# Iodine

By Phyllis A. Lyday

**Domestic survey data and tables were prepared by Lisa D. Miller, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.**

Three producers of crude iodine supplied about one-fifth of domestic demand in 2003 based on reported figures (table 1). Domestic and imported iodine was consumed in intermediate products prior to being sold to consumers (table 2). Iodine and its derivatives are used principally in animal feed, catalysts, colorants, inks, pharmaceutical and medical applications, photographic equipment, sanitation or disinfectants, and rosin stabilizers, in decreasing order. Published prices for crude iodine in 2003 are found in table 3. Imports of crude iodine increased by 7%, and imports of potassium iodide decreased by 36% (table 4). Exports of crude iodine remained essentially at 2002 levels, and exports of potassium iodide decreased by 39% during 2003 (table 5). Because some exports and imports are in product categories rather than listed as elemental iodine, net imports are not clearly distinguished. The United States is the world's third leading iodine producer following Chile and Japan (table 6). In Chile, iodine is a coproduct of sodium nitrate production. Japan produces iodine from brines associated with natural gas production.

## Legislation and Government Programs

The Defense Authorization Act for Fiscal Year 2003 (Public Law 108-136) was enacted on November 24, 2003. The revised fiscal year 2003 Annual Materials Plan authorized the disposal of 453,593 kilograms (kg) (1 million pounds) of crude iodine from the National Defense Stockpile (NDS) classified as excess to goal (U.S. Department of Defense, 2003§[1]). Stocks of iodine classified as excess to goal at the end of fiscal year 2003 (September 30, 2003) were all subject to disposal limits. On January 13, 2003, the Defense National Stockpile Center (DNSC) issued "Amendment No. 006 to Solicitation of Offers for DLA-IODINE-003." The amendment solicited offers for the sale of 453,593 kg (1 million pounds) of crude iodine in fiscal year 2003, with quarterly sales of approximately 113,398 kg (250,000 pounds) (Defense National Stockpile Center, 2003a). On February 21, the DNSC announced the award of approximately 117,934 kg (260,000 pounds) of crude iodine for an approximate value of $1.2 million ($10.18 per kilogram or $4.62 per pound) (Defense National Stockpile Center, 2003c). On July 17, the DNSC issued "Solicitation of Offers for Crude Iodine DLA-IODINE-004." On August 28, the DNSC announced the award of approximately 118,000 kg (260,000 pounds) of crude iodine for an approximate value of $1.3 million ($11.02 per kilogram or $5.00 per pound) (Defense National Stockpile Center, 2003b). On October 30, the DNSC announced "Amendment No. 001 to Solicitation of Offers for DLA-IODINE-004." The amendment solicited offers for the sale of 453,593 kg (1 million pounds) of crude iodine in fiscal year 2004, with quarterly sales of approximately 113,398 kg (250,000 pounds) (Defense National Stockpile Center, 2004b). On November 26, the DNSC announced the award of approximately 124,738 kg (275,000 pounds) of crude iodine for an approximate value of $1.5 million ($12.02 per kilogram or $5.45 per pound) (Defense National Stockpile Center, 2004a). At yearend 2003, sales totaled 360,606 kg (795,000 pounds) valued at $4 million, and the excess iodine was 1.30 million kilograms (Mkg) (2.86 million pounds) valued at $14.4 million ($11.11 per kilogram or $5.04 per pound).

On September 9, representatives of the DNSC described the stockpile material as 11.3-kg (25-pound) glass jars in 45.4-kg (100-pound) wooden cases. The iodine is stored in depots in New Haven, IN (296,000 kg), Somerville, NJ (658,000 kg), and Binghamton, NY (297,000 kg). The iodine sales program offered quarterly sales with solicitations; the terms of sale were a negotiated contract (U.S. Department of Defense, 2003). DNSC awards from 1999 to 2003 were between 0.13% and 1.20% of world production. The names of companies making an offer for iodine were submitted to the Drug Enforcement Administration (DEA) for review because iodine is a controlled substance. DEA certification was effective for 1 year (Schloss, 2003).

The Centers for Disease Control and Prevention (2003§) published information on preparedness and response to dirty bombs, which can expose people to radioactive materials. Potassium iodide (KI) only protects a person's thyroid gland from exposure to radioactive iodine. KI will not protect a person from exposure to other radioactive materials or protect other parts of the body from exposure to radiation. KI must be taken prior to or immediately after exposure to be effective. Taking KI is not recommended unless there is a risk of exposure to radioactive iodine.

Perchlorates can interfere with the uptake of iodine by the thyroid, yet perchlorates were detected in at least five playas in three Southwestern States with concentrations between 17 and 112 parts per billion (ppb). Perchlorates were also detected in three samples of older marine evaporites that underlie large areas of the Southwestern United States. The findings suggest that the formation of perchlorate is not limited to the extreme conditions of the Atacama Desert in Chile where naturally occurring perchlorates have been known for more than 100 years to occur in nitrate deposits and numerous playas (Orris, 2004).

