



2015 Minerals Yearbook

IODINE [ADVANCE RELEASE]

IODINE

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In 2015, there were three domestic producers of crude iodine. Reported consumption by producers and consuming industries was 3,610 metric tons (t) in 2015, which was a 4% decrease from that in 2014 (table 1). Crude iodine exports decreased to 1,190 t valued at \$29 million in 2015 compared with 1,240 t valued at \$36.2 million in 2014 (table 3). Imports of crude iodine increased to 5,630 t compared with 5,360 t in 2014 although the value decreased to \$156 million compared with \$198 million in 2014 (table 4). World production, excluding U.S. production, was estimated to be 30,600 t in 2015 compared with the revised 29,600 t in 2014 (table 5). Chile was the world's leading producer of iodine, followed by Japan and the United States.

Iodine and its compounds are primarily used in x-ray contrast media (XRCM), pharmaceuticals, liquid-crystal-display (LCD) screens, and iodophors, in descending order. Other applications of iodine include animal feed, antiseptics, food supplements, nylon, and water purification. Globally, XRCM was the largest single market for iodine in 2015, accounting for approximately 22% of consumption (Sociedad Química y Minera de Chile S.A., 2016, p. 21).

Production

The U.S. Geological Survey obtained domestic production data for iodine from a voluntary canvass of three U.S. operations. U.S. production increased in 2015 from that of 2014; data were withheld to avoid disclosing company proprietary data (table 1).

IOCHEM Corp. produced iodine near Vici, in Dewey County, OK, from 16 production wells that extract brine from a sandstone layer approximately 2 miles below the surface. The brines contained between 300 and 400 parts per million (ppm) iodine. According to the company, IOCHEM was the leading producer of iodine in North America with an estimated 1,200 metric tons per year (t/yr) of iodine manufactured. Iodine produced by IOCHEM has a minimum specification of 99.5% iodine content (IOCHEM Corp., undated).

Woodward Iodine Corp. (owned by Ise Chemicals Corp. of Japan) produced iodine near Woodward, in Woodward County, OK, with 22 production and 10 injection wells. Woodward produced iodine from brines and also recycled iodine from other sources. The associated plant has an estimated capacity of 900 t/yr (Roskill Information Services Ltd., 2013, p. 151).

Iofina plc (United Kingdom) had iodine production operations in Oklahoma and Texas. The Texas facility, which had been in operation for less than 3 years and was used primarily as a proof of concept for their other plants, was closed in April owing to poor brine availability and low iodine prices (Syrett, 2015; Iofina plc, 2016, p. 3). In Oklahoma, Iofina operated five extraction plants that used the company's Wellhead Extraction

Technology® (WET®) and WET® IOsorb™ method to process saltwater waste brines from shale-oil production. According to the company, WET® IOsorb™ plants are capable of producing between 50 and 450 t/yr of iodine, depending on the location's flow and iodine concentrations (Iofina plc, undated). In 2015, the company produced 569 t of crystallized iodine, 73% more than the 328 t produced in 2014 owing to successfully commissioning three new plants in late 2014 (Iofina plc, 2015, p. 1; 2016, p. 1).

Consumption

The U.S. Geological Survey obtained domestic consumption data for iodine from a voluntary canvass of 19 U.S. operations. Of the 19 companies to which a survey form was sent, 16 responded to the annual or preliminary surveys. Accurate end-use statistics were difficult to gather because domestic and imported iodine were used to produce many intermediate iodine compounds, typically by downstream manufacturers.

Reported consumption by producers and consuming industries decreased by 4% to 3,610 t in 2015 compared with the 3,740 t reported in 2014. Consumption of potassium iodide, the leading inorganic iodine compound by weight consumed in 2015, increased by 9% to 616 t compared with the 567 t consumed in 2015 (table 2). Potassium iodide is primarily used to block the thyroid from absorbing radioactive iodine during radiation emergencies and to treat certain thyroid conditions. It can also be used as an expectorant. Reported consumption of ethylenediamine dihydroiodide (EDDI), the leading identified organic compound consumed in 2015, increased to 321 t from 225 t in 2014. EDDI is most commonly used as an additive in pet food to prevent iodine deficiency.

