IODINE

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Three producers of crude iodine supplied about 30% of domestic demand; the remainder was imported. Because some exports and imports are in product categories rather than crude products, net imports are not clearly distinguished. The largest producer, Chile, produced iodine as a coproduct of sodium nitrate. The world's second largest producer, Japan, produced iodine from brines associated with gas production.

Legislation and Government Programs

Public Law 105-85, the National Defense Authorization Act for Fiscal Year 1998, was enacted on November 17, 1997. Calendar year 1998 included parts of the U.S. Government fiscal year (October 1 to September 30) 1998 and 1999. The Strategic and Critical Materials Stock Piling Act, Public Law 105-261, enacted October 17, 1998, gave the U.S. Department of Defense (DOD) authority to maintain a stockpile of strategic and critical materials to supply the military, industry, and essential civilian needs of the United States for national defense. By 1968, the DOD had acquired 3.7 million kilograms (8.1 million pounds). In 1992, Public Law 102-484 had reduced the stockpile goal to zero, and the U.S. Congress authorized the sale of excess material.

The DOD Annual Materials Plan proposed sale of iodine for fiscal year 1998 (October 1, 1997, through September 30, 1998) was 453,593 kilograms (kg) (1 million pounds). On February 17, 1998, 204,117 kg (450,000 pounds) of iodine were awarded by the Defense National Stockpile Center (DNSC) of the Defense Logistics Agency (DLA) under DLA-IODINE-002 for a market value of $3.9 million ($19.10 per kilogram). On April 1, 1998, the Revised Annual Materials Plan–FY98 continued to list iodine at 453,593 kg. On July 17, an amendment to DLA-Iodine-002 announced that 86,757 kg (191,267 pounds) of iodine from Scotia, NY, Gadsden, AL, and Stockton, CA, would to be the last offering for fiscal year 1998. On September 17, DNSC announced the award of 87,090 kg (192,000 pounds) valued at $1.5 million ($17.22 per kilogram). In October 1998, the DNSC issued a Solicitation of Offers for DLA-Iodine-003 for 453,593 kg (1 million pounds) with quarterly sales of approximately 113,398 kg (250,000 pounds). On December 9, DNSC announced the award of 24,040 kg (53,000 pounds) valued at $410,000 ($17.05 per kilogram). Total sales for 1998 were 290,874 kg (641,267 pounds) valued at $5.4 million ($18.56 per kilogram). As of September 30, 1998, 86,703 kg (191,148 pounds) of iodine was sold but not shipped. At yearend, the excess iodine remained at 1.9 Mkg (4.2 million pounds).

Production

Domestic production data for iodine were derived from a voluntary survey of U.S. operations by the U.S. Geological Survey (USGS). The three companies to which a survey request was sent responded, representing 100% of the total production (tables 1, 6).

In 1987, IOCHEM Corp. began producing iodine by the blowing-out process at a plant 1.2 kilometers (km) east of Vici, Dewey County, OK. IOCHEM was a privately held joint venture between Tomen America Inc. and a private family. The majority of production was shipped to Schering AG, Germany under a long-term contract. IOCHEM reported having nine production wells and four injection wells with a total production capacity of 1,400 metric tons per year (t/yr) at Vici.

North American Brine Chemicals, owned by Beard Oil Co. (40%), Godoe. (USA) Inc. (50%) and Mitsui and Co.(USA), Inc. (10%), began operating a miniplant at Dover in Kingfisher County, OK, in 1983. The company operated two plants, one of which was at an oilfield injection-disposal site that obtained brines from about 50 wells in the Oswego Formation. Iodine concentrations were as much as 1,200 parts per million. The company also operates a major plant that opened in 1991 at Woodward, OK.

Woodward Iodine Corp., which began production in 1977, was purchased by Asahi Glass Co., Japan, in 1984 and sold to Ise Chemical Industries Co. Ltd., Japan, in 1994. Woodward's plant in Woodward County, OK, produced iodine from 22 brine production wells, which used the blowing-out process, and injected waste through 10 injection wells. Mica Specialty Chemicals, a subsidiary of Mitsubishi International Corp., was the exclusive distributor for Woodward iodine. Mica also distributed iodine for Ise in the United States (Mirasol, 1998).

Consumption

Estimated end uses by percentage for iodine in 1996 were estimated from a USGS survey canvass of consumers as follows: sanitation (39%); pharmaceutical (24%); heat stabilizers (13%); catalyst (9%); animal feed (7%); and other (8%). Other smaller uses included inks and colorants, photographic chemicals, laboratory reagents, production of batteries, high-purity metals, motor fuels, and lubricants (table 2).

Commercial crude iodine normally has a minimum purity of 99.5%. Impurities are chiefly water, sulfuric acid, iron, and insoluble materials. The U.S. Pharmacopoeia XVII specifies an iodine content of not less than 99.8%. The Committee on Analytical Reagents of the American Chemical Society allows a maximum of 0.005% total bromine and chlorine and 0.010% nonvolatile.

