IODINE

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Three producers of crude iodine supplied about 36% of domestic demand (table 1). Domestic and imported iodine was consumed in intermediate products prior to being sold to consumers (table 2). Iodine and derivatives find principal uses in pharmaceutical and medical applications, sanitation or disinfectants, animal feed, catalysts, inks, colorants, photographic equipment, and stabilizers. Published prices for crude iodine remained the same (table 3). Consumption of crude imports of crude iodine and potassium iodide decreased (table 4). The primary end use was in potassium iodide, which remained very close to 1998 consumption, and sodium iodide, which decreased 11%. Exports of iodine and potassium iodide decreased significantly during 1999 (table 5). Because some exports and imports are in product categories rather than crude products, net imports are not clearly distinguished. Chile produced iodine as a coproduct of sodium nitrate. Japan produced iodine from brines associated with natural gas production (table 6).

Legislation and Government Programs

The Annual Materials Plan (AMP) of the U.S. Department of Defense proposed the sale of iodine for fiscal year 1999 (October 1, 1999, through September 30, 1999). The National Defense Authorization Act for Fiscal Year 1999 (Public Law 106-79), signed on May 21, 1999, transfers $150 million from the Defense National Stockpile Center (DNSC) Transaction Fund equally to the operation and maintenance accounts of the Army, Navy, and Air Force. The National Defense Authorization Act for Fiscal Year 2000 (Public Law 106-65) signed on October 5, 1999, required the sale of authorized commodities that would result in receipts of $10 million by the end of fiscal year 2000; $100 million during the fiscal year period ending September 30, 2004; and $300 million during the fiscal year period ending September 30, 2009. The revised AMP for 1999 and 2000 included the sale of 453,593 kilograms (kg) (1,000,000 pounds) of crude iodine. On July 23, 1999, the DNSC issued an Amendment No. 001 to Solicitation of Offers for DLA-Iodine-003 that changed the time for receipt offers from 2:00 p.m. to 4:00 p.m. (local time). On October 29, Amendment No. 002 to the Solicitation changed the sale of the 453,593 kg to quarterly sales of 113,398 kg (250,000 pounds) and set subsequent offering dates for 1999 and 2000. On March 3, 1999, the DNSC announced the award of 90,000 pounds at a value of $700,000 ($17.15 per kilogram, or $7.78 per pound). On June 10, 1999, the DNSC announced the sale of 77,000 pounds at a value of $540,000 ($15.46 per kilogram, or $7.01 per pound). On September 1, 1999, DNSC announced the sale of 5,000 pounds at a value of $35,000 ($15.43 kilogram, or $7.00 per pound). At yearend, the excess iodine was 1.8 million kilograms (Mkg) valued at $25 million (3.9 million pounds, $14.11 per kilogram, or $6.40 per pound).

The transport of illegal drugs, some of which were made with iodine, across U.S. borders is of utmost concern to the U.S. Government. The Attorney General at the U.S. Department of Justice appointed a chief science and technology advisor who reports directly to the Attorney General, but also will advise other senior department official. The advisor is now working on communications technology among the various components of Justice. The Federal Bureau of Investigation, the Immigration & Naturalization Service, the Drug Enforcement Administration, and U.S. Marshals are moving to narrowband, digital, wireless communications to insure "interoperability" between the Department's components and between the Department and State and local law enforcement agencies. Other problems the advisor will be involved with are the control of the flow of drugs across the 2,000-mile U.S. border with Mexico now patrolled by 7,300 border control officers (Ember, 1999).

In 1906, the Food and Drug Act was passed to ensure the safety and effectiveness of drugs and to set standards for which drugs can be sold over the counter and which ones require a prescription. During 1997 and 1998, online pharmacies were selling drugs to consumers without a valid prescription. Iodine and many of the products made from iodine are controlled substances. To protect consumers from illegal sales of drugs over the Internet, the White House unveiled an initiative in December that would require all online pharmacies to demonstrate that they comply with State and Federal laws and are licensed by the Food and Drug Administration (FDA). The maximum civil penalty would be raised from $1,000 to $500,000. The proposal would give the FDA subpoena power to investigate online pharmacies, and provide $10 million to set up a rapid-response team to go after illicit drugs (Hileman, 2000).