Perchlorate is used in car air bags, fireworks, matches, and safety flares, but about 90% is used in solid rocket fuel for the National Aeronautics and Space Administration (NASA) space shuttle and military missiles. Analysis of government data showed perchlorate contamination in drinking water supplies, groundwater, and soil in at least 43 States. The U.S. Environmental Protection Agency (EPA) was not expected to set enforceable national standards before 2008. California's current provisional drinking water standard is 2 to 6 ppb. The EPA's current draft standard is equivalent to 1 ppb (Environmental Working Group, 2003§).

A National Academy of Sciences (NAS) panel began assessing the health implications from ingestions of perchlorate. At issue

[1]References that include a section mark (§) are found in the Internet References Cited section.

was a 2002 draft EPA standard that required cleanup of water with 1 ppb perchlorate. Three agencies that face liability for perchlorate pollution from rocket fuel are the U.S. Department of Defense (DOD), the U.S. Department of Energy (DOE), and the NASA. The NAS review will also influence the U.S. Food and Drug Administration on the issue of perchlorate levels in food as a public health concern. The NAS panel's report was expected in mid-2004 (Hogue, 2003). On March 11, the California Environmental Protection Agency set a public health goal standard of 6 ppb perchlorate in drinking water (Chemical & Engineering News, 2004).

## Production

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

In 1987, IOCHEM Corp. (owned by the Kita family and Tomen Corp.) began producing iodine at a plant 1.2 kilometers east of Vici, Dewey County, OK. This was the largest U.S. iodine plant. The majority of production was shipped to Schering AG of 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 began operating a miniplant located at Dover, Kingfisher County, OK, in 1983. In 2003, the miniplant continued operating at an oilfield-injection-disposal site near Dover.

Ise Chemical Corporation of Japan owned Woodward Iodine Corp., which began production in 1977. Woodward's plant in Woodward County, OK, produced iodine from 22 brine production wells and injected waste through 10 injection wells. MIC Specialty Chemicals, Inc. (a subsidiary of Mitsubishi International Corp.) was the exclusive distributor for iodine produced by Woodward.

## Consumption

World iodine usage was estimated to be as follows: x-ray contrast media, 23%; chemical, 17%; iodophors and biocides, 17%; organic compounds, 12%; human nutrition, 8%; pharmaceuticals, 8%; nylon 6%; animal feeds, 5%; and herbicides, 4%. Other small uses included batteries, high-purity metals, inks and colorants, laboratory reagents, lubricants, motor fuels, and photographic chemicals.

Commercial crude iodine normally has a minimum purity of 99.5% to 99.8%, depending on the supplier. Impurities, in order of quantity, are chiefly insoluble materials, iron, sulfuric acid, and water. The U.S. Pharmacopeia 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.

Radiopaque agents are drugs used to help diagnose certain medical problems. They contain iodine, which absorbs x rays. Radiopaque-diagnosed medical problems included brain disorders, cardiac disease, central nervous system disorders, cerebrospinal fluid, disk disease, gastrointestinal (gall bladder) disorders, peritoneal disorders, splenic and portal vein disorders, urinary track disorders, and vascular disease.

Iodine was used in tall oil (from the Swedish word talloja, or pine oil) and rosins as a stabilizer. Tall oil rosins (TORs) are friable glassy materials that range from light yellow to dark brown in color and are derived from crude turpentine, extraction from ground timber (wood) by organic solvents, or distillation of crude tall oil. TORs are used in the production of natural and synthetic rubbers and plastic, in resins and varnishes, as a dead flux for tinning and soldering of metals, and by applying or "drawing" the rosin on a surface of the hair of string instrument bows. Crude tall oil (CTO) originates as tall oil soap, which is separated from recovered black liquor in the Kraft pulping process. The soap is then acidified to yield CTO. The tall oil is fractionated to produce fatty acids, pitch, and rosin. Fatty acids are sold in competition with vegetable fatty acids to producers of detergents, oilfield chemicals, and paint or are converted to derivatives, such as dimer acid. Rosin is almost always chemically modified into esters or adducts that are used to make adhesives, inks, and paper size.

International Specialty Products (ISP) produces a polyvinyl pyrrolidone (PVP)-base polymer used in coatings applied over various substrates to improve the adherence of printing ink. PVP has been used in coated plastic sheets for overhead slide presentations. ISP developed water-fast copolymers that combine PVP with acrylates and other monomers (McCoy, 2003).

ISP became privately owned after the chairman and majority stockholder acquired the 19% outstanding stock. ISP shares will no longer be traded on the New York Stock Exchange (Chemical & Engineering News, 2003a). ISP introduced chromabond, a second generation PVP laundry application that bonds with dyes released from colored fabrics. Chromabond is a polyvinyl pyridinium betaine that performs efficiently as a dye transfer inhibitor. The latest dye transfer product is an oxidized form of polyvinyl pyridine.

Eastman Chemical Co. closed its 70,000-t/yr CTO fractionation capacity at Savannah, GA, and planned to expand its Franklin, VA, capacity to 100,000 t/yr from 70,000 t/yr. Total U.S. CTO capacity after the consolidation was estimated to be 755,000 t/yr (De Guzman, 2003).

MeadWestvaco Corp. was formed in February 2002 with the merger of Mead Corp. and Westvaco Corp. Its two tall oil plants at Charleston Heights, SC, and De Ridder, LA, have a combined capacity of 215,000 t/yr and use iodine in the processing of TORs (Chemical Market Reporter, 2003).