The World Health Organization (WHO) estimated that about 2 billion people are at risk for iron, iodine, and vitamin A deficiencies. Ending micronutrient malnutrition has been the most achievable international health goal of the decade. Iodine deficiency is the world's leading cause of physical and mental defects in the form of severe retardation, deaf-mutism, cretinism, and partial paralysis, as well as more-subtle problems, such as clumsiness, lethargy, and reduced learning capacity. Iodine is an essential part of a thyroid hormone that contributes to fetal brain development and metabolism after birth; a lack of iodine in the diet can cause goiters, a thyroid disorder.

A worldwide effort was underway in 130 countries to eliminate iodine-deficiency disorders of an estimated 740 million people by fortifying the world's salt supply. Universal salt iodization for eliminating iodine deficiency disorder (IDD) has been endorsed by the WHO. Table salt in the United States has been fortified with potassium iodide since 1924, when Michigan required it in all table salt. In 1974, the Food and Drug Administration conducted the Total Diet Study. In 1980, the National Academy of Sciences recommended 0.15 milligram per day of iodine for adults. WHO issued a statement that summarized the cumulative scientific and epidemiological evidence as follows: the WHO specified that a safe daily intake of iodine for adults should be between 50 micrograms and 1,000 micrograms; a generally accepted desirable intake for adults is from 100 to 300 micrograms per day. Although potassium iodine was first used in salt iodization, the use of iodate is now recommended because it is more stable than iodide under varying climatic conditions. Average daily salt intakes range from 5 to 15 grams per day depending on the country. Instead of increasing salt consumption, the quantities of iodate added to salt should be adjusted to provide approximately 150 micrograms per day of iodine. Sea fish, other sea food, and seaweed are rich in iodine (World Health Organization, accessed August 10, 1998 at URL http://www.who.int/inf-pr-1999/en/pr99-wha17.html).

In remote areas, iodine has sometimes been used instead of chlorine to purify drinking water. This can add 1,000 to 2,000 micrograms to the daily iodine intake of the people who drink this water.

Arizona Chemical Co., a wholly owned subsidiary of International Paper, and one of two producers in the polyterpene resin field that uses iodine to stabilize crude tall oil (CTO), completed a major debottlenecking of its plant in Pensacola, FL. The company was also developing a new line of terpene resins. The expansion and other improvements will increase capacity of terpene resins by 25% per year. Demand for terpene phenol resins in the adhesives industry has been outpacing growth in production. Terpene phenol resins were used in packaging and book binding adhesive applications, as well as in certain inks and coatings applications and in the emerging polymer additives market (Floreno, 1998).

International Paper agreed to buy Union Camp Corp., another producer of CTO, for $6.6 million. During 1998, CTO prices decreased as the market remained oversupplied by the strong pulp and paper market and Asia's financial troubles continued to weaken demand for CTO's end products. Derivatives of CTO are used to make tall oil fatty acid and tall-oil-rosins used in the production of resins, adhesives, and coatings. Specific crude oil prices depended on grade, freight, and volume (Papanikolaw, 1998).

The other large producer of tall-oil-rosins-based resins and terpene chemicals, Hercules Incorporated, expanded its paper chemical business with the acquisition of Houghton International (Reisch, 1999).

Celanese A.G., the chemicals arm of Germany's Hoechst A.G., and BP Chemicals, which acquired Monsanto Co.'s carbonylation process for making acetic acid, accounted for nearly half of the world's acetic acid production using iodine in the process. Acetic acid licenses granted by Monsanto have begun to expire. As the license expires, the plants must convert to a new process or close. The future of acetic acid is projected to be big plants based on cheap gas. Eastman Chemical Co. decided to market its acetic acid through Celanese. Smaller producers also have to prepare for a period of low prices, with Celanese and BP each bringing a massive plant on-stream (Layman, 1998a).

The two largest U.S. producers of nylon 6,6, which is stabilized with iodine, were increasing integration with key petrochemical intermediates. E.I. du Pont de Nemours and Co. announced plans to expand North American capacity for adipic acid, one of two key intermediates for nylon 6,6, and continued with a project in China that will make hexamethlenediamine (HAD), the other main nylon 6,6 precursor. Solutia, Inc., the former chemical arm of Monsanto, had two projects that will further integrate production of adipic acid and HAD. Solutia's capacity was estimated to be more than 300,000 t/yr. A 135,000-t/yr plant in Pensacola, FL, will produce phenol, which is used in adipic acid production. Solutia's other large project was a 230,000-t/yr acrylonitrile plant in Chocolate Bayou, TX, that was backed by Bayer, Novus Financial, and Asahi (McCoy, 1998). As nylon production increases, the demand for iodine will increase.