In Pennsylvania 19 years ago, the release of radioactive iodine occurred at Three Mile Island (TMI) Unit 2 during a near meltdown of the reactor's core. The Kemeny Commission, which was appointed by President Carter to investigate the TMI accident, urged communities around nuclear plants to stockpile nonradioactive iodine pills (potassium iodide) to be taken in the event of a radiation leak. However, it was not until 1998 that the Nuclear Regulatory Commission (NRC) reversed its position and recommended States and communities near nuclear plants should stockpile the drug. The NRC has even agreed to pay for the drug. The cost was estimated to be less than $500,000 to provide enough pills for every American living near one of the Nation's 72 nuclear powerplants. The NRC cannot force the States to stockpile potassium iodide, but recommended that the pills be stockpiled (Lieberman, 1999).

Potassium iodide, if taken shortly after exposure to radiation, blocks the thyroid glands's intake of radioactive iodine, thus providing protection against thyroid cancer and other diseases.

It does not protect against other types of radiation. New Hampshire State officials were making a decision about whether to distribute antiradiation pills to residents near the Seabrook nuclear powerplant (Boston Globe, 1999).

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, the largest U.S. plant, was owned by the Kita family and Tomen Corp. 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 Resources, which was owned by Beard Oil Co. (40%), Godoe Shigen (USA) Inc. (50%) and Mitsui & 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 (ppm). The company also operated 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. Mical Specialty Chemicals, Inc., a subsidiary of Mitsubishi International Corp., was the exclusive distributor for Woodward Iodine. Mical also distributed iodine for Ise in the United States.

Consumption

Estimated end uses by percentage for iodine in 1999 were estimated from a USGS survey canvass of consumers as follows: sanitation, 45%; animal feed, 27%; pharmaceutical, 10%; catalysts, 8%; heat stabilizers, 5%; and other, 5%. 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 matter.

The World Health Organization (WHO) estimated that about 2 billion people are at risk for iron, iodine, and vitamin A deficiencies. 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 goiter, which is a thyroid disorder. Iodine deficiency has been identified as a significant public health problem in 129 countries. At least 1,500 million people, or 29% of the world's population, live in areas at risk of iodine deficiency (World Health Organization, November 1996, Iodine deficiency disorders, Fact sheet no. 121, accessed August 10, 1999, at URL http://www.who.int/inf-fs/en/fact121.html). Iodine-deficiency disorders (IDD) of an estimated 740 million people can be eliminated by fortifying the world's salt supply. Universal salt iodization for eliminating IDD has been endorsed by the WHO. 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. 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. 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.

Britain is free from iodine-deficiency diseases because milk has become the main source of iodine in the diet, followed by meat. Milk as an iodine source is partly the result of iodine added to animal feeds and partly because the iodine that is used to sterilize udders and teats prior to milking finds its way into the milk (Hawkes, 1999).

Arizona Chemical, which is a subsidiary company of International Paper, was a leading producer of pine chemicals that include tall oil and rosins, which use iodine as a stabilizer. These pine products were used globally for a variety of end uses, including adhesives, inks, coatings, chewing gum, soaps and cleaners, rubber, plastics, lubricants, and other markets (Arizona Chemical, July 26, 2000, Arizona Chemical launches new internet site at URL http://www.arizonachemical.com/press/press_internet_7-26-00.htm). The crude tall oil market which fell in 1998 because of the depressed Asian demand for products, stabilized because of the curtailed paper production, solid North American demand, and hints of a turnaround in Asia (Papanikolaw, 1999).

AlliedSignal, Inc., which was a maker of iodine catalyst for nylon production, merged with Honeywell, Inc., and took the name "Honeywell" in a massive $14 billion stock swap. The new company will assume $1.5 billion of Honeywell debt. The AlliedSignal office in Morristown, NJ, will serve as the center of operations, and the Honeywell home office in Minneapolis, MN, will be eliminated (Scheraga, 1999).

Celanese, which was a producer of acetic acid by using an iodine catalyst, filed a lawsuit against Millennium Petrochemicals Inc., in the U.S. District Court in Houston charging patent infringement that related to Celanese's acetic acid technology. The company maintains that technology disclosed in a recently published patent granted to Millennium overlaps with Celanese's acid optimization methanol carbonylation technology (Chemical Market Reporter, 1999a).

