releases, 2012 to 2016

A dozen plants in the US and Canada use asbestos diaphragm technology in chlor-alkali production.

Disposal reports vary widely among plants. Some report air emissions (less than 10 kilograms per year, overall), leases were solid-waste transfers from chlor-alkali plants that had already transitioned to non-asbestos technologies. This indicates that plants may store used asbestos diaphragms and related waste for years before disposing of them.

Asbestos diaphragms are not recycled, and so must be released from the plant in some form and place. In January 2018, the U.S. Geological Survey (USGS) estimated that chlor-alkali producers are consuming 300 tons of asbestos per year. Therefore, HBN estimates, the industry releases 300 tons of asbestos per year, almost entirely as solid waste destined for landfills. This figure may be low: between October 2013 and February 2017, the US industry imported an average of 532 tons of asbestos per year, mainly from Brazil (and, on occasion, Russia).<sup>1535</sup> However, some of these imports may have been for building stock in anticipation of Brazil’s 2016 ban on asbestos mining.

TABLE 15 . ANNUAL ASBESTOS RELEASES: US &amp; CANADA, 2012 – 2016

PLANT NAME	INVENTORY CODE	RELEASE TYPE	KILOGRAMS/ YEAR (AVG.)	NOTES
Chemtrade - North Vancouver Westlake - Plaquemine	AMCAN01 AMUSA20	Off-Site Disposal	7,100	Converted to membrane in 2010.
		Off-Site Recycling	10,400	
Olin - Bécancour	AMCAN03	Off-Site Disposal	25,800	
Occidental - Deer Park	AMUSA05	Disp Non Metals	11,163	
Occidental - La Porte	AMUSA06	Disp Non Metals	1,836	
Occidental - Ingleside	AMUSA07	Air Stack	7.35	
Occidental - Convent Occidental - La Porte	AMUSA09 AMUSA06	Air Stack	0.34	
		Disp Non Metals	5.20	
Occidental - Hahnville/Taft Westlake - New Martinsville	AMUSA10 AMUSA24	Air Stack	0.03	
		Disp Non Metal	3,674	
Olin - McIntosh	AMUSA14	Unknown	≤226	
Olin - Plaquemine	AMUSA18	Solid Waste	212,582	
Westlake - Plaquemine	AMUSA20	Air Stack	2.09	
Westlake - Natrium	AMUSA24	Disp Non Metals	7,028	Converted to synthetic diaphragm in 2015.

US EPA Toxic Release Inventory Data.

EPA defines "Disp Non Metals" as:

The summation of a group of the methods that can be used to dispose of a metal or non-metal chemical off-site.

The methods are:

- M10 Storage Only
- M63 Surface Impoundment
- M64 Other Landfills
- M65 RCRA Subtitle C Landfills
- M66 RCRA Subtitle C Surface Impoundment
- M67 Other Surface Impoundment
- M71 Underground Injection
- M72 Landfills/Disposal Surface Impoundment
- M73 Land Treatment
- M79 Other Land Disposal
- M81 Underground Injection to Class I Wells
- M82 Underground Injection to Class II-V Wells
- M90 Other Off-site Management
- M94 Transfers to Waste Broker for Disposal
- M99 Unknown<sup>1536</sup>

## Mercury Releases - European Union, 2012-2016

Although many mercury cell plants have closed in recent years, plants in the European chlor-alkali industry have continued to release tons of mercury per year. The following table lists the average kilograms (kg) per year of mercury released only by plants listed in this report's inventory. Combined, these plants released on average 1.5 tons of mercury per year into the air and water. Other plants have closed and are not included in this table.