Dow Chemical Co. signed an agreement to market nylon 6,6 resins made by Solutia, and will assume commercial and marketing control of the products. Dow will focus on injection molding, including automotive, telecommunications, appliances, and electrical and electronic materials. Solutia will still market nylon for nonthermoplastic applications, such as carpeting and textiles, and thermoplastic uses, such as film and monofilament. Solutia was considering two additional polymerization expansions of about 27 million kg (60 million pounds) in 1999 and 2001 (Tullo, 1998).

Prices

Prices for iodine are negotiated on long- and short-term contracts. The average declared c.i.f. value for imported crude iodine was $16.45 per kilogram. The average declared c.i.f. value for iodine imported from Chile was $16.30 per kilogram. The average declared c.i.f. value for imported crude iodine from Japan was $16.96 per kilogram. The average sale price of iodine sold from the DNSC was $18.56 per kilogram. Quoted yearend U.S. prices for iodine and its primary compounds are listed in table 3.

Since 1977, when the first United States plant in Oklahoma was built, iodine c.i.f. prices per kilogram have been as follows: 1977, $4.39; 1978, $4.72, 1979, $6.57; 1980, $13.80; 1981, $13.12; 1982; $12.92; 1983; $12.06; 1984, $10.58; 1985, $11.86; 1986, $12.52; 1987, $15.26; 1988, $17.46; 1989, $17.67; 1990, $15.19; 1991, $10.16; 1992, $9.03; 1993, $7.90; 1994, $7.56; 1995, $9.88; 1996. $12.90; and, 1997 $14.66. At the same time U.S. capacity increased to 1.4 Mkg (3 million pounds), and world production to 21 Mkg in 1998 from 9 Mkg in 1977.

Foreign Trade

The General Agreement on Tariffs and Trade (GATT) was signed into law in December 1994 and took effect on January 1, 1995. GATT lowered chemical tariffs by an average of 30%. Chemicals, including iodine, were the Nation's largest export commodities, as more than 10 cents of every export dollar was a product of the chemical industry. The intellectual property provisions include greater patent protection for products developed by American firms. GATT changed patent enforcement from 17 years from the date of issue to 20 years from the date of application. Patents issued on applications filed before June 8, 1995, will be enforceable for either 17 years from the issue date or 20 years from the filing date, whichever is longer.

The U.S. Government adopted the Harmonized Commodity Description and Coding System as the basis for its export and import tariff and statistical classification systems. The system is intended for multinational use as a basis for classifying commodities in international trade for tariff, statistical, and transportation purposes. It includes resublimed and crude iodine under the same code and a free duty rate. Values that differ significantly could be a result of items being placed in the wrong category (tables 4 and 5).

The ministers of the World Trade Organization met in December and approved the permanent establishment of the Committee on Trade and the Environment (CTE). The U.S. chemical industry, which imports more than 50% of iodine consumed, will be an active participant because of the major environmental issues affecting trade that it would like to see resolved. As a major representative of the U.S. chemical industry, the Chemical Manufacturers Association (CMA), finds ecolabeling to be one area on which it and its European counterparts cannot agree. Ecolabels, which list specific environmental standards on packaging, recycling, and even production processes, must be prominently displayed before the product can be imported into Europe. In a policy paper, CMA stated, "The proliferation of different types of environmental labeling systems...contributes to the creation of nontariff barriers." Problems arise when countries try to use trade measures unilaterally to achieve environmental goals. The issue of flexibility in achieving international environmental objectives will continue at future CTE meetings (Hanson, 1997).

The U.S. Department of Commerce (DOC) revised crude iodine export data going into Mexico during 1997. Exporters were listing cattle dip as crude iodine. The revisions affected iodine in El Paso, Houston, and Lariat, TX, and Nogales, AZ (B.J. Boney, U.S. Department of Commerce, written commun., April 27, 1998).

The increased importation of medicinal and pharmaceutical products was a factor in the decline of the domestic pharmaceutical industry. More than 50% of the iodine consumed in the United States was imported, and many of the iodine compounds are used in the medical and pharmaceutical industries. According to the most recent data from the DOC, U.S. imports of medicinals for the first 4 months of 1998 climbed 23% compared with those of 1997. The biggest surprise in 1997 was Germany, whose exports surged 115% to $1.7 billion, overtaking the United Kingdom as the leading exporter of medicinals to the United States. During 1998 German exports to the United States increased 95% over the same period in 1997 (Rogers, 1998).

World Review

Argentina.—The Resin unit of Akzo Nobel nv, Arnhem, the Netherlands, and Ascona Resins of Argentina signed a letter of intent to form an alliance that will likely lead to Akzo Nobel's acquisition of Ascona's production of resins and gum rosins for printing inks. Color printing inks are made primarily with oil or petroleum distillate combined with organic pigments. Iodine is used as a stabilizer for tall-oil rosins used to produce some ink resins. The partnership will increase Akzo Nobel's resin market to around 25% for offset printing resins in the United States (Chemical Market Reporter, 1998).

