IODINE

By Phyllis A. Lyday

Three producers of crude iodine supplied approximately 34% of domestic demand; the remainder was imported. Some exports and imports are in product categories rather than crude products, net imports are not clearly defined. The major world producer, Japan, produced iodine from brines associated with gas production. The second largest producer, Chile, produced iodine as a coproduct of sodium nitrate.

Legislation and Government Programs

The Strategic and Critical Materials Stock Piling Act, as amended, gives the Department of Defense (DOD) authority to maintain a stockpile of strategic and critical materials to supply the military, industrial, and essential civilian needs of the United States for national defense. By 1968, 3.7 million kilograms (kg) (8.1 million pounds) were acquired. In 1992 Public Law 102-484 reduced the stockpile goal for iodine to zero and Congress authorized the sale of excess material.

On March 9, 1995, the Defense National Stockpile (DNS) manager submitted a revision to the FY 1995 Annual Materials Plan (AMP) to Congress that would authorize 137,473 kg (744,000 pounds) of iodine. By law, the proposed revision would have been effected 45 calendar days after submission to Congress, if approved. The DNS Center announced on March 24, 1995, that fiscal year (FY) 1995 amount of iodine for sale was lowered from 453,593 kg (1 million pounds) to 204,117 kg (500,000 pounds). The DNS Advisory Committee also met in March to discuss the status of the DNS operations and the procedures used by the DOD to establish stockpile policy. The Committee was established under Public Law 102-484 for the purpose of advising on the Operation and Modernization of the DNS.

In September, the DNS Center awarded iodine under solicitations of Offers DLA-MIN-080. The total disposal for calendar year 1995 was 11,524 kg (255,911 pounds) valued at $1,063,856.31.

In November, the DNS Impact Committee published a request in the Federal Register seeking public comment on the market impact of the DOD's proposed sale of excess materials from the DNS. The Committee provides advice to DOD on the acquisition and disposal of materials from the DNS that are included in the AMP. The Committee considered DOD's proposed FY 1997 AMP and revisions to the FY 1996 AMP. The Federal Register notice, published November 7, 1995, announced that 453,592 kg (1 million pounds) were proposed for disposal each year for FY 1996 and 1997.

The DNS Center invited reviews and comments on a Draft Solicitation of Offer for Crude Iodine on November 30, 1995. In December the DNS Center at Ft. Belvoir, VA, held an industry meeting to discuss the sale of 2.28 million kg (5.03 million pounds) of iodine, with 453,592 kg (1 million pounds) to be offered in FY 1996. The meeting addressed procedures and contracting methods involved in the sale, as well as the commercial and normal operating practices of the industry and overall market conditions.[1]

Production

Domestic production data for iodine are developed by the U.S. Geological Survey from a voluntary survey of U.S. operations. Of the three operations to which a survey request was sent, two responded, representing an estimated 100% of the total production shown in tables 1 and 6. *(See tables 1 and 6.)*

IOCHEM Corp. began production in 1987, 1.2 kilometers east of Vici, Dewey County, OK, by the blowing-out process. IOCHEM is privately held joint venture between Tomen (USA) (50%) and a privately held family group (50%). The majority of production was shipped to Schering under a long-term contract. IOCHEM was reported to have nine production wells and four injection wells with a total production capacity of 1,400 kg per year.

North American Brine Chemicals began operating a miniplant at Dover in Kingfisher County, OK, in 1983. Two plants are at an oilfield injection disposal site that obtains brines from about 50 wells in the Oswego Formation. Iodine concentrations ranged up to 1,200 parts per million. The company closed a plant in 1992 that began operating in 1991 because of the low-market prices for iodine. Higher prices during 1995 may be incentive for reopening the plant during 1996.

Woodward Iodine Corp. began production in 1977 and was purchased by Asahi Glass Co. of Japan in 1984. Woodward operated a plant in Woodward County, OK, that produced iodine from 22 brine production wells using the blowing-out process and injected waste through 10 injection wells.