Celanese's October debut on the New York Stock Exchange after an absence of 12 years returned the company to a publicly traded company. In the 1940's, Celanese back-integrated into production of petrochemicals to ensure a secure source of raw material for its fiber operations and expansion in Texas for acetaldehyde, acetic acid, formaldehyde, and methanol. In the 1950's and 1960's, the firm added polyester and nylon production. By 1986, Celanese had become the ninth largest U.S. chemical company. The following year, Hoechst acquired Celanese to form Hoechst Celanese. Eight years later, Hoechst combined its chemical industry into Celanese A.G.

DSM Chemicals North America, Inc., and AlliedSignal, Inc., Performance Polymers opened the world's first large-scale carpet recycling plant in Augusta, GA, worth $83 million. The plant will operate under the name "Evergreen Nylon Recycling" and convert 90,000 metric tons of nylon-6 carpet waste into nylon-6 raw material each year. The facility was expected to reduce by one-fifth the nylon-6 carpet waste that is land filled in the United States each year. DSM will market its 50% share of the recycled material under the trade name ReCap (Chemical Market Reporter, 1999e).

Iodine is used as a catalyst for nylon production. E.I. du Pont de Nemours and Co. doubled its capacity for nylon 6/6 resins with the addition of 25 Mkg (55 million pounds) per year of capacity in Richmond, VA (Chemical Market Reporter, 1999b). In addition to price hikes, DuPont was focusing on partnerships and consolidation and branching into value-added products for its $4.6 billion nylon enterprise. Demand for flooring-grade nylon has been strong because of low interest rates and the brisk construction market. There was an overcapacity of tire-cord grade nylon during 1999 (Tullo, 1999).

Agfa-Gevaert Group, which was a subsidiary of Germany's Bayer Corp., agreed to acquire Sterling Diagnostic Imaging, formerly DuPont Diagnostic Imaging, a leading producer of iodine imaging products. Sterling had the worldwide annual sales of $500 million in diagnostic medical x-ray film and equipment. Sterling had more than 2,000 employees worldwide with three-quarters of those in the United States (Chemical & Engineering News, 1999a).

Despite controversy, antibacterial products, such as iodophors, which contain iodine in a surfactant, continued to be in demand. Antibacterial cleaning products can neutralize a variety of bacteria on many surfaces and are used in hand cleaning, hard-surface cleaners, and dishwashing liquids. Reports warned that repeated use of antibacterial wash products could cause bacterial resistance. Although demand is strong, surveys on cleaning habits show that 65% of consumers do not realize that it is important to leave disinfectants on surfaces for a specified length of time to get their full germ-killing benefits (Morse, 1999).

Kodak Polychrome Graphics, which was the joint venture between Eastman Kodak Co. and Dainippon Ink and Chemicals Inc., consolidated to prepare digital photography. Digital graphic arts are about 10% of the graphic arts market. Silver halide chemistry, which uses bromine and iodine, is the basis of conventional photography and is still very inexpensive for the image quality (Chemical Market Reporter, 1999e).

Researchers at North Carolina State University report that adding 4 ppm of iodine to turkey feed additives, increase the number of eggs that hatch, improves the survival of young birds, and speeds their growth rate (Business Week, 1999).

Prices

Prices for iodine are negotiated on long and short-term contracts. The average declared c.i.f. value for imported crude iodine was $16.15 per kilogram. The average declared c.i.f. value for iodine imported from Chile was $15.70 per kilogram. The average declared c.i.f. value for imported crude iodine from Japan was $17.16 per kilogram. The average sale price of iodine sold from the DNSC was $16.34 per kilogram ($7.41 per pound). Published 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; 1997, $14.66; and 1998, $16.45. At the same time U.S. production increased to 1.6 Mkg from 1.5 Mkg and world production to 19 Mkg in 1999 from 18 Mkg in 1998.

Foreign Trade

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 4-5).

World Review

Argentina.—The Resin unit of Akzo Nobel NV, Arnhem, the Netherlands, and Ascona Resins, 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 and new projects continued to be announced to increase production (table 6). Atacama Minerals Corp., formerly Boron Chemical International Ltd., Vancouver, entered into a sales agreement to buy 100% of the S.L.M. Petronila Doescientos Sesenta y Nueve del Sector de Aguas Banes' existing and future rights, title, and interest in Aguas Blancas Project in Chile. Atacama will pay Petronila $4.8 million during a 15-year period; the first payment of $500,000 will be due on June 18, 2000. The company was still conducting tests to determine the site's potential iodine capacity. Long-term plans called for possible potassium nitrate production 7 years after initial construction (Green Markets, 1999).