Chile.—Chile was the leading producer of iodine (table 6), and new projects continued to be announced to increase production. Atacama Minerals Corp., formerly Boron Chemical International Ltd., Vancouver, Canada, received approval from the Chilean State Foreign Investment Committee for a $55 million investment by its Chilean subsidiary, Minera Teslin. The State approval was for the development of the Aguas Blancas Project in Region II, northern Chile (Industrial Minerals, 1998e), and $13 million for infrastructure. The cost for the project was estimated to be slightly more than $100 million (Fertilizer Markets, 1998). The caliche ore body is 95 km southeast of the port of Antofagasta. By using a cut-off of 200 parts per million iodine, the proven and probable reserves are 29.5 metric tons (Mt); most of the caliche averages 683 parts per million iodine. The ore is shallow, and mining depth will reach a maximum of 7 meters (m). Overburden is less than 1 m (Cogliandro, 1997). Processing of the ore involves crushing, leaching with freshwater, thickening, filtration, and iodine precipitation. The direct capital costs were expected to be $74.6 million. A test of mining machines produced 46,000 metric tons (t) of ore that was stockpiled at the plant site. The breakdown in million U.S. dollars is: process facility 59.3; mining, 6.8; water infrastructure, 6.1; and roads, 2.4 (North American Minerals News, 1998). The company planned to build a chemical manufacturing plant to produce 1,000 t/yr of iodine, 300,000 t/yr of sodium sulfate, and 70,000 t/yr of potassium nitrate (Industrial Minerals, 1998d). Atacama reported a multiyear agreement with Gas Atacama SA, a consortium of CMS Energy Corp. and Endesa SA, to provide the power required by the mine and plant. Production of iodine and sodium sulfate was expected in 1999, and potassium sulfate, in 2006 (Fertilizer Markets, 1998b).

Compania de Salitre Y Yodo de Chile (Cosayach), part of Inverraz S.A., mined iodine and nitrates from caliche reserves in Region I and II. Reserves consist of more than 90,000 hectares, which correlates to 300,000 t of iodine and 50 Mt of sodium nitrate. The Cala-Cala plant, begun in 1991, has a capacity of 648-t/yr. The Negreiros plant, begun in 1995, has a capacity of 1,080-t/yr. The Soledad plant, has a capacity of 1,080-t/yr. Total capacity in 1996 was 2,808-t/yr. The processing uses bulldozers to load the ore onto trucks that transport it to a leaching area where the ore is deposited 4 to 4.5 m high on a base of polyvinylchloride waterproof liner. A sprinkling system provides water to dissolve the salts found in the ore. The solutions are captured and sent to the iodine plant for recovery where the iodide is reduced with sulfur dioxide to iodine. The precipitate is refined and then washed to produce 99.7% pure iodine. The solution is concentrated by a two-stage crystallizer and solar evaporation to achieve a nitrate-rich solution, which produces sodium or potassium nitrate. The design capacity is 200,000 t/yr of nitrates. Nitrate production was expected to reach more than 400,000 t by the end of 1999 (Sarah Hall, Tamaya Chemical Corp., written commun., 1997).

KAP Resources Ltd., Vancouver, Canada, announced that its Chilean subsidiary, Cia Minera Yolanda SA, operated its plant in the Tarapaca region of northern Chile. Members of Canpotex, the export consortium for Saskatchewan producers, have purchased equity in the project and have agreed to supply Minera Yolanda with its potash requirements. Potash Corp. of Saskatchewan Sales Inc. had the exclusive rights to market and sell Minera Yolanda's potassium (Parson, 1998). Caliche ore production has increased to 160,253 metric tons per month (t/mo) (Industrial Minerals, 1998c). Minera Yolanda's production of iodine totaled 4,000 kg during 1997. Revised production levels for 1998 were set at 250,000 kg of iodine (Industrial Minerals, 1997, 1998a). Plans called for the production of 25 t/mo of iodine with an annual capacity of 300 t (Green Markets, 1998).

Sociedad Quimica y Minera de Chile (SQM), has mining rights to the world's largest known deposits of nitrates and iodine in caliche. Once known as white gold, caliche is surface deposits of soluble salts precipitated by evaporation. SQM restructured its group of subsidiary companies. The managing company, SQM Holdings, will control four businesses. SQM Chemicals will control the lithium operation and iodine output (Industrial Minerals, 1998b). Caliche-based operations were Pedro de Valdivia (379 parts per million), Maria Elena (392 parts per million), and Sierra Gorda (529 parts per million). After blasting to break the caliche, the caliche ore mined at Valdivia and Elena was transported 17 and 25 km, respectively, to the processing operation. The ore was crushed to approximately 1 centimeter (½ inch) and transferred to leaching vats for removal of the water-soluble minerals. At Sierra Gorda, mine tailings were heap leached with water to obtain iodine solutions. The size of the mine tailings material (a proprietary number) was related to the recovery of iodine. Production at the satellite plants produced about 1,000 t/yr of crude iodine. One satellite plant, owned by Cimin, a subsidiary of SQM Iodo, a subsidiary of SQM, was located about 100 km from the main mines. In August, Cimin's Pinto plant came online at 1,000 t/yr and complements a 500-t/yr unit.