Honeywell International Inc. acquired BASF Corp.'s nylon fibers business and combined the operations with its nylon carpet fiber and specialty fiber businesses, which include nylon, polyester, polyethylene naphthalate, and Spectra polyethylene fibers. Iodine is used as a catalyst in the manufacture of nylon. As part of the deal, Honeywell acquired BASF's headquarters at Charlotte, NC, polymerization and fiber plants in South Carolina and Ontario, Canada, and a carpet fiber plant in Shanghai, China (Tullo, 2003).

Global Industry Analyst, Inc. published a report on iodine in January 2004 that included overviews on the industry, products, end use, new products, and global markets and companies (Global Industry Analysts, Inc., 2004).

The Chemical Industry Data Exchange (CIDX) cyber security initiative was formed in January 2003, by CIDX and the Chemicals Sector Cyber-Security Information Sharing Forum. It consisted of 10 chemical industry trade associations representing more than 2,000 companies. More than 90 companies participate in CIDX, a trade association and standards group focused on improving the ease and cost-effectiveness of business-to-business transactions among chemical companies and their partners involved in brachytherapy, a minimally invasive procedure that implants small radioactive pellets (called seeds) that are about the size of a grain of rice into the prostate where they irradiate the cancer from inside the gland (Glasgow, 2003).

Theragenics Corporation (2003), the Georgia-based manufacturer and marketer of the TheraSeed $I^{125}$ cancer treatment device, announced the purchase of the U.S. brachytherapy business of BEBIG Isotopen-und Medizintechnik Gmbh (a subsidiary of German-based Eckert & Ziegler AG). The acquisition will allow Theragenics to market palladium and iodine brachytherapy devices to provide physicians and other purchasing organizations with a choice of therapeutic devices.

**Prices**

Actual prices for iodine are negotiated on long- and short-term contracts between buyers and sellers. The average declared cost, insurance, and freight (c.i.f.) value for imported crude iodine was $11.89 per kilogram. The average declared c.i.f. value for iodine imported from Chile was $11.91 per kilogram. The average declared c.i.f. value for imported crude iodine from Japan was $11.84 per kilogram. The average sale price of iodine sold by the DNSC was $11.11 per kilogram ($5.04 per pound). Published yearend U.S. prices for iodine and its primary compounds are listed in table 3. Solicitations for NDS iodine sales are made on a quarterly basis. Since 1998, only three companies—Dewey Chemicals Inc., West Agro Chemical Inc., and H&S Chemical Co. Inc.—have purchased stockpile iodine. Producers believe that the large quantities of iodine the NDS offers for sale each year depress the price that producers can ask since they are in competition with 454 metric tons (t) (1 million pounds) of excess stockpile iodine each year (figure 1).

During the past few years, the iodine market was oversupplied, and prices dropped. Sociedad Quimica y Minera de Chile S.A. (SQM) reported a decline in the average sale prices for iodine by $1.30 per kilogram during 2002 compared with 2001. However, during the fourth quarter of 2002, the increased global demand for iodine resulted in price increases (Van Savage, 2003).

During 2002, U.S. domestic iodine prices fell because U.S. chemicals became less competitive owing to a strong U.S. dollar that made the United States an attractive destination for exports from foreign countries and U.S. exports more costly (Hamel, 2003).

**Foreign Trade**

The United States and Chile signed a free trade agreement (FTA) on June 6, 2003, that, when fully implemented, will eliminate bilateral tariffs, expand opportunities for the peoples of both countries, lower trade barriers, and promote economic integration. The United States and Chile began bilateral negotiations on an FTA in December 2000, holding a series of 14 negotiating rounds. After working with the Congress to draft implementing legislation, the President will submit the agreement to the U.S. Congress for approval, along with an implementing bill, a description of administrative changes needed to carry out the agreement, and other supporting documents. Once submitted, the House of Representatives and the Senate will review the implementing package and vote under an expedited timetable. The United States currently has four free trade partners—Canada and Mexico (under the North American Free Trade Agreement), Israel, and Jordan. An FTA with Singapore was recently signed and, along with the Chile FTA, must be approved by the Congress before it can take effect (Mills and Ricardo, 2003).

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 unification of resublimed and crude iodine under the same code and free duty rate. Values that differ significantly could be a result of items being placed in the wrong category (tables 4, 5). The International Trade Administration of the U.S. Department of Commerce provides monthly and annual import and export data by harmonized tariff code.

**World Review**

Worldwide production of iodine in 2003 was estimated to be 20,900 t, of which 11,900 t (57%) was from Chile, and 6,500 t (31%) was produced in Japan. Industrial uses of iodine are still increasing, and areas of applications are expanding beyond the established markets, which are as follows: catalysts, germicides and disinfectants, pharmaceuticals, various additives, x-ray contrast media, and other.

***Chile.***—Atacama Minerals Corp. reported that its 50%-owned Aguas Blancas industrial mineral project located in the Atacama Desert of northern Chile was in its first full year of production in 2002 (Clark, 2003, p. 5). Operating costs were reported to be below budget, and total iodine production was 710 t. Iodine prices in 2002 continued a downward trend not experienced by the industry for some time. This trend stabilized by the end of the year, and Atacama successfully established itself as a new supplier of the highest quality iodine, capable of quantity supply. Consequently, processed iodine inventories at Aguas Blancas remain consistently low (Clark and Shane, 2004).