Campania de Salitre y Yodo de Chile (Cosayach), which was part of Inverraz S.A., mined iodine and nitrates from caliche

reserves in Regions I and II. Reserves cover more than 90,000 hectares (ha), which correlates to 300,000 metric tons (t) of iodine and 50 million t of sodium nitrate. The Cala-Cala plant, begun in 1991, has a capacity of 648 t/yr. The Negreiros plant, which was begun in 1995, had a capacity of 1,080 t/yr. The Soledad plant, had a capacity of 1,080 t/yr. Total capacity in 1996 was 2,808 t/yr.

ACF Minera Ltda., which was a unit of DSM N.V., Netherlands, entered the iodine business in 1991 through the acquisition of the Dutch iodine chemicals producer ACF Chemie N.V. DSM Minera Ltda. and the Chilean firm ACF Minera were the successor of the former joint venture ACF Chemie. Their combined output has increased to about 2,200 t in 1998 from 1,000 in 1995. As production increases, the share going to the DSM iodine derivatives plant in Maarssen, the Netherlands, has remained steady at about two-thirds; the balance has been sold on the merchant iodine market (McCoy, 1999).

Minera Yolanda SCM, which was a subsidiary of Kap Resources Ltd., a resources company in Vancouver, suspended nitrate production at its mine in the Atacama Desert and its plant in the Tarapaca region because of financial difficulties. Production was halted after Kap failed to secure suitable strategic investors or joint-venture partners for the project (Industrial Minerals,1999). Kap announced that Potash Corp. of Saskatchewan had completed the $36 million recapitalization and purchase of the Minera Yolanda potassium- and sodium-nitrate project. No proceeds accrued to Kap. As senior project lender, Inter-American Investment Corp. had initiated foreclosure proceedings and waived its rights to take 1.9 million shares of Kap under a 1995 share-swap agreement (Fertilizer Markets, 1999).

Sociedad Quimica y Minera de Chile (SQM), which was the largest producer of iodine, had a 31% share of the global market. SQM had 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. Caliche-based operations were Pedro de Valdivia (379 ppm), Maria Elena (392 ppm), and Sierra Gorda (529 ppm). Because of an over-supply situation, SQM idled two production facilities at Mapocho and Nueva Victoria (2,000 t/yr capacity) in June, 1999. The two SQM facilities will be brought back to full production once the market correction ends (Chemical Market Reporter, 1999c). SQM restructured its group of subsidiary companies. SQM Holdings S.A., the managing company, will control four businesses. SQM Chemicals S.A. will control the lithium operation and iodine output. The U.S. office was renamed "SQM North America" and relocated from Norfolk to Atlanta. The Atlanta office will cover North America, Central America, and Chile. The SQM office in Santiago, Chile, will be responsible for sales in the rest of the world (Fertilizer International, 1999). As a result of SQM's expansion effort, Chilean iodine exports rose by 50% to about 9,500 t between 1995 and 1998; 5,500 t came from SQM. DSM Minera and Cosayach were the number two and three Chilean producers (McCoy, 1999).

The nitrate and iodine project at Pampa Dominador, northern Chile, was being developed by Minera Cero Imán SCM (MCI), which was a wholly owned subsidiary of Minera Soledad S.A., which was a Chilean private company established in 1988. The deposit is located within the Atacama Desert at an altitude of 1,750 meters (m) and 160 km southeast from the Pacific port of Antofagasta in the Region II. The site is the location of the former "oficina Salitrera Dominador," which was operated from 1925 to 1930. A total of 8,750 ha of MCI's mining property at Pampa Dominador is the main deposit for the nitrate and iodine project. An export program that covered about 5,000 ha was carried out during 1998. Nine ore bodies with an average ore strata thickness of 2 m and an overburden thickness that averages 0.6 m were defined. Reserves calculated to January 1999 included proven reserves of 540 Mkg of iodine with probable reserves of 620 Mkg iodine (Minera CerroImán, 2000).