Germany.—Hoechst A.G. announced the spin-off of its chemicals operations into an independent company called Celanese A.G. Shareholder approval was to be sought at a special January 22, 1998 meeting (Layman, 1998b).

Hoechst used a specific ion-exchange resin to remove iodide contaminants introduced during the processing from acetic acid, a process BP Chemicals, a wholly owned subsidiary of The British Petroleum Company p.l.c., formerly used. Hoechst successfully defended an appeal by BP in the Court of Appeals in London to overturn a patent infringement decision of February 1997 (Chemical & Engineering News, 1998a).

International Speciality Products (ISP), a producer of pyrrolidone-based polymers (PVP), acquired Huls's 50% interest in the GAF-Huls Chemie joint venture in Marl, Germany. The venture makes butane-diol, which is the main raw material for ISP's solvents and PVP polymers (Chemical & Engineering News, 1998b).

Japan.—Japan was the world's second largest producer of iodine (table 6). During 1998, the First Forum on Iodine Utilization was held in Chiba Prefecture. Papers were presented on a wide range of topics–organic reaction, x-ray spectroscopies, basic physical chemistry, synthetic uses of hypervalent iodine compounds, geochemical research, dissolved water types of deposits, role of iodine in photographic materials, stabilization effect of iodine, development of iodine lasers, reactions between polyvinyl alcohol and iodine, and, antimicrobial effects of iodine (Yokoyama, 1998).

Turkmenistan.—The Nebitdag plant was located in Vyshka, 26 km southwest of Nebitdag City in Balkan velayat. The source of bromine and iodine was underground brines of the Nebitdag-Monjoukley deposit. The plant reported production capacities of 255 t/yr of iodine and 3,200 t/yr of ferrous bromide, as well as 1,300 t/yr of bromine derivatives and 100 t/yr of sodium hypochlorite. It was commissioned in 1969 and had 33 employees.

The Cheleken plant was located 10 km north in Cheleken City in Balkan velayat. The source of iodine and bromine was underground brines of the Cheleken deposit. The plant's reported production capacities were 335 t/yr of iodine and 6,400 t/yr of ferrous bromide. In addition, the plant produced 60 t/yr of potassium iodide, 45 t/yr of potassium iodate, 60 t/yr of other derivatives, and 100 t/yr of sodium hypochlorite. The plant was commissioned in 1932 and has 548 employees (Saparmurat Noureyer, 1996) (table 6).

United Kingdom.—Hoechst Celanese Corp. filed claims against BP Chemicals for using its process to remove iodide contamination during the production of acetic acid. BP appealed the High Court decision, a process that could take a year. If BP is found guilty, then another hearing will be held to determine damage awards or whether BP has to pay the profits made from using the technology (European Chemical News, 1997).

Current Research and Technology

International Isotopes Inc. (I^3), Denton, TX, planned to produce ^{123}I (half-life, 13 hours, used in brain, thyroid, and renal imaging), ^{125}I (half life, 59.4 days, used in cancer therapeutic, brain, blood, metabolic function diagnostic), and ^{131}I (half-life 8 days, used in brain, pulmonary, thyroid diagnostic). I^3 will run the linear accelerator (LINAC) that was to have been the injector stage of the $11 billion Superconducting Super Collider. The firm intended to use its LINAC to become the first commercial U.S. producer to offer a full range of radioisotopes, radiopharmaceuticals, and medical imaging instruments (Thayer, 1998).

Recent research published in the Geographical Reviews, suggested that the Neanderthal could be a species of modern human who suffered from chronic iodine deficiency and cretinism. This suggestion was based on large heads, ridged eyebrows, heavy muscles, and the thick, curved bones that are common characteristics of the Neanderthal. The map of sites where Neanderthal remains have been found corresponds fairly closely to a pattern of cretinism common in the “goiter belts” of Alpine and Central Europe until well into the 20th century, when iodized salt was introduced (Gugliotta, 1999).

Outlook

During the past decade, iodine production capacity in the United States and Chile has doubled, thus ensuring an adequate future world supply. Overall growth in traditional uses is projected to grow by as much as 2% per year. Uses for iodine in specialty chemicals have remained stable.

Recent developments in digital imaging can produce electronic prints and overhead transparencies without the need for wet processing. By using a digital camera or scanning the film and converting to digital, the images are produced and stored on hard drives, disks, tape. Digital imaging is used for recording most sporting events, game shows, and some situation comedies for television broadcast. From 75% to 85% of all televised programs seen during prime time are recorded on 35-millimeter (mm) motion picture film and then transferred to video tape or laser disc for display. Furthermore, the majority of feature films for movie theater presentations are shot and printed on film because of better image quality. A frame of 35-mm color negative film contains about 6.6 million pixels, or about 15 times that of the best high-definition television system and 4 times that of the digital systems now in development. Most popular home video rentals have been box office movie hits which were filmed and then transferred to video. In the next decade, future uses of iodine in films and processing could be limited to specialty imaging as digital imagery technology improves and the cost of acquisition of equipment becomes more affordable.