Consumption

Iodine deficiency is the world's leading cause of mental defects in the form of severe retardation, deaf-mutism, and partial paralysis and more subtle problems such as clumsiness, lethargy, and reduced learning capacity. Iodine is an essential part of a thyroid hormone, a substance that contributes to brain development during fetal life and metabolism thereafter. A worldwide effort is underway to eliminate iodine-deficiency disorders by fortifying the world's salt supply. The international

salt iodization campaign will pay for simple machinery that adds iodate to crystallized salt and for the quality control and education necessary to ensure the transformation is permanent.[2]

Tall oil rosin (TOR) is used as a paper filler, and in ink resins and tackifying resins for adhesives. The main competition for TOR was hydrocarbon resins made from byproducts of ethylene production.[3] Three U.S. companies use iodine to stabilize TOR. Deepwater Iodide Inc. opened a 1,400-ton-per-year plant in Woodward, OK, during 1994 to manufacture a line of organic and inorganic iodine compounds. Deepwater was forced into bankruptcy by the city of Woodward on February 1, 1995. A $3.9 million deal with LBS Chemical Corp., a division of LBS Industries Inc., to purchase 80% of Deepwater did not occur. In October, Deepwater's annual sales were about $12 million and the company commanded roughly 30% of the iodine derivatives market before bankruptcy.[4] In November, Deepwater was purchased by Tomen America Inc. and continued to operate under the new name Deepwater Chemicals Inc.

In October, Ajay Chemicals Inc., Georgia, and Sociedad Quimica y Minera de Chile (SQM) Iodo SA, Chile, completed a joint-venture agreement. SQM bought 49% of Ajay and Ajay bought 49% of Inquim, SQM's Chile-based derivative company. The joint ventures allow the two companies to cooperate in the development of new iodine products. Ajay continues to be a customer of SQM and SQM is not involved in operations.[5]

Iodine is used in radioisotopes in the following forms: I^{123} used to diagnose thyroid disorders; I^{125} used to evaluate glomerular filtration rate of kidney, to diagnose deep vein thrombosis in the leg, and in assays as an X-ray source for bone density measurements; I^{129} used to check some radioactivity counters in in-vitro diagnostic testing laboratories, and I^{131} used in functional imaging, to diagnose and treat thyroid disorders, carcinomas, abnormal liver function, kidney blood flow, and urinary tract obstruction.[6]

Iodine was used primarily in animal feed supplements, catalysts, inks and colorants, pharmaceutical, photographic equipment, sanitary and industrial disinfectants, stabilizers, and radiopaque medium. Other smaller uses included production of batteries, high-purity metals, motor fuels, iodized salt, and lubricants. *(See table 2.)*

Prices

Tall oil rosin (TOR) prices increased in August, which responded to a rosin resin increase effective January 1, 1995. Pricing for all TOR derivatives will increase 5% to 12%.[7]

The averaged declared c.i.f. value for imported crude iodine was $9.88 per kg. The average declared c.i.f. value for imported crude iodine from Japan was $10.10 per kg. The average declared c.i.f. value for iodine imported from Chile was $9.65 per kg. The average producer price was $10.19 per kg. Quoted yearend U.S. prices for iodine and its primary compounds are shown in table 3. *(See table 3.)*

Foreign Trade

The General Agreement on Tariffs and Trade (GATT) was signed into law in December 1994 and took effect January 1, 1995. GATT will lower chemical tariffs by an average of 30%. Chemicals, including iodine, are the nations' largest export commodity, as more than 10 cents out of every export dollar is a product of the chemical industry. The agreement's 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 (Harmonized 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. The Harmonized System, as proposed, includes resublimed and crude iodine under the same code, and the duty rate is free. Values that differ significantly could be a result of items being placed in the wrong category. *(See tables 4 and 5.)*

World Review

Chile.—Boron Chemical International Ltd. announced the commercial development of the Aquas Blancas project for the production of iodine in northern Chile. The planned design would produce 1,000 metric tons of iodine, 150,000 tons of sodium sulfate, and 70,000 tons of potassium nitrate per year by 1998.[8]

Compania Salitre Y Yodo de Chile (COSAYACH), part of a multi-sectorial Inverraz S.A., mines raw material in the form of boron, chlorides, iodine, magnesium from caliche, nitrates, and sulfates. COSAYACH has assets of 190,000 acres of mining claims in the Atacama and Antofagasta Deserts. Reserves are estimated as 356,000 tons of iodine, 46 million tons of sodium nitrate, and 80 million tons of sodium sulfate. Present capacity exceeds 340 tons of iodine per year. Planned capacity increases in Cala-Cala and construction of an additional plant at Chinquiquiray are planned to reach a production level of 1,000 tons per year by 1997.[9]

