

## 5. PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL

### 5.1 PRODUCTION

Iodine, a halogen, occurs in low concentrations in nature in the form of iodides mainly in sea water, although there are a number of major sources iodine including the underground waters from certain deep-well boring and mineral springs (i.e., brines) and natural deposits of sodium nitrate ore (i.e., caliche) found in the northern part of Chile. Only a few marine organisms contain iodine in relatively large quantities including seaweeds, sponges, and corals. The different production processes for recovering iodine are based on the raw materials used. Approximately 54% of the iodine consumed in the world is obtained from Chile as a coproduct from surface mineral deposits used to produce nitrate fertilizers (USGS 2002). About 43% of the iodine consumed in the world comes from brines processed in Japan, the United States, and the former Soviet Union. The primary production process for recovery of iodine from brines is the blow-out process. The blow-out process for brines can be divided into brine clean-up, iodide oxidation followed by air blowing and recovery, and iodine finishing. In 2001, iodine was recovered from brines by the blow-out process by three companies operating in Oklahoma, which accounted for 100% of the U.S. elemental iodine production. These three companies are IOCHEM Corporation (Dewey County, Oklahoma), North American Brine Resources (Dover, Oklahoma), and Woodward Iodine Corporation (Woodward County, Oklahoma). Production of iodine in the United States has remained steady ranging from 1,270 to 1,620 metric tons between the years 1996 and 2000 (Lauterbach and Ober 1995; USGS 1998, 2002).

After World War II, the U.S. government began stockpiling iodine for defense applications. By 1968, the DOD had acquired 3,700 metric tons of iodine. In 1992, Congress determined that the stockpile was unnecessary, reduced the stockpile goal to zero, and authorized the sale of all excess material. As of September 30, 2001, the uncommitted inventory of stockpile-grade iodine was 1,629 metric tons (USGS 1998, 2002).

The only naturally occurring isotopes of iodine are  $^{127}\text{I}$  and  $^{129}\text{I}$ , which are stable and radioactive, respectively. Other radioactive iodine isotopes (e.g.,  $^{131}\text{I}$ ) do not occur in nature; they are the direct result of anthropogenic activity. As discussed in Chapter 4,  $^{129}\text{I}$  and  $^{131}\text{I}$  are produced by nuclear fission. Nearly all of the  $^{129}\text{I}$  and  $^{131}\text{I}$  generated in the United States is present in spent nuclear reactor fuel rods. These fuel rods are currently located at commercial reactor facilities or at Department of Energy (DOE)

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facilities across the United States. The cumulative yield of  $^{129}\text{I}$  is about 1% of all fission products. Thus,  $^{129}\text{I}$  represents only a very small fraction of the total fission product inventory in the nuclear fuel cycle. A limited amount of  $^{123}\text{I}$ ,  $^{125}\text{I}$ , and  $^{131}\text{I}$  will be produced for industrial, scientific, and medicinal applications by International Isotopes Inc. (Denton, Texas) using a linear accelerator (DOE 1996d; International Isotopes 2001; USGS 1998).

## 5.2 IMPORT/EXPORT

In 2000, 77% of the apparent consumption of iodine in the United States (6,320 metric tons) was imported. Of the 4,790 metric tons of iodine imported in 2000, approximately 67% was imported from Chile, 21% from Japan, and 11% from Russia. Exports of iodine have decreased from 2,410, 2,760, and 2,790 metric tons in 1996, 1997, and 1998, respectively, to 1,130 and 900 metric tons in 1999 and 2000, respectively (USGS 1998, 2002).

## 5.3 USE

End uses for iodine in 1999 were estimated from a United States Geological Survey (USGS) canvass of consumers as follows (by percentage): sanitation (45%); animal feed (27%); pharmaceutical (10%); heat catalyst (8%); stabilizers (5%); and other (5%) (USGS 1999). Other smaller uses included inks and colorants, photographic chemicals, laboratory reagents, production of batteries, high-purity metals, motor fuels, and lubricants. Hydrogen iodide (i.e., HI) is used in the manufacture of hydroiodic acid and organic iodo compounds, and to remove iodine from iodo compounds. Potassium iodide (i.e., KI) is used in animal feeds, catalysts, photographic chemicals, for sanitation, and for treatment of radioiodine poisoning resulting from nuclear accidents. Sodium iodide (i.e., NaI) is used in photography and for the production of organic chemicals. Methyl iodide (i.e.,  $\text{CH}_3\text{I}$ ) is used as a methylation agent in organic synthesis, in microscopy, as an embedding material for examining diatoms, and in testing for pyridine. Potassium iodate (i.e.,  $\text{KIO}_3$ ) is used in salt iodization, as an oxidizing agent in analytical chemistry, and as a maturing agent and dough conditioner (Lauterbach and Ober 1995; USGS 1998).

Radioactive iodine has been used successfully for the treatment of cancer of the thyroid. The radioactive isotope  $^{123}\text{I}$  is considered the agent of choice for brain, thyroid, and renal imaging and uptake measurements.  $^{125}\text{I}$  is used as a cancer therapeutic, and as a brain, blood, and metabolic function diagnostic.  $^{131}\text{I}$  is used as a brain, pulmonary, and thyroid diagnostic (Lauterbach and Ober 1995; USGS 1998).

## 5.4 DISPOSAL

Most nonradioactive iodine minerals, iodine compounds, and iodine-containing materials do not require special disposal or handling requirements. However, some chemical forms may be classified as hazardous materials if the compound is chemically reactive, flammable, or toxic. Care should be taken to read and understand all of the hazards, precautions, and safety procedures for each specific chemical form. In addition, all federal, state, and local laws and regulations should be investigated and subsequently followed with regard to disposal and handling of the specific chemical form of the iodine compound or material.