New uses of fluoroiodocarbon as halogen replacements may cause an increased demand for iodine. More tests need to be completed on the iodated fluorocarbons before they are acceptable, but preliminary tests are promising. Supplemental programs designed to alleviate IDD in China and India are consuming large amounts of iodine. X-ray contrast media, containing up to 60% iodine, will continue to have annual growth of between 4% and 5%. In Chile and Mexico, individual water purification units that use iodine are a new application. Purification applications could become significant consumers of iodine (Chemical Market Reporter, 1997).

Automotive International reports that the director of engineering material at Du Pont Automotive foresees a 72% increase in the use of nylon during the next 8 years. This would result in about 7 kg of nylon in the average car in the United States by 2005. Air intake manifolds provide the greatest growth area, although nylon is also making inroads into other components, such as cylinder-head covers.

References Cited

Chemical & Engineering News, 1998a, Business concentrates—Hoechst, BP to work out patent suit damages: Chemical & Engineering News, v. 76, no. 27, July 6, p. 10.

———1998b, Business concentrates—ISP buys out Huls in German venture: Chemical & Engineering News, v. 76, no. 27, July 6, p. 10.

Chemical Market Reporter, 1997, Iodine pricing stays up high despite new capacity additions: Chemical Market Reporter, v. 251, no. 12, March 24, p. 15-16.

———1998, Akzo buys gum rosins: Chemical Market Reporter, v. 254, no. 20, November 9, p. 5.

Coligandro, Robert, 1997, The Aguas Blancas project—A new source of iodine, sodium sulphate & nitrates in Chile: North American Industrial Minerals Annual Meeting, 2d, Cancun, Mexico, December 3-4, 1997, p. 5.

European Chemical News, 1997, Reports jump the gun, says BP: European Chemical News, v. 67, no. 1754, p. 4.

Fertilizer Markets, 1998, Elsewhere this week—Atacama Minerals Corp.: Fertilizer Markets, v. 9, no. 2, August 3, p. 4.

Floreno, Anthony, 1998, Arizona Chemical refocuses on terpene phenolic resins: Chemical Market Reporter, v. 253, no. 16, April 20, p. 15.

Green Markets, 1998, KAP reports successful start-up: Green Markets, v. 22, no. 34, August 24, p. 10.

Gugliotta, Guy, 1999, The Neanderthal—A modern man with disease?: Washington Post, May 24, p. A9.

Hanson, David, 1997, Global trade panel fails to resolve environmental issues: Chemical & Engineering News, v. 75, no. 4, January 27, p. 23.

Industrial Minerals, 1997, Minera Yolanda project update: Industrial Minerals, no. 358, July, p. 10-11.

———1998a, Yolanda I/NO_3 project on-stream: Industrial Minerals, no. 364, January, p. 9-10.

———1998b, World of minerals—Chile—SQM plans to invest $600 million into business: Industrial Minerals, no. 367, April, p. 24.

———1998c Chile—Yolanda nitrates operating successfully: Industrial Minerals, no. 373, October, p. 11.

———1998d, Company news—Positive results for Aquas Blancas: Industrial Minerals, no. 373, October, p. 109.

———1998e, Fillers and extenders—Aquas Blancas gets I/NO_3 go ahead: Industrial Minerals, no. 374, November, p. 14.

Layman Patricia, 1998a, Acetic acid industry gears up for possible building boom: Chemical & Engineering News, v. 76, no. 31, August 3, p. 17-18.

———1998b, Celanese—The once and future company: Chemical & Engineering News, v. 76, no. 47, November 23, p. 9-10.

McCoy, Michael, 1998, Nylon feeds get new attention: Chemical & Engineering News, v. 76, no. 15, April 13, p. 34.

Mirasol, Feliza, 1998, Strong iodine market gives Chileans an edge: Chemical Market Reporter, v. 253, no. 22, June 1, p. 4 and 14.

North American Minerals News, 1998, Latin American focus—Forget eastern promise—Look south!: North American Minerals News, no. 23, April, p. 9.

Parson, Karine, 1998, Potash producers: Industrial Minerals, no. 367, April, p. 54.

Papanikolaw, Jim, 1998, Inventories hurt tall oil, Asian crisis slows demand: Chemical Market Reporter, v. 254, no. 3, July 20, p. 11.

Reisch, M.S., 1999, A modern-day Hercules bulks up: Chemical & Engineering News, v. 77, no. 14, April 5, p. 13-15.