Full production at Aguas Blancas (300,000 t of sodium sulfate, 100,000 t of nitrates, and 1,500 t of iodine) requires the construction of a mechanical leaching facility to maximize recoveries from the salt rich ore at Aguas Blancas. A pilot mechanical leach plant was expected to be operational by third quarter of 2003. Design and development of a full-scale commercial plant by September 2004 will follow successful testing and operation of the pilot facility. Significantly, this pilot operation could increase monthly iodine production at Aguas Blancas by as much as 10% and will produce commercial quantities of sodium sulfate. Aguas Blancas expected to be one of the lowest cost producers of sodium sulfate, enjoying an industry advantage of coproduct production (iodine, nitrates, and sodium sulfate) from the same ore. At full production, Aguas Blancas will be the largest producer of sodium sulfate in South America (Clark and Shane, 2003).

SQM was the largest producer of iodine. All production is from caliche ore. The geologic origin of the caliche ore is not clear, but it is thought to be of sedimentary origin. There is between 0.5 and 2.5 meters of overburden above the ore. Iodine concentrations vary among mines. Ore was crushed to 12.5 millimeters (0.5 inch) in size and transferred to a leaching plant in vats where iodine, nitrate, and sulfate are extracted. At the Pampa Blanca Mine, located in the Sierra Gorda area, the ore is leached in piles to obtain solutions of iodine, which are transported to solar evaporation ponds. SQM produced intermediate iodine at its Pedro de Valdivia, Maria Elena, Pampa Blanca, and Nueva Victoria facilities. The iodine is treated at the Pedro de Valdivia and Nueva Victoria plants to obtain refined iodine that is smelted, prilled, and packed for shipping. SQM announced a series of projects to increase iodine and potassium nitrate production capacity by about 30%. A new mining sector at Maria Elena will replace the area currently being mined. The company was planning to increase iodine production in the Nuevo Victoria facility (Green Markets, 2004).

***Finland.***—Forchem Oy began operations of a new CTO plant in Western Europe at Rauma, Finland, in November 2002. The plant is the largest in the world with 150,000 t/yr of capacity, accounting for 10% of the world's CTO fractionation capacity (Forchem Oy, 2002).

***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: Ise Chemical Co, Ltd. had two plants in Chiba Prefecture and one in Miyazaki Prefecture and produced 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 plants in Chiba Prefecture, 100 t/mo.

The Working Group on the Function and Cycling of Iodine in Biosphere was established in 2002 with the aid of the Forum on Iodine Utilization. In April 2003, the first workshop on Iodine in Biosphere was held in Chiba at the National Institute of Radiological Sciences (IseChem, 2004§). Topics covered by papers presented included $I^{129}$ in algae, animals, atmosphere, bacteria, food, seawater, and soil (Forum on Iodine Utilization, 2003, p. 96).

## Current Research and Technology

An iodine compound comprising periodic acid and a surfactant was introduced as a replacement for chrome, copper, and arsenic (CCA) preservative for lumber. Mold and insects do not recognize iodine as a food. By wrapping wood cells in iodine crystals and thus reducing leaching, iodine-treated wood does not attract mold and insects and is safe for playground equipment and decks (EcoTreat, Inc., 2004).

A high-efficiency dye-sensitized solar cell was fabricated using an iodide/triiodide redox couple. The ionic liquid was 1-methyl-3-propylimidazolium iodide. The cell, which has a light-to-energy conversion efficiency of 5.3%, was fabricated at The Swiss Federal Institute of Technology in Lausanne. The new material is mechanically stable and flexible. Other benefits are high ionic conductivity, negligible vapor pressure, and nonflammability.

An iodine-based fungicide, Plantpro 45, manufactured by Ajay North America, LLC was being tested as a seed treatment for a fungus that produces harmful toxins. Studies of commercial sweet corn showed that Plantpro 45 reduced F. verticillioides growth by about 75% in infected kernels when applied at rates of 10 micrograms per kilogram of seed (Durham, 2003§).

ISP announced that it had added a new fungicide to its broad range of biocides that contain iodine. The products acts as a fungicide with antibacterial properties, was stable under freeze thaw conditions, and had no odor (Reisch, 2003).

The United States committed $1.7 billion for the first 5 years of a development program for fuel cell, hybrid-vehicle, and hydrogen infrastructure technologies. Sulfur-iodine (S-I) water-splitting cycle is one of three technologies under development. Wide spread adoption of clean hydrogen as the fuel of the future is dependent on being able to create commercial quantities of hydrogen. The S-I technology relies on the thermochemical cycle to create reactions between iodine, sulfur, and water to produce hydrogen and oxygen. The process offers higher efficiency than electrolysis without the production of carbon dioxide or the use of fossil fuels (Radler, 2003).

The gas turbine-modular helium reactor (MHR) is an advanced nuclear power system that offers competitive electricity generation costs, high thermal efficiency, high proliferation resistance, low environmental impact, unparalleled safety, and waste management benefits. Because the high outlet temperature of the MHR reactor can be used to provide high-temperature process heat, it has a high potential for using a S-I thermochemical water-splitting process to produce hydrogen. The S-I cycle consists of three chemical reactions, which dissociate water. All chemical reagents are regenerated and recycled; there are no effluents (LaBar and others, 2003).