Commercial crude iodine typically has a minimum purity of 99.5% to 99.8%, depending on the supplier. The primary impurities, in order of quantity, are insoluble materials, iron, sulfuric acid, and water. The U.S. Pharmacopeia specifies an iodine content of no less than 99.8% for commercial iodine. 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 in its specifications for iodine.

Biocides and Disinfectants.—Because iodine is one of the most effective medical antiseptics available, it is used in biocides and disinfecting chemicals. Iodine is a cost-efficient, effective, and simple means of water disinfection. Iodophors, water-soluble chemical complexes designed to carry large amounts of iodine, were incorporated into disinfectants for use in dairies, food processing plants, hospitals, and laboratories.

The most popular iodophor for surgical scrub and gargle is povidone-iodine, which contains about 10% iodine. This form has almost completely replaced tincture of iodine as it does not cause any burning sensation when applied to human tissue (Harvey, 1980, p. 973).

Catalysts.—Iodine catalysts were used to manufacture acetic acid and synthetic rubbers. Acetic acid was used in the manufacture of certain adhesives, dyes, pharmaceuticals, plastics, surface coatings, and vinegar. Most acetic acid is produced using the methanol carbonylation process, which uses methyl iodide at an intermediate step. Catalysts were generally recycled and reused in new processes.

Chemicals.—Iodine was used as a stabilizer in the manufacture of nylon for tire cord and carpets and for converting resins, tall oil, and other wood products to more stable forms.

Medical.—Radiopaque agents, drugs that absorb x rays, are used to help diagnose certain medical conditions and may contain iodine. Problems diagnosed using radiopaque agents include brain disorders, cardiac disease, central nervous system disorders, cerebrospinal fluid disorders, disk disease, gastrointestinal (gall bladder) disorders, peritoneal disorders, splenic and portal vein disorders, urinary track disorders, and vascular disease. These agents, or XRCM, are substances that cause soft tissues to become visible during x-ray examination. The media are typically injected or swallowed by the patient and block the ability of x rays to pass through, temporarily changing the appearance of body tissue, blood vessels, and organs. XRCM in use today are frequently organic iodine derivatives. Although many elements have higher atomic numbers than iodine, no other element has the chemical characteristics to form soluble compounds with low toxicity. It is this latter property that makes iodine-containing contrast media suitable for radiography.

Radioactive iodine, the isotope ^{131}I , is a major fission product produced in both nuclear powerplants and nuclear bombs. The ingestion or inhalation of a very small amount of radioactive iodine can cause thyroid cancer. Potassium iodide tablets can be taken to prevent radioactive iodine from accumulating in the thyroid gland (Roskill Information Services Ltd., 2013, p. 210). Iodine prophylaxis is especially important for children under the age of 18 and pregnant women. The World Health Organization recommends the stockpiling of potassium iodide tablets near any nuclear powerplant (World Health Organization, 1999).

Potassium iodide was also used as an expectorant in cough medicine, and hydriodic acid and potassium iodide were used in the synthesis of amphetamine, ethylamphetamine, and methamphetamine. Because of controlled substances produced from iodine, such as amphetamines and methamphetamines, iodine is regulated under the U.S. Controlled Substances Act (U.S. Department of Justice, 2016, p. 77).

Nutrition.—Iodine is an essential component of thyroid hormones, which directly affect processes in the brain, muscles, heart, pituitary gland, and kidneys. Iodine deficiency, a world health problem affecting approximately 2 billion people, can cause goiters in adults, increased mortality and impaired cognitive development in children, and reproductive failure (World Health Organization, undated). Since the 1920s, iodized salt has been the primary source of supplemental dietary iodine in the western world. Iodine deficiency disorder can be prevented by consuming about 150 milligrams per day of iodine for a human adult (Institute of Medicine of the National Academies, 2006).