Japan.—Japan was the world's second largest producer of iodine (table 6). Iodine was manufactured in Chiba, Miyazaki and Niigata prefectures; Chiba prefecture accounted for about 90% of all production in Japan. The following 8 companies operated 11 plants in Japan during 1999: Ise Chemical Corp., two in Chiba Prefecture and one in Miyazaki Prefecture, 300 metric tons per month (t/mo); Kanto Natural Gas Development Co., Ltd., Chiba Prefecture, 100 t/mo; Godo Shigen Sangyo Co., Ltd., Chiba Prefecture, 200 t/mo; Japan Energy Development Co., Ltd., Niigata Prefecture, 30 t/mo; Teikoku Oil Co., Ltd, Chiba Prefecture, 50 t/mo; Toho Earthtech, Inc., Niigata Prefecture, 60 t/mo; Nippoh Chemicals Co., Ltd., Chiba Prefecture, 60 t/mo; and Nihon Tennen Gas Co., Ltd., two in Chiba Prefecture, 100 t/mo.

Godo Shigen produced iodine by the blow-out process. Clarified brine is acidified to a pH of 7.0 and mixed with chlorine at the entry tower. The iodine liberated by the chlorine is vaporized in an air stream. The iodine vapors are absorbed in an iodine solution containing dissolved sulfur dioxide. The iodine solution is separated by gravity at the bottom of the tower. The solution is treated with chlorine to precipitate the iodine. The iodine sludge is purified, and the waste, liquid returned to the tower (Godo Shigen Sangyo Co., Ltd., 1999).

Kanto Natural Gas Development Co., Ltd., was established in May 1931 as Japan's first natural gas enterprise. Kanto operated the Southern Kanto gasfield, which is one of the few areas in Japan with large methane reserves. In 1938, Kanto began production of iodine from brine after removal of natural gas. The company operated about 300 wells in the gasfield, which covers an area of 4,300 square kilometers (km^2). After the gas is separated form the brine, the brine is sent to the iodine production plants. The gas can be returned to injection wells or discharged into the sea. Iodine is recovered by the ion-exchange resin method and the blowing-out method. In the ion-exchange process, impurities are removed from the brine by precipitation or filtration. The iodine is separated from the brine by means of an oxidizing agent and collected by adsorption on the ion-exchange resin. The iodine is eluded from the resin, crystallized, and refined. The blowing-out process is useful with high-temperature brines. After removal of sand and other impurities by precipitation and separation of the iodine using an oxidizing agent, the brine is exposed to air. The iodine evaporates, and is then absorbed, crystallized, and refined (Kanto Natural Gas Development Co., Ltd., 1999).

Nihon Tennen Gas Co., Ltd., was established in 1940 to produce and sell natural gas and brine. Nihon used an ion-exchange resin method to produce iodine. The natural gas

fields are approximately 3,000 km^2. The production process uses a gas lift method utilizing compressed gas to recover gas and brine. The brine is sent to an iodine manufacturing plant and used as a raw material. The production involves the extraction of iodine from brine and the refining of the extracted iodine. In the adsorption process, the brine passes through an ion-exchange resin and is adsorbed into the resin. The iodine in the resin is eluded and processed as a highly concentrated solution (Nihon Tennen Gas Co., Ltd., 1999).

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. In 1999, the State Foreign Trade Company Energokhimmashexport was looking for investors interested in providing technical equipment and expertise to update and operate three chemical enterprises that included the Nebitdag Iodine Production Plant. The Nebitdag plant seeks to increase capacity to 255 t (Business Information Service for the Newly Independent States, May 24, 1999, Search for partners, May 26, 1999, from e-mail bisnis3@ita.doc.gov).

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. During 1999 Energokhimmashexport was looking for investors interested in increasing capacity to 220 t of iodine and 5,150 t of ferric bromide per year (Business Information Service for the Newly Independent States, May 24, 1999, Search for partners, May 26, 1999, from e-mail bisnis3@ita.doc.gov) (table 6).

Current Research and Technology

A senior researcher at the University of Göttingen, Germany, prepared the first method for the direct free-radical iodination of aliphatic hydrocarbons by using a multiphase system. Straight-chain, branched, cyclic, and cage alkanes were converted into their corresponding alkyl iodides by treatment with iodoform at room temperature in the presence of powdered sodium hydroxide. The radical chain carrier is the triiodomethyl radical, which is generated in situ. This process is the only efficient method to replace an alkane C–H bond directly by a C–I bond in one step (Chemical & Engineering News, 1999c).