Researchers at Tulane University developed a Grignard-type reaction to prepare amines used in agricultural and pharmaceutical chemicals using silver iodide to produce yields of 85% (Ritter, 2003).

A study sponsored by Press Enterprise of Riverside, CA, found perchlorate, which disrupts thyroid uptake of iodine, in all 18 samples of lettuce analyzed, and a test sponsored by the Environmental Working Group detected perchlorate in 4 of 22 lettuce samples contaminated by irrigation water in southern California. The source is believed to be irrigation water from the lower Colorado River, which carries perchlorate from a former industrial plant near Las Vegas, NV. In 2002, the EPA planned to lower the safe level of perchlorate to 1 ppb, but the DOD advocated a 20-ppb standard. The EPA, joined by the DOD, the DOE, and the NASA, asked the NAS to review the health impact of perchlorate (Chemical & Engineering News, 2003b).

Researchers at Chiba University in Japan studied intracellular metabolism, therapeutic efficacy on tumors, and tumor uptake of 3-[iodo$^{125}$-ά-methyl-L-tyrosine] ($I^{125}$-IMT) to develop radiopharmaceuticals. The uptake of $I^{125}$-IMT before and after radiotherapy was completely blocked by the presence of an inhibitor for the aminoacid transport system. After irradiation with $I^{125}$-IMT, the tumor volume in mice was reduced. Findings suggested that radiopharmaceuticals that reflect intracellular energy levels would provide sensitive and earlier prediction of therapeutic efficacy than by heavy ion beam (Uehara and others, 2003, p. 82).

Isephor, a kitchen cleaner, used polyvinyl pyrrolidone iodine (PVPI) and possessed antibacterial activity over a broad spectrum of applications that included antimildew and deodorant (Murakami and Fukuzawa, 2003, p. 88). Isephor is an iodine containing disinfectant that uses a stable compound made from iodine and glycine. Isephor-L and Isephor-LS are improvements that have different concentrations and disinfection characteristics (Sawada, 2003, p. 92). Methyl iodide is the major component of Ioguard, a fungicide and insecticide that performs better than methyl bromide (Taguchi and Akaga, 2003, p. 90).

A method was developed by researchers at the University of Tsukuba, Japan, to screen high iodine concentration in algae (Shiraiwa and Iwamoto, 2003, p. 102).

The accumulations of iodine have only been studied in algae and in mammals. The accumulation of iodine in bacteria was studied by researchers at Chiba University because bacteria were thought to have developed earlier than algae. More than 170 bacteria strains were collected from the environment to identify iodine-accumulating bacteria. Eight strains of bacteria were isolated from marine sediments or natural gas brines. The strains were cultured with sodium iodide ($NaI^{125}$) in a liquid medium, and the iodide content of the cells was measured. Results showed that iodine-accumulating bacteria are found in marine environments and that iodide accumulates as a result of enzymatic uptake of iodide inside the cells (Mishima, Amachi, and Fujii, 2003, p. 106). The uptake and volatilization of iodine by fungi was studied by researchers at the National Institute of Radiological Sciences by radiotracer experiments using $I^{125}$. The rate of accumulation of $I^{125}$ varied from 50% for Alternaria alternate to 0.2% for Cladosporium resinae. The percentage of evaporation from the medium was highest in Penicillium roqueforti (0.5%) and lowest in Cladosporium resinae (0.02%) (Ban-nai and Yasuyuki, 2003, p. 104).

The accumulation and percolation of bromine, chlorine, and iodine in soils was studied by researchers at the Institute of Physical and Chemical Research (Japan), the National Institute for Agro-Environmental Science (Japan), and Tokyo (Japan) University of Agriculture. The purpose was to clarify the environmental conditions for accumulation and percolation of the three halogens. Sorption rates between 40% to 80% moisture saturation conditions were largest for iodine (mean 98%) followed by bromine (mean 39%) and chlorine (mean 19%); organic soils lowered the sorption rates. The sorption rates for the three halogens in saturated soil that was submerged under water were mean 62%, 10%, and 15%, respectively. In addition, the sorption rates of the three halogens in soil were highest at a pH between 3.5 and 4.0 (Yuita and others, 2003, p. 108).

## Outlook

During the past decade, iodine production capacity in Chile and the United States has doubled, thus ensuring an adequate world supply. Global demand for iodine increased between 4% and 5% in 2002, and the demand for 2003 was forecast to increase by 3% (Van Savage, 2003). Most of the iodine producers were operating close to full capacity, and there may be some tightness of supply in the short term. Domestic demand was expected to remain at current levels because production of derivatives to supply the world market listed in table 2 is expected to move overseas.

***Animal Feed Supplements.***—Iodine is a necessary part of animal feed to prevent goiter and regulate metabolism. People commonly receive iodine from KI added to salt. Demand for KI as a preventive of cancer of the thyroid in the event of a nuclear accident increased sales of pills to government and private individuals. The peak for demand for KI was expected to be the 2003 level because of the distribution of KI pills to States through a Federal Government program.