Other Uses.—Developments in digital imaging have allowed electronic prints to be produced without the need for wet

processing film, and therefore without the use of iodine as a light sensitive chemical. The majority of feature films now use a digital format for shooting and 9 out of 10 movie screens in the United States have switched from 35-millimeter film to digital imagery (Alexander and Blakely, 2014).

Iodine was also used for manufacturing iodine-adsorbed polyvinyl alcohol polarizing films for LCDs for electronic equipment, including appliances, computers, digital cameras, personal handheld devices, and televisions. Polarizers are added to LCDs to enhance the light contrast between the screen and the liquid crystals, making the LCD more visible. These polarizers are usually made from stretched polyvinyl alcohol films that contain iodine.

Prices

Iodine prices declined throughout 2015. The spot price of crude crystal iodine, 99.5% minimum purity, in 50-kilogram (kg) drums, as reported by Industrial Minerals, ranged from \$31 to \$35 per kilogram in early 2015. This is a decrease compared to January 2014 prices, which ranged from \$45 to \$55 per kilogram. By December 2015, prices ranged from \$27.50 to \$32 per kilogram. Actual prices for iodine are negotiated on long- and short-term contracts between buyers and sellers.

Foreign Trade

Net trade was not easily defined because iodine was exported and imported in many forms other than elemental iodine and potassium iodide. Exports of crude iodine decreased by 4% to 1,190 t, and the free alongside ship (f.a.s.) value of those exports decreased by 20% to \$29 million compared with those in 2014. Exports of crude iodine to Canada and Germany represented 65% of total crude iodine exported in 2015. The quantity of exported potassium iodide increased by 10% to 282 t with only a slight increase in value compared with 2014. The leading destinations for exported potassium iodide were Taiwan and Saudi Arabia, in descending order, which received 66% of the total potassium iodide exported in 2015 (table 3).

Imports of crude iodine increased by 5% to 5,630 t; however, the value of those imports decreased by 21% compared with those in 2014. The average price of imported crude iodine decreased by 25% to \$27.74 per kilogram from \$37.04 per kilogram in 2014. Imports of crude iodine from Chile represented 90% of total crude iodine imported in 2015. Imports of potassium iodide decreased by 7% to 262 t and the cost, insurance, and freight (c.i.f.) value of those imports decreased by 9% compared with those in 2014. Imports of potassium iodide from Brazil, Canada, and Germany represented 87% of total potassium iodide imported in 2015 (table 4). The decrease in value for both exported and imported crude iodine, 20% and 21% respectively, illustrates the global decline of iodine prices in 2015.

World Review

World production of iodine, excluding U.S. production, was estimated to be 30,600 t in 2015 compared with the revised

29,600 t in 2014 (table 5). Chile was the world's leading producer of iodine, followed by Japan and the United States.

Chile.—Sociedad Química y Minera de Chile S.A. (SQM), the world's leading iodine producer, produced 10,309 t of iodine in 2015 with reported sales for iodine and its derivatives of 9,300 t of contained iodine valued at \$263 million. This was a 7% increase in production and a 6% increase in quantity sold compared with the 9,602 t produced and 8,800 t sold in 2014. Although the amount of iodine produced and sold in 2015 increased, revenues decreased by approximately 22% compared with 2014 revenues of \$335 million (Sociedad Química y Minera de Chile S.A., 2015, p. 31; 2016, p. 21, 33). The decrease in revenue was largely attributed to the decrease in global iodine prices in 2015. According to SQM, their average price in 2015 was \$28 per kilogram, approximately 26% less than their average 2014 reported price of \$38 per kilogram (Sociedad Química y Minera de Chile S.A., 2015, p. 54; 2016, p. 23). In 2015, SQM operated two mines in northern Chile, Nueva Victoria and Pedro de Valdivia, producing iodine and nitrates from caliche ore deposits. In November 2015, mining operations at Pedro de Valdivia were suspended and iodine production was reduced to allow SQM to focus on their operations at Nueva Victoria. Mining operations at their other facilities, Pampa Blanca and Maria Elena, were suspended in 2010 and 2013, respectively (Sociedad Química y Minera de Chile S.A., 2016, p. 30).