Radioactive iodine does require special disposal and handling requirements and is regulated by the Nuclear Regulatory Commission. Radioactive waste-containing radioactive iodine can be grouped into three categories: low-level waste (LLW); high-level waste (HLW) and spent nuclear fuel; and mixed waste. As defined by the Nuclear Waste Policy Act, high-level radioactive waste is “the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentration.” However, most classifications of HLW also include spent nuclear fuel. Most HLW was generated from the production of plutonium. A small fraction is related to the recovery of enriched uranium from naval reactor fuel. This waste typically contains highly radioactive, short-lived high activity fission by-products as well as other long-lived isotopes, hazardous chemicals, and toxic heavy metals. Radioiodine contamination is only a small fraction of the activity of HLW. Liquid HLW is typically stored in large underground tanks of either stainless steel or carbon steel depending on whether they are acid or alkaline solutions. There are about 100 million gallons of high-level liquid waste stored in underground tanks in Washington, South Carolina, Idaho, and New York. These tanks contain a variety of radioactive liquids, solids, and sludges. Some of the liquid wastes have been solidified into glass, ceramic slag, salt cakes, and sludges (DOE 1996a; Murray 1994).

Spent nuclear fuels, such as fuel elements and irradiated targets used in nuclear reactors, are currently disposed of at the commercial nuclear power plants and DOE facilities where they were produced. Spent fuel is highly radioactive due to the large concentration of fission products and must be stored in special water-cooled pools that shield and cool the material. Most of the radioactive iodine remains trapped in the spent fuel rod matrix and is never released. Roughly all DOE spent fuel, about 3,000 metric tons, is stored at four sites: Hanford, Savannah River, Idaho National Engineering and Environmental Laboratory

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(INEEL), and West Valley, New York. Commercial reactors have generated more than 30,000 metric tons of spent fuel. The spent fuel from these facilities is stored at the more than 100 commercial nuclear reactor sites around the United States. Since spent commercial nuclear reactor fuel is placed in on-site storage while awaiting off-site disposal, the only isotope of iodine remaining in the fuel matrix when it leaves the generating facility will be  $^{129}\text{I}$ . The establishment of an HLW and spent fuel repository for both DOE and commercial waste is currently under construction at Yucca Flats, Nevada. It is not projected to be in operation until after the year 2010 (DOE 1996b, 2001d; Eisenbud 1987; Murray 1994). A temporary storage site for spent fuel rods has been proposed on the Goshute Indian Reservation in the Skull Valley of Utah (MHR 2001; NCSL 2002). However, as of 2003, the U.S. Nuclear Regulatory Commission (USNRC) has blocked the issuance of a license for the project (USNRC 2003).

Mixed waste contains both radioactive and chemically hazardous materials such as toxic, corrosive, flammable, or explosive materials. The radioactive component may be either HLW or LLW. All liquid HLW is mixed waste, usually in the presence of organic solvents or heavy metals in addition to radioactive components. Disposal of mixed wastes is regulated by the EPA under the Resource Conservation and Recovery Act (RCRA) and by the USNRC under the Atomic Energy Act. The EPA and the USNRC have developed special procedures on how to handle and dispose of this special category. The DOE operates an incinerator in Oak Ridge, Tennessee, which burns mixed hazardous radioactive wastes (DOE 1996a).

Low-level waste is all radioactive waste that cannot be classified as HLW, spent fuel, or mixed waste. Low-level does not necessarily mean low radioactivity or low environmental hazards. However, the bulk of LLW has relatively little radioactivity and practically no transuranic elements. Thus, LLW usually does not require shielding from radioactivity or heat removal equipment. Most LLW is acceptable for near surface land disposal. LLW types that may be contaminated with  $^{129}\text{I}$  include both wet and dry wastes. Examples of the physical form of LLW are spent ion exchange resins, filter sludges, filter cartridges, evaporator bottoms, compactible trash, noncompactible trash, irradiated components, ashes produced from the incineration of combustible material, contaminated detergents or solvents, organic liquids, and discarded contaminated equipment or tools. Of the LLW generated today, approximately 64% of the volume and 70% of the radioactivity are generated as a result of nuclear power plant activities or supporting fuel cycle operations. Other sources of LLW are industrial, academic, government, and medical. Radioiodine contamination accounts for only a small fraction of the activity of LLW. LLW typically is packaged in drums or boxes and buried in shallow pits or trenches. Approximately 3 million cubic meters of LLW generated in the United States have been disposed of this way. LLW from DOE

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sources is currently disposed of at several DOE facilities across the United States. Only three sites accept non-DOE LLW, Barnwell, South Carolina; Richland, Washington; and Envirocare of Utah, Inc. (Clive, Utah). Over half of the LLW in the eastern United States is disposed of at the Barnwell site. As required by the Federal LLRW (Low Level Radioactive Waste) Policy Act in 1980 and the 1985 amendments, states or interstate compacts are required to build facilities to contain LLW generated from sources within their boundaries. However, other than Barnwell, South Carolina; Richland, Washington; and Clive, Utah sites, no other facility in the United States is currently accepting LLW from non-DOE sources. Currently, many generators store LLW on-site until additional facilities can be constructed in the future (DOE 1996a; Eisenbud 1987; Envirocare 2001; Murray 1994).

Decay on-site is one method chosen in the medical community to handle their low level radioiodine waste. Contaminated clothing, food trays, linen, materials used to clean patients' rooms, furniture, and telephones are quarantined until levels of radioiodine are sufficiently low. A period of 10 half-lives may be adequate to reduce the radioactivity to safe levels to permit reuse of the materials without controls.