Lockheed Martin Missiles & Space is part of a team to develop an oxygen iodine laser and ground support. The airborne laser (ABL), which will be carried on a 747 aircraft, has been designed to autonomously detect, track, and destroy ballistic missiles. ABL will operate above the clouds, where it will detect and track missiles as they are launched by using an onboard surveillance system (Lockheed Martin Missiles & Space, Airborne Laser, accessed July 9, 1999, at URL http://www.Imsw.external.Imco.com/defsys/abl.html).

Researchers at the Institute of Food Research in Reading, England, used idohexanoic acid to imprint its shape onto a synthetic polymer template. This template is then used to nucleate a crystal to create a replica of calcium carbonate under conditions that favor aragonite, which is a different crystalline form of calcium carbonate compared to calcite. Researchers note that it might provide a way to crystalize a single enantiomer from a racemic mixture (Chemical & Engineering News, 1999b).

Scientist at International Business Machines's T. J. Watson Research Center in Yorktown Heights, NY, have shown that a new iodine organic-inorganic hybrid material can offer the best features of both kinds of materials. Inorganic semiconductors have excellent charge-carrier mobilities. Organic semiconductors can be chemically tailored and deposited by low-cost, low-temperature processes, such as spin coating. The new material is a tin iodide that consists of alternating organic and inorganic layers spin coated on a wafer and used as the semiconducting channel in a thin-film transistor. The results are comparable to that of amorphous silicon and the best vacuum-deposited organic semiconductors (Chemical & Engineering News, 1999d).

A 6-year study by the Center for Disease Control and Prevention of cows, deer, birds, fish, and plants near Georgia's Savannah River Site, which had been contaminated by radiation releases in the 1960's, was completed. Radioactive iodine and other radioactive contaminates, such as strontium, cesium, and plutonium, were routinely released on the site. According to unclassified information that was released in a 1,400-page report, which cited research from more than 30 years ago, the effects on humans might not show up for another 30 years (Augusta Chronicle, 1999).

Outlook

During the past decade, iodine production capacity in the Chile and the United States 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 tapes, the images are produced and stored on disks, hard drives, and 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 that 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 iodine deficiency disorder in China and India are consuming large amounts of iodine. X-ray contrast media, which contain as much as 60% iodine, will continue to have an 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.

Automotive International reports that the director of engineering material at Du Pont Automotive foresees significant increases in the use of nylon during the next 6 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 (FT Information Online Ltd., 1997).

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

TABLE 1
SALIENT IODINE STATISTICS 1/

(Thousand kilograms, unless otherwise specified)

	1995	1996	1997	1998	1999
United States:					
Production	1,220	1,270	1,320	1,490	1,620
Imports for domestic consumption 2/ 3/	3,950	4,860	6,380	5,960	5,430
Exports 2/ 3/	1,220	2,410	2,760	2,790	1,130
Consumption:					
Reported 4/	3,680	3,920	4,500	4,100	4,540
Apparent 5/	3,540	3,700	5,140	4,950	5,990
Price, imports, average c.i.f. value, 2/ dollars per kilogram	$10.32	$12.82	$14.74	$16.45	$16.15
World, production	12,900 r/	14,000 r/	15,600 r/	18,400 r/	19,300 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to no more than three significant digits, except prices.

2/ U.S. Census Bureau.

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.

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

(Thousand kilograms)

	1998		1999	
Product	Number of plants	Quantity	Number of plants	Quantity
Inorganic compounds:				
Resublimed iodine	10	241	9	196
Potassium iodide	7	673	9	676
Sodium iodide	6	418	7	373
Ammonium iodide	2	W	1	W
Calcium iodate	2	W	2	W
Cuprous iodide	2	W	2	W
Hydriodic acid	3	160	4	177
Potassium iodate	4	77	3	70
Other inorganic compounds	5	265	6	367
Total	XX 2/	1,840	XX 2/	1,860
Organic compounds:				
Ethylenediamine dihydroiodide	3	817	4	877
Methyl and/or ethyl iodide	2	W	3	68
Povidone-iodine (idophors)	3	681	4	645
Other organic compounds	6	770	8	1,090
Total	XX 2/	2,270	XX 2/	2,680
Grand total:				
Reported consumption 3/	XX 2/	4,100	XX 2/	4,540
Apparent consumption 4/	XX	4,950	XX	5,990

W Withheld to avoid disclosing company proprietary data; included with "Other inorganic/organic compounds," respectively. XX Not applicable.