Rogers, Ronald, 1998, Medicinal imports climbing sharply: Chemical and Engineering News, v. 76, no. 31, August 3, p. 18-19.
Saparmurat Noureyev, H.E., 1996, The solid raw mineral resources of Turkmenistan. Paper in Proceedings of Mining Investment and Business Opportunities in Central Asia and the Balkan and Caucasus Counties. Montreal, Canada, p. 31.
Thayer, A.M., 1998, International isotopes: Chemical & Engineering News, v. 76, no. 38, September 21, p. 27-28.
Tullo, Alex, 1998, Dow, Solutia set worldwide link for nylon 6,6: Chemical Market Reporter, v. 254, no. 13, September 28, p. 1 and 16.
Yokoyama, Masataka, 1998, Proceedings of First Symposium on iodine utilization, Chiba, October 16, 1998,: Chiba, Japan, Kanto Natural Gas Development Co., 67 p.

SOURCES OF INFORMATION

U.S. Geological Survey Publications

Iodine. Ch. in Mineral Commodity Summaries, annual.[1]
Iodine. Ch. in Minerals Yearbook, annual.[1]
Iodine. Ch. in United States mineral resources, U.S. Geological Survey Professional Paper 820, 1973.

Other

Iodine. Ch. in Mineral Facts and Problems. U.S. Bureau of Mines Bulletin 675, 1985.

[1]Prior to January 1996, published by the U.S. Bureau of Mines.

TABLE 1
SALIENT IODINE STATISTICS 1/

(Thousand kilograms unless otherwise specified)

	1994	1995	1996	1997	1998
United States:					
Production	1,630	1,220	1,270	1,320	1,490
Imports for domestic consumption 2/ 3/	4,360	3,950	4,860	6,380	5,960
Exports 2/ 3/	1,200	1,220	2,410	2,760	2,790
Consumption:					
Reported 4/	3,690	3,680	3,920	4,500	4,100
Apparent 5/	4,780	3,540	3,700	5,140	4,950
Price, imports, average c.i.f. value, 6/ dollars per kilogram	$8.02	$10.32	$12.82	$14.74	$16.54
World: Production	14,300	13,400	14,200 r/	15,800 r/	21,300 e/

e/ Estimated. r/ Revised.
1/ Data are rounded to three significant digits, except prices.
2/ Bureau of the Census.
3/ Only the crude iodine "content" of the potassium iodide as declared by tables 4 and 5 is incorporated in data or calculations for this table.
4/ Reported by voluntary response to the U.S. Geological Survey from a survey of domestic establishments.
5/ Calculated by using domestic production plus imports minus exports plus adjustments for Government and domestic industry stock changes.
6/ Bureau of the Census.

TABLE 2
DOMESTIC CONSUMPTION OF CRUDE IODINE, BY PRODUCT 1/

(Thousand kilograms)

Product	1997 Number of plants	1997 Quantity	1998 Number of plants	1998 Quantity
Inorganic compounds:				
Resublimed iodine	8	197	10	241
Potassium iodide	5	750	7	673
Sodium iodide	5	392	6	418
Ammonium iodide	1	W	2	W
Calcium iodate	2	W	2	W
Cuprous iodide	2	W	2	W
Hydriodic acid	3	248	3	160
Potassium iodate	4	115	4	77
Other inorganic compounds	5	530	5	265
Total	XX 2/	2,230	XX 2/	1,840
Organic compounds:				
Ethylenediamine dihydroiodide	2	W	3	817
Methyl and/or ethyl iodide	3	40	2	W
Povidone-iodine (idophors)	3	686	3	681
Other organic compounds	6	1,540	6	770
Total	XX 2/	2,270	XX 2/	2,270
Grand total:				
Reported consumption 3/	XX 2/	4,500	XX 2/	4,100
Apparent consumption 4/	XX	5,140	XX	4,950

W Withheld to avoid disclosing company proprietary data; included with "Other inorganic/organic compounds," respectively. XX Not applicable.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Nonadditive because some plants produce more than one product concurrently.
3/ Reported by voluntary response to the U.S. Geological Survey in a survey of domestic establishments.
4/ Calculated by using domestic production plus imports minus exports plus adjustments for Government and domestic industry stock changes.

TABLE 3
YEAREND 1998 PRICES OF ELEMENTAL IODINE AND SELECTED COMPOUNDS

(Dollars)

Elemental iodine/compounds	Value	
	Per kilogram 1/	Per pound 1/
Calcium iodate, FCC drums, f.o.b. works	16.42	7.45
Calcium iodide, 50-kilogram drums, f.o.b. works	30.00	13.61
Iodine, crude, drums	19.00-20.00	8.62-9.07
Potassium iodide, U.S.P., drums, 5,000-pound lots, delivered	26.48	12.01
Sodium iodide, U.S.P., crystals, 5,000-pound lots, drums, freight-equalized	36.38	16.50

1/ Conditions of final preparation, transportation, quantities, and qualities not stated are subject to negotiations and/or somewhat different price quotations.