***Catalyst.***—Iodine is used as a catalyst in the making of various chemicals, including acetic acid. Feedstock costs for natural gas increased, resulting in lower profits and increases in prices of acetic acid, which could result in less demand for iodine.

Studies continued on polythiophenes that are produced with bromine or iodine gas. These plastics with electrical conductivity properties will produce such products as paper-thin television screens and sensors for chemical-weapons detectors (Gorman, 2003).

***Photography.***—Recent developments in digital imaging can produce electronic prints and overhead transparencies without the need for wet processing film. Using a digital camera or scanning the film and converting to digital tapes, images are produced and stored on disks, hard drives, and tapes. Digital imaging is used for recording game shows, some situation comedies for television broadcast, and most sporting events. This would appear to cause a decrease in iodine usage in color film and film developing, but 75% to 85% of all televised programs seen during prime time are recorded on 35-millimeter (mm) motion picture film and then transferred to videotape or laser disc for display. Furthermore, the majority of feature films for movie theater presentations are shot and printed on film because film provides higher image resolution. A frame of 35-mm color negative film contains about 6.6 million pixels, 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 may be limited to specialty film imaging as digital imagery technology improves and the cost of such equipment becomes more affordable.

***Stabilizers.***—CTO inventories were at a very high level, and storage capacity was running out at midyear. From January to March 2003, average CTO stocks were estimated to be 75 Mkg (166.5 million pounds). CTO was exported to Europe and Asia, although Finland and Norway were the leading importers of CTO from the United States.

***Surfactants.***—Demand for biocides and disinfecting chemicals was up by about 7.8% in 2002. The water treatment market moved from South America to India and Pakistan and then into China. Expanding treatment of water supplies will increase the demand for these chemicals in the future (Challener, 2003).

***X-Ray Contrast Media.***—X-ray contrast media, which contain as much as 60% iodine, will continue to grow between 4% and 5% per year. More medical tests on an older population will result in increased demand for iodine-containing x-ray contrast media.

***Other Applications.***—New uses of fluoroiodocarbon as halogen replacements may increase demand for iodine in fire suppression chemicals. More tests need to be completed on the iodated fluorocarbons before they are acceptable, but preliminary tests were promising. Supplemental programs designed to alleviate iodine deficiency disease (IDD) in China and India were consuming large amounts of iodine to prevent IDD. In Chile and Mexico, individual water purification units that use iodine are a new application of existing purification process using iodine in the camping, hiking, and military water needs. Purification applications could become significant consumers of iodine. The use of iodine to treat wood for prevention of damage by insects was approved by the EPA to replace the use of CCAs. The potential for demand in this use is high because the iodine PPV treatment is not water soluble like other replacement material for CCA treatments.

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TABLE 1
SALIENT IODINE STATISTICS[1]

(Metric tons and dollars per kilogram)

| | 1999 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Production | 1,620 | 1,470 | 1,290 | 1,420 | 1,090 |
| Imports for domestic consumption[2] | 5,140 | 4,790 | 5,020 | 6,190 | 5,750 |
| Exports[2] | 1,110 | 1,010 | 1,460 | 1,580 r | 1,590 |
| Consumption: | | | | | |
| Reported[3] | 4,540 | 3,990 | 3,560 | 4,540 | 3,930 |
| Apparent[4] | 5,990 | 5,420 | 4,730 | 6,520 | NA |
| Price, imports, average cost, insurance, and freight value[2] | 16.15 | 14.59 | 13.94 | 12.70 | 12.70 |
| World, production | 18,400 | 19,500 | 20,700 | 21,000 r | 20,900 e |

eEstimated. rRevised. NA Not available.
[1]Data are rounded to no more than three significant digits, except prices.
[2]Source: U.S. Census Bureau information reported by Harmonized Tariff Schedule of the United States code 2801.20.0000.
[3]Reported by voluntary response to the U.S. Geological Survey from 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 2
DOMESTIC CONSUMPTION OF CRUDE IODINE, BY PRODUCT[1]

| | 2002 | | 2003 | |
|---|---|---|---|---|
| Product | Number of plants | Quantity (metric tons) | Number of plants | Quantity (metric tons) |
| Inorganic compounds: | | | | |
| Resublimed iodine | 8 r | 309 r | 8 | 165 |
| Potassium iodide | 7 r | 468 r | 5 | 394 |
| Sodium iodide | 7 | 557 | 5 | 427 |
| Hydriodic acid | 3 | 166 | 3 | 74 |
| Potassium iodate | 3 | 90 | 3 | 69 |
| Miscellaneous iodate, and iodides[2] | 4 r | 42 r | 3 | 82 |
| Other inorganic compounds | 3 r | 546 r | 5 | 662 |
| Total | 16 [3] | 2,180 | 20 [3] | 1,870 |
| Organic compounds: | | | | |
| Ethylenediamine dihydroiodide | 3 | 182 | 3 | 141 |
| Povidine-iodine (idophors) | 2 r | 165 r | 3 | 401 |
| Other organic compounds[4] | 8 r | 2,020 r | 7 | 1,520 |
| Total | 16 [3] | 2,360 | 20 [3] | 2,060 |
| Grand total: | | | | |
| Reported consumption[5] | XX | 4,540 | XX | 3,930 |
| Apparent consumption[6] | XX | 6,520 | XX | NA |

rRevised. NA Not available. XX Not applicable.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes ammonium iodide, calcium iodate, and cuprous iodide.
[3]Nonadditive because some plants produce more than one product concurrently.
[4]Includes methyl and/or ethyl iodide.
[5]Reported by voluntary response to the U.S. Geological Survey in a survey of domestic establishments.
[6]Calculated by using domestic production plus imports minus exports plus adjustments for Government and domestic industry stock changes.