Compañía de Salitre y Yodo (Cosayach) produced iodine from caliche ore at its three operations, Cala Cala, Negreiros, and Soledad, with a total capacity of 6,000 t/yr of iodine (Compañía de Salitre y Yodo, undated). Other iodine producers in Chile included ACF Minera S.A., which produced iodine at its Lagunas Mine, and Algorta Norte S.A., which operated northwest of Baquedano in the Antofagasta Region, with a total capacity of 4,000 t/yr (Algorta Norte S.A., undated; Independent Iodine, undated).

Japan.—Crude iodine was produced from underground brines associated with wet natural gas deposits. An estimated 80% of output was from Chiba Prefecture, from the Southern Kanto gasfield, and the remainder from Niigata and Miyazaki Prefectures. Historically, Japanese crude iodine producers have had high production costs owing to subsidence caused by the brine extraction, which can require expensive land reclamation (Roskill Information Services Ltd., 2013, p. 107).

In 2015, iodine producers in Japan included Godo Shigen Co. Ltd., Inpex Co., Ise Chemicals Co., Kanto Natural Gas Development Co. Ltd., Nihon Tennen Gas Co. Ltd., Nippon Chemicals Co., Ltd., and Toho Earthtech Inc.

Outlook

In 2015, the global demand for iodine was estimated to have increased approximately 3% to 4%, but production growth continued to exceed growth in consumption and prices continued to decline throughout 2014 and 2015 (Iofina plc, 2016, p. 7; Sociedad Química y Minera de Chile S.A., 2016, p. 62, 316). In 2016, global consumption of iodine is expected to increase by approximately 2% (Sociedad Química y Minera de Chile S.A., 2016, p. 316). Growth in iodine consumption will likely continue to be driven by applications for LCD screens and medical applications, especially in developing countries where

much of the global increase in iodine consumption is taking place (Iofina plc, 2016, p. 7). Additionally, expanding treatment of municipal water supplies could increase the demand for biocides and disinfectants in the future.

Iodine recycling also continued to increase in 2015. Recycling facilities are used to recover iodine and iodine derivatives from iodine waste streams. In 2015, it is estimated that 75% of the global iodine recycling was conducted by Japanese producers. Iodine recycling has increased over the past few years and represents approximately 18% of world iodine sales (Sociedad Química y Minera de Chile S.A., 2016, p. 22).

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TABLE 1
 SALIENT IODINE STATISTICS¹

(Metric tons, unless otherwise specified)

| | 2011 | 2012 | 2013 | 2014 | 2015 |
|--|--------------------|--------------------|--------------------|---------------------|--------|
| United States: | | | | | |
| Production | W | W | W | W | W |
| Imports: | | | | | |
| Quantity, for consumption ² | 6,620 | 5,960 | 5,960 | 5,360 | 5,630 |
| Price, average dollars per kilogram ³ | 38.35 | 42.28 | 42.77 | 37.04 | 27.74 |
| Exports ² | 902 | 1,040 | 1,150 | 1,240 | 1,190 |
| Consumption: | | | | | |
| Reported | 4,560 ^r | 4,920 ^r | 4,050 ^r | 3,740 ^r | 3,610 |
| Apparent | W | W | W | W | W |
| World, production ^c | 26,200 | 27,800 | 30,800 | 29,600 ^r | 30,600 |

^cEstimated. ^rRevised. W Withheld to avoid disclosing company proprietary data.

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

²Source: U.S. Census Bureau information reported by Harmonized Tariff Schedule of the United States code 2801.20.0000.