DSM Andeno B.V. owns a 60% share in ACF Minera Ltda. DSM markets the products, a variety of inorganic iodides and organic iodine, derivatives throughout the world.[10]

KAP Resources Ltd., Vancouver, Canada, has secured financing for a potassium nitrate project in northern Chile. The nitrates are reported to also contain high concentration of iodides. Cia Minera Yolanda SA is 95% owned by KAP Resources and 5% by Interamerican Investment Corp., a division of Interamerican Development Bank. One of KAP's major shareholders is Potash Corp. of Saskatchewan, Canada. The mine will produce sodium and potassium nitrate and 330

tons per year of iodine. Extraction would be accomplished by pumping water into the ore beds to dissolve salts and recovering the brine. The brine would be evaporated to recover the nitrates. The Yolanda property is about 400 kilometers (km) south of SQM's operation in the Atacama Desert in norther Chile.[11]

SQM, formerly known as SOQUIMICH produced 99.5% iodine as a byproduct of nitrate production. SQM Iodine S.A. restarted its satellite plants, which produced approximately 1,000 metric tons per year of crude iodine. The satellite plants, located about 100 km from the main mines, began production at midyear. The startup will put iodine production capacity for SQM at 5,000 tons per year.[12] SQM was producing iodine derivatives through a subsidiary Inquim, and marketing the derivatives to South America and Asia.[13] During 1995, SQM acquired Cosal S.A. an iodine producer with significant iodine reserves.[14] In December 1995, SQM purchased the remaining 18% stake in the Minsal project in northern Chile. SQM now owns 100% of the project. Another $150 million was planned to be spent on increasing potassium nitrate production capacity to about 500,000 metric tons per year and increasing iodine output by 2,000 metric tons per year.[15] The first stage will add 1,000 tons per year of iodine capacity on stream at Florencia, an ex-nitrate oficina located 100 km from Antofagasta. In addition, two iodine plants will be built, one at ex-oficina Pinto and another in the Iquique District.[16]

China.—The health ministry estimated that more than 10 million cases of metal retardation in China are due to iodine shortages. A lack of iodine may result in an enlarged thyroid gland, slow mental reaction, dry skin and hair, weight gain, and loss of physical and mental vigor. China planned to add iodine to salt to aid the thyroid gland of the 1.2 billion Chinese.[17]

Iodine in concentrations of 100 parts per million as a percent of dry ore is reported in local Yingping phosphate rock at Wengfu, Guizhou Province. The Yingping Mine is due on-stream in 1998. The phosphate rock will be used by the Wengfu Mining & Fertilizer Development Group to produce phosphoric acid.[18]

Japan.—Japan was the world's leading producer of iodine in 1994. Six companies operated 17 plants with a total production capacity of 9 million kg per year. Two small plants closed in midyear 1994. Production of iodine was from underground brines associated with natural gas.

Turkmenistan.—The Nebitdag plant is located in Vyshka, 26 km southwest of Nebitdag City of Balkan Velayat. The plant reported production capacities of 255 tons per year of iodine and 3,200 tons per year of ferrous bromide. The plant also produces 1,300 tons per year of bromine derivatives and 100 tons per year of sodium hypochlorite. It was commissioned in 1969 and employs 33 persons. The source of bromine and iodine is underground brines of the Nebitdag-Monjoukley deposit.

The Cheleken plant is located 10 km north of Cheleken City of Balkan Velayat. The plant reported production capacities of 335 tons of iodine, and 6,400 tons of ferrous bromide per year. In addition, the plant produces 60 tons per year of potassium iodide, 45 tons per year of potassium iodate, 60 tons per year other derivatives and 100 tons per year of sodium hypochlorite. The plant was commissioned in 1932 and employes 548 persons. The source of iodine and bromine was underground brines of the Cheleken deposit.[19] *(See table 6.)*

Current Research and Technology

Every photograph is created by light rays that make marks on photosensitive material such as silver salts, usually silver iodide. Silver's chemical properties make it the best photo material for everything from beach scenes to X-rays. Photograph companies are trying to revolutionize everyday photography by producing a "smart film." Five of the world's largest film and camera companies formed a partnership to develop a new technology to revolutionize 35-millimeter (mm) photography. The film is "smart" because it has magnetic strips, which can record data that will later be read and translated onto prints by compatible photofinishing equipment. The film can be removed and reinserted into a camera so each shot will have the correct film. Additionally, the film can be shot in three different formats, even on the same roll, as follows: 2:3 ratio, standard 35 mm; 16:9 ratio, high-definition TV; or, 1:3 ratio, panoramic. The film and cameras to shoot the advanced film were introduced during 1995.