TABLE 3
YEAREND 2003 PRICES OF ELEMENTAL IODINE AND SELECTED COMPOUNDS

| Elemental iodine/compounds | Value[1] Dollars per kilogram | Dollars per pound |
|---|---|---|
| Iodine, crude, drums | 13.25-14.50 | 6.11-6.69 |
| Potassium iodide, U.S. Pharmacopeia, drums, 5,000-pound lots, delivered | 25.76 | 12.27 |

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

Sources: Chemical Market Reporter, 2003, Current prices of chemicals and related materials, v. 264, no. 22, December 29, p. 22; U.S. Census Bureau.

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

(Thousand kilograms and thousand dollars)

| Type and country of origin[2] | 2002 Quantity | 2002 Value[3] | 2003 Quantity | 2003 Value[3] |
|---|---|---|---|---|
| Iodine, crude: | | | | |
| Belgium | 19 | 253 | -- | -- |
| Canada | 11 | 180 r | (4) | 39 |
| Chile | 4,250 | 53,500 r | 3,870 | 46,100 |
| France | 39 | 539 r | 21 | 273 |
| Germany | 14 | 152 | -- | -- |
| India | 12 | 146 | 11 | 22 |
| Japan | 1,820 | 22,700 r | 1,790 | 21,200 |
| Jordan | -- | -- | 16 | 205 |
| Netherlands | 18 | 212 r | 35 | 410 |
| Total | 6,190 | 77,700 r | 5,750 | 68,300 |
| Potassium iodide:[5] | | | | |
| Canada | 303 | 3,910 r | 487 | 5,410 |
| Chile | 103 | 1,340 r | 268 | 3,110 |
| Japan | 1 | 9 | 1 | 18 |
| Netherlands | 123 | 1,450 | -- | -- |
| Other[6] | 103 | 1,210 r | 106 | 1,220 |
| Total | 633 | 7,930 r | 862 | 9,760 |

[r]Revised. -- 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 Harmonized Tariff Schedule of the United States codes 2801.20.0000 and 2827.60.2000, respectively.
[3]Declared cost, insurance, and freight valuation.
[4]Less the 1/2 unit.
[5]Gross potassium iodide contains 76% crude iodine.
[6]Includes Brazil, Germany (2002), and Italy (2003).

Source: U.S. Census Bureau.

TABLE 5

U.S. EXPORTS OF CRUDE IODINE AND POTASSIUM IODIDE, BY COUNTRY OF ORIGIN[1]

(Thousand kilograms and thousand dollars)

| Type and country of origin[2] | 2002 Quantity | 2002 Value[3] | 2003 Quantity | 2003 Value[3] |
|---|---|---|---|---|
| Iodine, crude/resublimed: | | | | |
| Brazil | 32 | 366 | 93 | 1,040 |
| Belgium | 154 | 1,950 r | -- | -- |
| Canada | 218 r | 3,940 r | 389 | 7,060 |
| Chile | 252 | 2,210 | -- | -- |
| China | 1 | 9 | 17 | 247 |
| Germany | 607 | 6,900 | 588 | 6,430 |
| India | 3 | 47 | -- | -- |
| Japan | 46 | 687 | 167 | 1,910 |
| Korea, Republic of | 4 r | 61 r | 1 | 11 |
| Malaysia | 10 | 58 | 5 | 19 |
| Mexico | 132 | 2,130 | 321 | 2,740 |
| Netherlands | 86 | 793 | -- | -- |
| Thailand | 14 | 197 | -- | -- |
| Venezuela | 10 | 154 | 4 | 65 |
| Other[4] | 15 r | 219 r | 6 | 72 |
| Total | 1,580 r | 19,700 r | 1,590 | 19,600 |
| Potassium iodide:[5] | | | | |
| Australia | 2 | 45 | 2 | 55 |
| France | 39 | 526 | 18 | 299 |
| Jamaica | 1 | 11 | -- | -- |
| Korea, Republic of | 2 | 41 | -- | -- |
| Mexico | 3 | 55 | 1 | 24 |
| Netherlands | -- | -- | (6) | 5 |
| Singapore | (6) | 19 | (6) | 9 |
| Taiwan | 30 | 306 | 29 | 295 |
| Trinidad and Tobago | 1 | 10 | -- | -- |
| United Kingdom | 6 | 139 | 1 | 22 |
| Other[7] | (6) r | 23 r | (6) | 303 |
| Total | 84 r | 1,180 r | 51 | 1,010 |

r Revised. -- 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 Harmonized Tariff Schedule of the United States codes 2801.20.0000 and 2827.60.2000, respectively.

[3] Declared free alongside ship valuation.