³Cost, insurance, and freight valuation.

TABLE 2
 DOMESTIC CONSUMPTION OF IODINE, BY PRODUCT^{1,2}

| Product | 2014 | | 2015 | |
|---|------------------|------------------------|------------------|------------------------|
| | Number of plants | Quantity (metric tons) | Number of plants | Quantity (metric tons) |
| Inorganic compounds: | | | | |
| Ammonium iodide | 1 | (3) | 1 | 1 |
| Crude iodine | -- ^r | -- ^r | -- | -- |
| Hydriodic acid | 3 | 126 | 2 | 51 |
| Potassium iodate | 3 | 35 | 3 | 35 |
| Potassium iodide | 3 | 567 | 3 | 616 |
| Resublimed iodine | 6 | 80 | 6 | 63 |
| Sodium iodide | 3 | 79 | 3 | 151 |
| Miscellaneous iodate and iodides ⁴ | 1 | 78 | 1 | 45 |
| Other inorganic compounds | 5 | 899 ^r | 4 | 411 |
| Total | XX ⁵ | 1,860 ^r | XX ⁵ | 1,370 |
| Organic compounds: | | | | |
| Ethylenediamine dihydroiodide | 1 | 225 | 3 | 321 |
| Povidine-iodine (iodophors) | -- | -- | 1 | 276 |
| Other organic compounds ⁶ | 12 ^r | 1,650 ^r | 7 | 1,640 |
| Total | XX ⁵ | 1,880 ^r | XX ⁵ | 2,240 |
| Grand total | XX | 3,740 ^r | XX | 3,610 |

^rRevised. XX Not applicable. -- Zero.

¹Data are rounded to no more than three significant digits; may not add to totals shown.

²Reported by voluntary response to the U.S. Geological Survey from a survey of domestic establishments.

³Less than 1/2 unit.

⁴Includes calcium iodate and cuprous iodide.

⁵Nonadditive because some plants produce more than one product concurrently.

⁶Includes methyl and (or) ethyl iodide and other unspecified products.

TABLE 3
U.S. EXPORTS OF CRUDE IODINE AND POTASSIUM IODIDE, BY COUNTRY OF ORIGIN¹

| Type and country of origin ² | 2014 | | 2015 | |
|---|---------------------------|-----------------------------------|---------------------------|-----------------------------------|
| | Quantity (metric tons) | Value ³ (thousands) | Quantity (metric tons) | Value ³ (thousands) |
| Iodine, crude: | | | | |
| Belgium | 38 | \$552 | 31 | \$507 |
| Canada | 199 | 3,310 | 144 | 2,950 |
| Germany | 687 | 25,800 | 631 | 18,100 |
| India | 4 | 62 | 73 | 1,570 |
| Italy | 18 | 644 | 73 | 2,050 |
| Japan | 58 | 2,080 | 74 | 2,060 |
| Korea, Republic of | 39 | 1,360 | (4) | 6 |
| Latvia | 41 | 107 | 65 | 128 |
| Mexico | 28 | 147 | 4 | 122 |
| New Zealand | 56 | 926 | 25 | 500 |
| South Africa | 24 | 403 | 23 | 372 |
| Thailand | 10 | 175 | -- | -- |
| Other ⁵ | 38 ^r | 653 ^r | 50 | 771 |
| Total | 1,240 | 36,200 | 1,190 | 29,100 |
| Potassium iodide:⁶ | | | | |
| Brazil | -- | -- | 6 | 100 |
| China | (4) | 33 | 7 | 135 |
| Indonesia | 21 | 360 | -- | -- |
| Korea, Republic of | 20 | 409 | 36 | 709 |
| Malaysia | -- | -- | 6 | 100 |
| Mexico | 27 | 653 | 17 | 492 |
| Netherlands | 6 | 104 | -- | -- |
| Saudi Arabia | 46 | 1,260 | 85 | 1,730 |
| Taiwan | 103 | 1,940 | 100 | 1,770 |
| Turkey | 19 | 499 | 3 | 103 |
| Other ⁷ | 14 ^r | 352 ^r | 23 | 527 |
| Total | 256 ^r | 5,610 | 282 | 5,670 |

^rRevised. -- Zero.