TABLE 16 . **MERCURY RELEASES: EUROPEAN UNION, 2012–2016**

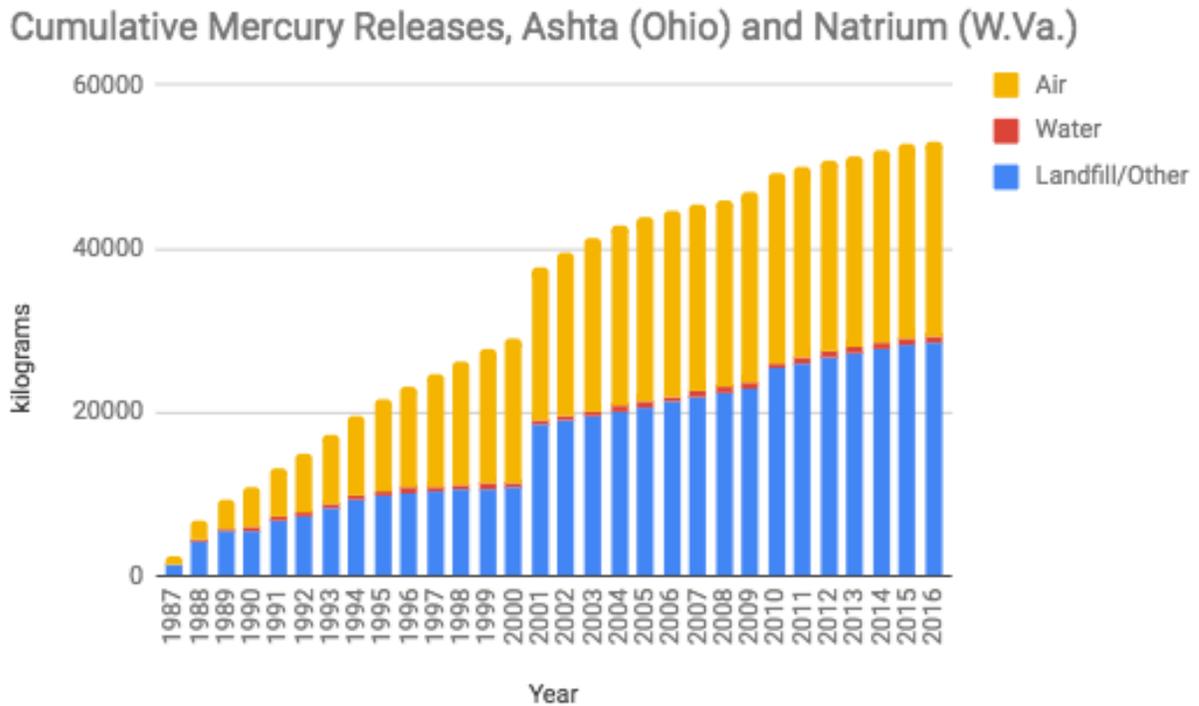
RANK	PLANT NAME	INVENTORY CODE	AVERAGE KG MERCURY AIR + WATER RELEASES PER YEAR	YEAR MERCURY CELL CLOSED
1	Inovyn - Runcorn, UK	EURUK01	327.0	2017
2	Kem One - Lavera, France	EURFR03	199.5	2017
3	Inovyn - Tavaux, France	EURFR01	125.4	2012
4	PCC Rokita - Brzeg Dony, Poland	EURPO01	119.8	2015
5	Wanhua (BorsodChem) - Kazincbarcika, Hungary	EURHU01	114.5	2019 (scheduled)
6	Vynova - Tessenderlo, Belgium	EURBE03	110.1	2018 (scheduled)
7	BASF - Ludwigshafen, Germany	EURDE03	96.1	staying open
8	Ercros - Vila-seca, Spain	EURES01	65.5	2017
9	Evonik - Lülisdorf, Germany	EURDE10	63.5	staying open
10	AkzoNobel - Ibbenbüren, Germany	EURDE02	56.8	2017
11	Oltchim - Râmnicu Vâlcea, Romania	EURRO01	56.9	2012
12	Inovyn - Rosignano Solvay, Italy	EURIT01	54.6	2007
13	AkzoNobel - Frankfurt, Germany	EURDE01	50.1	2014
14	Inovyn - Jemeppe-sur-Sambre, Belgium	EURBE01	30.4	2001
15	Inovyn - Lillo and Zandvliet (Antwerp), Belgium	EURBE02	18.8	2018 (scheduled)
16	Inovyn - Stenungsund, Sweden	EURSV01	18.5	2018
17	Dow - Schkopau, Germany	EURDE08	5.4	1999
18	Westlake (Vinnolit) - Hürth-Knapsack, Germany	EURDE14	0.4	2009
	<b>TOTAL</b>		<b>1513.4</b>	

## Mercury Releases - United States

Two mercury cell plants continue to operate in the United States: ASHTA Chemical of Ashtabula, Ohio, which is in the process of converting to membrane cell technology by 2019, and Westlake Chemical’s Natrium plant in Proctor, West Virginia. As of May 2018, Westlake has not announced plans to close or convert Natrium’s mercury cell production.

The following graph reveals the cumulative releases of mercury from these two remaining mercury plants, into the air and water, from 1987 to 2016.

Over the past 30 years (1987 to 2016), these two plants combined have reported releasing over 28 tons of mercury into the air, 742 kg of mercury into water, and 23 tons of mercury into landfills.



## Endnotes

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# Chlorine and Building Materials: A Global Inventory of Production Technologies, Markets, and Pollution

*Phase 1: Africa, The Americas,  
and Europe*

## Healthy Building Network Mission

To advance human and environmental health by improving hazardous chemical transparency and inspiring product innovation.

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