[4] Includes Argentina (2002), Australia (2003), Colombia (2002), Denmark (2002), the Dominican Republic, El Salvador, France (2002), Honduras (2002), Hong Kong (2002), Jamaica, Jordan, Mongolia, Peru, the Philippines (2003), Singapore (2002), Saudi Arabia (2003), Sweden, Taiwan (2002), the United Kingdom (2003), and Uruguay (2002).

[5] Gross potassium iodide contains 76% crude iodine.

[6] Less than 1/2 unit.

[7] Includes Belgium (2002), Colombia (2003), Germany (2002), Ireland (2002), New Zealand (2002), the Philippines (2002), and Sweden (2002).

Source: U.S. Census Bureau.

TABLE 6

CRUDE IODINE: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

| Country | 1999 | 2000 | 2001 | 2002 | 2003[e] |
|---|---|---|---|---|---|
| Azerbaijan[e] | 300 | 300 | 300 | 300 | 300 |
| Chile[3] | 9,317 | 10,474 | 11,355 | 11,648 r | 11,900 |
| China[e] | 500 | 500 | 500 | 500 | 500 |
| Indonesia[e] | 74 [4] | 75 | 75 | 75 | 75 |
| Japan | 6,152 | 6,157 | 6,643 | 6,548 r | 6,500 |
| Russia[e] | 300 | 300 | 300 | 300 | 300 |
| Turkmenistan[e] | 150 | 200 | 200 | 200 | 200 |
| United States | 1,620 | 1,470 | 1,290 | 1,420 | 1,090 [4] |
| Uzbekistan[e] | 2 | 2 | 2 | 2 | 2 |
| Total | 18,400 | 19,500 | 20,700 | 21,000 r | 20,900 |

[e]Estimated. [r]Revised.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

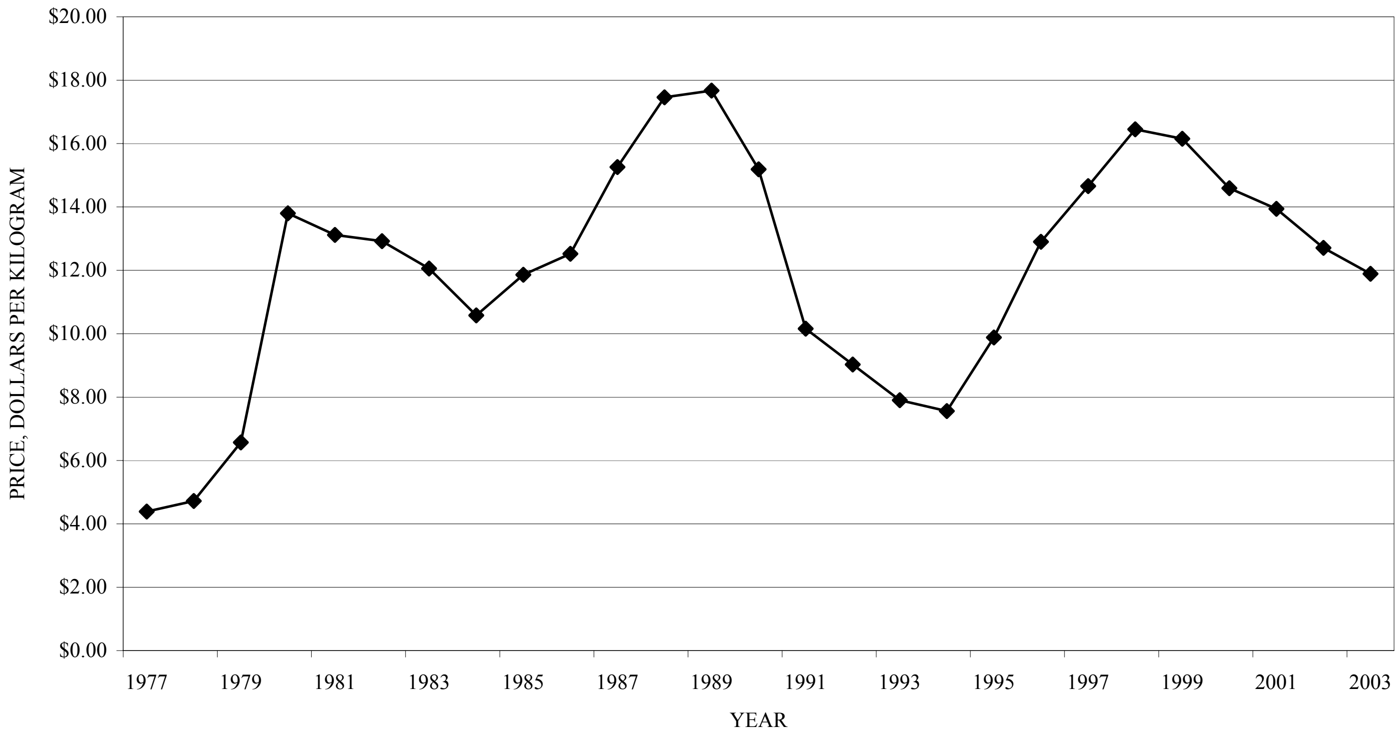
[2]Table includes data available through June 10, 2004.

[3]Includes iodine production reported by the National Geological and Mineral Service.

[4]Reported figure.

FIGURE 1

HISTORIC IODINE PRICES[1]




[1]Cost, insurance, and freight valuation.