In Japan, an oxygen-iodine laser system combined with fiber optics makes it possible to operate multiple industrial machines by remote control. The laser operated continuously at 1 kilowatt for 8 hours.[20]

The leaching process of gold in iodide solution was studied. The future of gold production may be the treatment of refractory-grade gold ores with iodine solutions. The cyanide-treatable gold ores coud be of a lower grade and less available, while refractory gold ores may become a more prominent gold resource. A large portion of finely disseminated gold remains with the host minerals and does not contact the cyanide solution. Pressure oxidation has gained attention for refractory ores. Hydrogen or ammonium and copper or iron ions can greatly accelerate the oxidation of iodide to iodine, resulting in a greater dissolution of gold.[21]

Outlook

Iodine production capacity in the United States and Chile has doubled during the past decade, ensuring an adequate world supply. Uses for iodine in specialty chemicals have remained stable.

Recent developments in digital images using computers can produce electronic prints and overhead transparencies without using processing. Using a digital camera or scanning the film and converting to digital, the images are produced and stored on hard drives, disks, tape, or optical storage.

The trend to digital imaging is used for recording most sporting events, game shows, and some situation comedies for broadcasts. However, 75% to 85% of all televised shows seen during prime time are recorded on 35-mm motion picture film and then transferred to video tape or laser disc for display.

Furthermore, just about all feature films for movie theater presentations are shot and printed on film because of superior image quality. Future use of iodine in films and processing could be limited to specialty imaging in the next decade.[23]

New uses of fluoroiodocarbon (IFC) as halogen replacements may cause an increased demand for iodine. More tests need to be completed on the IFC's before they are acceptable, but preliminary tests are promising.

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TABLE 1
SALIENT IODINE STATISTICS 1/

(Thousand kilograms and thousand dollars)

	1991	1992	1993	1994	1995
United States:					
Production	2,000	2,000	1,940	1,630	1,220
Imports for consumption 2/	3,560	3,750	3,620	4,360 r/	3,950
Exports 2/	1,320	1,810	1,220	1,200	1,220
Consumption: 3/					
Apparent	4,330	3,930	4,330	4,780 r/	3,540
Reported	3,200	3,400	3,550	3,690	3,680
Price, average c.i.f. value, dollars per kilogram	$10.16	$9.03	$7.98	$8.02	$10.32
World: Production	17,300 r/	16,500 r/	15,700 r/	14,000 r/	13,800 e/

e/ Estimated. r/ Revised.
1/ Data are rounded to three significant digits; except prices.
2/ Bureau of the Census.
3/ Calculated by production plus imports minus exports.

TABLE 2
U.S. CONSUMPTION OF CRUDE IODINE, BY PRODUCT 1/

	1994		1995	
Product	Number of plants	Consumption (thousand kilograms)	Number of plants	Consumption (thousand kilograms)
Reported consumption:				
Resublimed iodine	9	205	8	198
Hydriodic acid	3	30	3	27
Cuprous iodide	3	79	3	29
Potassium iodide	8	668	8	955
Potassium iodate	3	40	3	73
Sodium iodide	6	93	4	87
Other inorganic compounds	12	758	10	460
Ethylenediamine dihydroiodide	3	671	3	608
Povidone iodine	3 r/	892 r/	3	829
Other organic compounds	7	257 r/	3	410
Total	25 2/	3,690	25 2/	3,680
Apparent consumption	XX	4,780 r/	XX	3,540

r/ Revised. XX Not applicable.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Nonadditive total because some plants produce more than one product.