1/ Data are rounded to no more than 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 1999 PRICES OF ELEMENTAL IODINE AND SELECTED COMPOUNDS

(Dollars)

Elemental iodine/compounds	Value 1/	
	Per kilogram	Per pound
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	19.00-21.00	8.62-9.53
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	16.5

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. 257, no. 1, January 3, 2000, p. 19-25.

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/	1998		1999	
	Quantity	Value 3/	Quantity	Value 3/
Iodine, crude:				
Canada	4	27	4	33
Cayman Islands	70	947	--	--
Chile	3,800	61,900	3,490	54,800
China	13	120	--	--
Germany	7	83	3	52
Japan	1,740	29,500	1,480	25,300
Russia	29	546	109	1,880
Switzerland	--	--	36	540
Other 4/	(5/)	16	21	365
Total	5,660	93,100	5,140	83,000
Iodide, potassium: 6/				
Canada	288	5,200	247	4,310
Chile	8	162	36	622
Japan	1	19	1	9
Other 7/	4	91	9	154
Total	301	5,470	293	5,090
Grand total	5,960	98,600	5,430	88,100

-- Zero.
1/ Data are rounded to no more than 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 Georgia (1999), India, the Netherlands, and the United Kingdom (1998).
5/ Less than 1/2 unit.
6/ Gross potassium iodide contains 76% crude iodine.
7/ Includes Brazil (1998), Denmark (1999), Germany, India (1999), Israel (1999), Japan (1999), and the Netherlands (1998).

Source: U.S. Census Bureau.

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/	1998		1999	
	Quantity	Value 3/	Quantity	Value 3/
Iodine, crude/resublimed:				
Canada	19	385	28	551
Egypt	3	60	--	--
France	33	688	34	564
Germany	520	8,470	686	10,800
India	38	796	22	375
Israel	1	9	--	--
Mexico	1,900	11,100	166	2,170
Netherlands	--	--	34	630
Turkey	2	29	--	--
United Kingdom	63	1,040	--	--
Other 4/	138	2,340	138	2,340
Total	2,720	24,900	1,110	17,400
Iodide, potassium: 5/				
Australia	(6/)	11	1	20
Mexico	8	132	7	120
Netherlands	--	--	2	50
Thailand	(6/)	3	(6/)	9
Turkey	11	219	10	205
Other 7/	50	875	5	126
Total	69	1,240	25	530
Grand total	2,790	26,100	1,130	18,000

-- Zero.
1/ Data are rounded to no more than 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 (1998), Belgium, Brazil (1998), Costa Rica (1999), Chile (1998), the Czech Republic (1998), the Dominican Republic (1998), Denmark (1998), Finland (1998), Ireland (1998), Italy (1999), Japan, the Republic of Korea, Peru (1998), the Philippines (1998), Portugal (1999), Romania (1998), Spain, Thailand (1999), and Venezuela.
5/ Gross potassium iodide contains 76% crude iodine.
6/ Less than 1/2 unit.
7/ Includes Argentina (1998), Denmark (1999), France, Guatemala (1998), Indonesia (1999), Jamaica, Malaysia (1999), the Philippines (1998), Singapore, Switzerland (1998), Taiwan (1998), (1998), the United Kingdom, and Vietnam.

Source: U.S. Census Bureau.

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

(Thousand kilograms)

Country	1995	1996	1997	1998 e/	1999 e/
Azerbaijan e/	350	300	300	300	300
Chile 3/	5,103 r/	5,514	7,154	9,722 r/ 4/	9,800
China e/	500	500	500	500	500
Indonesia e/	77 4/	75	73	70	70
Japan	5,492	6,178	6,036	6,142 r/ 4/	6,700
Russia e/	160	150	150	120	120
Turkmenistan e/	30 r/	35 r/ 4/	87 r/ 4/	90 r/	150
United States	1,220	1,270	1,320	1,490	1,620
Uzbekistan e/	--	--	--	1	2
Total	12,900 r/	14,000 r/	15,600 r/	18,400 r/	19,300

e/ Estimated. r/ Revised. -- Zero.
1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
2/ Table includes data available through June 9, 2000.
3/ Includes iodine production reported by Servicio Nacional de Geologia y Minería.
4/ Reported figure.