¹Data are rounded to no more than three significant digits; may not add to totals shown.

²Source: U.S. Census Bureau information reported by Harmonized Tariff Schedule of the United States codes 2801.20.0000 and 2827.60.2000.

³Declared free alongside ship valuation.

⁴Less than ½ unit.

⁵Includes countries with quantities less than 10 metric tons.

⁶Contains 76% iodine.

⁷Includes countries with quantities less than 5 metric tons.

TABLE 4
U.S. IMPORTS OF CRUDE IODINE AND POTASSIUM IODIDE FOR
CONSUMPTION, BY COUNTRY OF ORIGIN¹

| Type and country of origin ² | 2014 | | 2015 | |
|---|---------------------------|-----------------------------------|---------------------------|-----------------------------------|
| | Quantity (metric tons) | Value ³ (thousands) | Quantity (metric tons) | Value ³ (thousands) |
| Iodine, crude: | | | | |
| Brazil | 39 | \$1,630 | -- | -- |
| Canada | (4) | 67 | 11 | \$341 |
| Chile | 4,670 | 175,000 | 5,080 | 141,000 |
| Japan | 642 | 21,600 | 538 | 15,100 |
| Other ⁵ | 3 | 52 ^r | 1 | 39 |
| Total | 5,360 | 198,000 | 5,630 | 156,000 |
| Potassium iodide:⁶ | | | | |
| Brazil | 30 | 1,130 | 82 | 1,400 |
| Canada | 148 | 2,600 | 67 | 1,820 |
| China | 20 | 207 | 10 | 65 |
| Germany | 33 | 445 | 79 | 981 |
| India | 27 | 368 | 22 | 405 |
| United Kingdom | 23 | 407 | (4) | 6 |
| Other ⁵ | 2 ^r | 43 ^r | 2 | 43 |
| Total | 283 | 5,200 | 262 | 4,720 |

^rRevised. -- Zero.

¹Data are rounded to no more than three significant digits; may not add to totals shown.

²Source: U.S. Census Bureau information reported by Harmonized Tariff Schedule of the United States codes 2801.20.0000 and 2827.60.2000.

³Declared cost, insurance, and freight valuation.

⁴Less than ½ unit.

⁵Includes countries with quantities less than 5 metric tons.

⁶Contains 76% iodine.

TABLE 5
CRUDE IODINE: WORLD PRODUCTION, BY COUNTRY^{1,2}

(Metric tons)

| Country ³ | 2011 | 2012 | 2013 | 2014 | 2015 |
|---------------------------|--------|--------|--------|---------------------|---------------------|
| Azerbaijan | 230 | 240 | 249 | 263 ^r | 247 |
| Chile | 16,000 | 17,494 | 20,656 | 18,989 ^r | 20,000 ^e |
| Indonesia | 61 | 44 | 43 | 56 ^r | 45 |
| Japan | 9,277 | 9,315 | 9,334 | 9,814 ^r | 9,800 ^e |
| Russia ^e | 210 | 200 | -- | -- | -- |
| Turkmenistan ^e | 470 | 480 | 500 | 500 | 510 |
| United States | W | W | W | W | W |
| Total ^{e,4} | 26,200 | 27,800 | 30,800 | 29,600 ^r | 30,600 |

^rRevised. W Withheld to avoid disclosing company proprietary data; not included in total. -- Zero.

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

²Includes data available through April 22, 2016.

³In addition to the countries listed, China and Iran also produce crude iodine, but output is not officially reported and available general information is inadequate for the formulation of reliable estimates of output levels.

⁴Does not include U.S. production.