TABLE 3
YEAREND 1995 PUBLISHED PRICES OF ELEMENTAL IODINE AND SELECTED COMPOUNDS

	Dollars per kilogram 1/	Dollars 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	11.50-12.50	5.22-5.67
Potassium iodide, U.S.P., drums, 5,000-pound lots, delivered	26.48	12.01
Iodine, U.S.P.	15.01	6.80
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 Marketing Reporter. V. 249, No. 1, Jan. 1, 1996, pp. 27-32.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF CRUDE IODINE, BY TYPE AND COUNTRY 1/

(Thousand kilograms and thousand dollars)

Country	1994		1995	
	Quantity	Value 2/	Quantity	Value 2/
Iodine, crude:				
Canada	3	52	12	146
Chile	1,560	12,200	1,890	18,300
Germany	7	262	--	--
Japan	2,670	19,800	1,860	18,800
Russia	18	130	39	354
Total	4,260	32,400	3,800	37,500
Iodide, potassium: 3/				
Brazil	2 r/	11	(4/)	3
Canada	34 r/	437	105	927
Chile	10 r/	133	24	400
India	8 r/	123	20	276
Italy	5 r/	29	2	10
Japan	40 r/	422	--	--
Total	99 r/	1,160	151	1,610
Grand total	4,360 r/	33,600	3,950	39,100

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Declared c.i.f. valuation.
3/ Gross potassium iodide contains 76% crude iodine.
4/ Less than 1/2 unit.
Source: Bureau of the Census.

TABLE 5
U.S. EXPORTS OF CRUDE IODINE, BY TYPE AND COUNTRY 1/

(Thousand kilograms and thousand dollars)

Country	1994		1995	
	Quantity	Value 2/	Quantity	Value 2/
Iodine, crude/resublimed:				
Brazil	19	153	24	190
Canada	80	736	49	816
Costa Rica	1	86	--	--
Egypt	2	25	--	--
France	--	--	75	723
Germany	518	3,770	561	4,650
Ghana	3	58	2	38
India	17	123	17	199
Israel	--	--	12	43
Italy	1	14	6	100
Jamaica	8	18	--	--
Mexico	461 r/	3,840 r/	388	3,280
Netherlands	2	45	--	--
Saudi Arabia	9	6	--	--
Turkey	1	22	--	--
United Kingdom	11	69	13	99
Other 3/	1	26	23	294
Total	1,130 r/	8,990 r/	1,170	10,400
Iodide, potassium: 4/				
Australia	2 r/	55	(5/)	5
Belgium	15 r/	185	5	93
Canada	22 r/	450	18	364
Mexico	2 r/	61	4	48
Panama	2 r/	6	--	--
Thailand	15 r/	45	1	24
Turkey	11 r/	173	15	238
Other 6/	(5/) r/	15	2	64
Total	69 r/	990	45	836
Grand total	1,200	10,100	1,220	13,000

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Declared f.a.s. valuation.
3/ Includes Australia (1994), Colombia, El Salvador, Hong Kong, Japan, the Republic of Korea, Panama, South Africa, Sweden, and Venezuela.
4/ Gross potassium iodide contains 76% crude iodine.
5/ Less than 1/2 unit.
6/ Includes Argentina, Colombia (1994), Hong Kong (1994), Malaysia, Peru (1994), Philippines, Spain (1994), and Taiwan.

Source: Bureau of the Census.

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

(Thousand kilograms)

Country	1991	1992	1993	1994	1995 e/
Azerbaijan e/	XX	600	500	400	350
Chile 3/	5,447 4/	5,839 4/	5,550 e/	5,600 e/	5,000
China e/	500	500	500	500	500
Indonesia	36	35 e/	14	89 r/	77 5/
Japan	7,492	6,764	6,489	5,592 r/	6,200
Russia e/	XX	200	180	160	160
Turkmenistan e/	XX	600	500	251	250
U.S.S.R. e/ 6/	1,800	XX	XX	XX	XX
United States	2,000	2,000	1,940	1,430	1,220 5/
Total	17,300	16,500	15,700	14,000 r/	13,800

e/ Estimated. r/ Revised. XX Not applicable.

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 July 16, 1996.

3/ Includes iodine production reported by Servicio Nacional de Geologia y Minería (SERNAGEOMIN) as follows in thousand kilograms: 1991--1,214; 1992--1,028; 1993--1,121; 1994--1,268; and 1995--not available.

4/ Includes iodine production reported by the nitrate industry (Industria Salitrera).

5/ Reported figure.

6/ Dissolved in Dec. 1991.