Source: Chemical Market Reporter. Current Prices of Chemicals and Related Materials; v. 255, no. 1, January 4, 1999, p. 30-37.

TABLE 4
U.S. CRUDE IODINE AND POTASSIUM IODIDE IMPORTS FOR
DOMESTIC CONSUMPTION, BY COUNTRY OF ORIGIN 1/

(Thousand kilograms and thousand dollars)

Material type and country of origin 2/	1997		1998	
	Quantity	Value 3/	Quantity	Value 3/
Iodine, crude:				
Canada	6	72	4	27
Cayman Islands	--	--	70	947
Chile	4,000	57,100	3,800	61,900
China	--	--	13	120
Germany	2	46	7	83
Japan	2,020	31,200	1,740	29,500
Russia	--	--	29	546
Other 4/	(5/)	(5/)	(5/)	16
Total	6,030	88,400	5,660	93,100
Iodide, potassium: 6/				
Canada	310	4,990	288	5,200
Chile	24	409	8	162
Japan	2	18	1	19
Other 7/	16	276	4	91
Total	352	5,690	301	5,470
Grand total	6,380	94,100	5,960	98,600

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Import information for crude iodine and potassium iodide are reported by HTS numbers 2801.20.0000 and 2827.60.2000, respectively.
3/ Declared c.i.f. valuation.
4/ Includes Belgium (1997), India (1998), the Netherlands (1998), and the United Kingdom (1998).
5/ Less than 1/2 unit.
6/ Gross potassium iodide contains 76% crude iodine.
7/ Includes Brazil (1998), Germany, Israel (1997), and the Netherlands.

Source: Bureau of the Census.

TABLE 5
U.S. EXPORTS OF CRUDE IODINE AND POTASSIUM IODIDE,
BY COUNTRY OF DESTINATION 1/

(Thousand kilograms and thousand dollars)

Material type and country of origin 2/	1997 Quantity	1997 Value 3/	1998 Quantity	1998 Value 3/
Iodine, crude/resublimed:				
Canada	89	1,560	19	385
Egypt	2	40	3	60
France	65	1,190	33	688
Germany	480	7,090	520	8,470
India	19	350	38	796
Israel	2	31	1	9
Mexico	1,820	10,100	1,900	11,100
Netherlands	3	15	--	--
Turkey	9	114	2	29
United Kingdom	17	310	63	1,040
Other 4/	126	1,980	138	23,700
Total	2,630	22,800	2,720	24,900
Iodide, potassium: 5/				
Australia	--	--	(6/)	11
Belgium	7	67	--	--
Canada	64	1,290	--	--
Mexico	12	171	8	132
Netherlands	3	54	--	--
Thailand	(6/)	12	(6/)	3
Turkey	21	381	11	219
Other 7/	29	520	50	875
Total	136	2,500	69	1,240
Grand total	2,760	25,300	2,790	26,100

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Export information for "Iodine, crude/resublimed" and "potassium iodide" are reported by HTS numbers "2801.20.0000" and "2827.60.2000," respectively.
3/ Declared "Free alongside ship" (f.a.s.) valuation.
4/ Includes Australia, Belgium (1998), Brazil (1998), Chile (1998), China (1997), the Czech Republic (1998), the Dominican Republic (1998), Denmark, Ecuador (1997), El Salvador (1997), Finland, Hong Kong (1997), Indonesia (1997), Ireland (1998), Japan, the Republic of Korea (1998), Lebanon (1997), Peru (1998), the Philippines (1998), Portugal (1997), Romania (1998), Spain, and Venezuela.
5/ Gross potassium iodide contains 76% crude iodine.
6/ Less than 1/2 unit.
7/ Includes Argentina (1998), France (1998), Guatemala (1998), Indonesia (1997), Jamaica, Malaysia (1997), Peru (1997), the Philippines, Singapore (1998), Switzerland, Taiwan, the United Kingdom, Venezuela (1997), and Vietnam (1998).

Source: Bureau of the Census.

TABLE 6
CRUDE IODINE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand kilograms)

Country	1994	1995	1996	1997	1998 e/
Azerbaijan e/	400	350	300	300	300
Chile 3/	5,644	5,444	5,514 r/	7,154 r/	12,618 4/
China e/	500	500	500	500	500
Indonesia e/	89 4/	77 4/	75	73	70
Japan	5,592	5,492	6,178	6,036 r/	6,000
Russia e/	160	160	150	150	120
Turkmenistan e/	251	137 4/	255	250	250
United States	1,630	1,220	1,270	1,320	1,490 4/
Total	14,300	13,400	14,200 r/	15,800 r/	21,300

e/ Estimated. r/ Revised.
1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.
2/ Table includes data available through June 10, 1999.
3/ Includes iodine production reported by Servicio Nacional de Geologia y Minería (SERNAGEOMIN).
4/ Reported figure.