



Review

Materials and processes for the effective capture and immobilization of radioiodine: A review



Brian J. Riley^{a,*}, John D. Vienna^a, Denis M. Strachan^b, John S. McCloy^c,
James L. Jerden Jr.^d

^a Pacific Northwest National Laboratory, Richland, WA 99352, USA

^b Strata-G, LLC, Knoxville, TN 37932, USA

^c School of Mechanical and Materials Engineering, Washington State University, Pullman, WA 99164, USA

^d Argonne National Laboratory, Lemont, IL 60439, USA

ARTICLE INFO

Article history:

Received 30 July 2015

Received in revised form

18 November 2015

Accepted 20 November 2015

Available online 2 December 2015

Keywords:

Radioiodine

Waste forms

Iodine capture

Reprocessing

ABSTRACT

The immobilization of radioiodine produced from reprocessing used nuclear fuel is a growing priority for research and development of nuclear waste forms. This review provides a comprehensive summary of the current issues surrounding processing and containment of ^{129}I , the isotope of greatest concern due to its long half-life of 1.6×10^7 y and potential incorporation into the human body. Strategies for disposal of radioiodine, captured by both wet scrubbing and solid sorbents, are discussed, as well as potential iodine waste streams for insertion into an immobilization process. Next, consideration of direct disposal of salts, incorporation into glasses, ceramics, cements, and other phases is discussed. The bulk of the review is devoted to an assessment of various sorbents for iodine and of waste forms described in the literature, particularly inorganic minerals, ceramics, and glasses. This review also contains recommendations for future research needed to address radioiodine immobilization materials and processes.

© 2015 Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Contents

1. Introduction	308
2. Radioiodine partitioning in a nuclear fuel reprocessing plant	309
2.1. Iodine in UNF	309
2.2. Fate of iodine during reprocessing of UNF	309
3. Iodine capture	309
3.1. Aqueous scrubbing options to capture iodine	310
3.1.1. Caustic scrubbing	311
3.1.2. Alternative scrubbing methods	311
3.2. Solid sorbents	311
3.2.1. Metal-exchanged ceramics	312
3.2.2. Silver-functionalized silica aerogels (AgAero)	312
3.2.3. Non-oxide, chalcogen-based aerogels (chalcogels)	312
3.2.4. Metal-organic frameworks (MOFs)	312
3.3. Processes for obtaining iodine precursors for waste form processing	312
3.3.1. Caustic scrub	312
3.3.2. General iodine streams	313
4. Waste form strategies for disposal of radioiodine	313
4.1. Consolidation options	314
4.2. Direct disposal of iodide or iodate salts	315

* Corresponding author.

E-mail address: brian.riley@pnnl.gov (B.J. Riley).

4.3. Glass 315

4.3.1. Borosilicate glass 315

4.3.2. Silver oxide glass 316

4.3.3. Phosphate glass 316

4.3.4. Lead glass 316

4.3.5. Chalcogenide glass 316

4.4. Glass ceramics 316

4.5. Ceramic composites 317

4.6. Cement 317

4.7. Inorganic minerals and ceramics 317

4.7.1. Methods for incorporating ions into minerals 317

4.7.2. Titanate ceramics 318

4.7.3. Sodalite 318

4.7.4. Cancrinite 319

4.7.5. Silver zeolite (AgZ) 319

4.7.6. Apatite: calcium phosphates (CaP) 319

4.7.7. Apatite: lead vanadates (PbV) 320

4.7.8. Bismuth oxides 320

4.7.9. Iodoboracite 320

4.7.10. AgNO₃-impregnated alumina (AgA) 320

4.7.11. AgNO₃-impregnated silica (AgS) 321

4.7.12. Silicon carbide (SiC) 321

5. Summary and conclusions 321

Acknowledgments 321

References 321

1. Introduction

Nuclear fuel treatment (such as reprocessing) and some nuclear accidents liberate radioactive iodine isotopes, principally ¹²⁹I and ¹³¹I, into aqueous solutions and gas streams. Iodine-131 raises concerns in nuclear accidents due to its high activity (half-life, *t*_{1/2} = 8.04 d) and the potential for incorporation into the human metabolic process [1–5]. This isotope does not pose a long-term disposal risk, because it decays to essentially zero dose (~4.6 × 10^{−28} of the starting inventory) in 2 y (see Table 1). Iodine-129, on the other hand, raises concerns for used nuclear fuel (UNF) reprocessing due to its very long half-life (*t*_{1/2} = 1.6 × 10⁷ y) and

high mobility in most geological environments. In fact, ¹²⁹I is consistently found to be one of the largest dose contributors in geologic repository performance assessments [6–8], despite the relatively low specific activity.

Sensitivity studies have been performed to determine the impact of iodine-containing waste forms on the projected dose to exposed individuals [7,9]. To make a significant difference in disposal system performance, the durability of the iodine- (and/or chlorine)-containing waste form should have a fractional degradation rate lower than 10^{−5} y^{−1}. In other words, if the fraction of the waste form dissolved per year is lower than 10^{−5}, then waste form durability does not significantly affect dose to an exposed

Table 1
Isotopes present in 51 GWd (tHM)^{−1} fuel at the time of discharge from a pressurized water reactor and after 2-y and 5-y cooling. Values are in g (tHM)^{−1}.

Isotope	Discharge	2 y	5 y
¹²⁷ I	8.25 × 10 ¹	8.45 × 10 ¹	8.45 × 10 ¹
¹²⁸ I	3.07 × 10 ^{−4}	—	—
¹²⁹ I	2.73 × 10 ²	2.75 × 10 ²	2.75 × 10 ²
¹³⁰ I	2.50 × 10 ^{−2}	—	—
^{130m} I	1.20 × 10 ^{−4}	—	—
¹³¹ I	7.50 × 10 ⁰	3.46 × 10 ^{−27}	—
¹³² I	1.29 × 10 ^{−1}	—	—
¹³³ I	1.62 × 10 ⁰	—	—
^{133m} I	6.41 × 10 ^{−6}	—	—
¹³⁴ I	7.52 × 10 ^{−2}	—	—
^{134m} I	5.65 × 10 ^{−4}	—	—
¹³⁵ I	4.91 × 10 ^{−1}	—	—
¹³⁶ I	8.15 × 10 ^{−4}	—	—
^{136m} I	2.63 × 10 ^{−4}	—	—
¹³⁷ I	2.32 × 10 ^{−4}	—	—
¹³⁸ I	2.97 × 10 ^{−5}	—	—
¹³⁹ I	4.91 × 10 ^{−6}	—	—
¹⁴⁰ I	4.85 × 10 ^{−7}	—	—
¹⁴¹ I	3.80 × 10 ^{−8}	—	—
¹⁴² I	2.85 × 10 ^{−9}	—	—
¹⁴³ I	3.24 × 10 ^{−10}	—	—
¹⁴⁴ I	1.08 × 10 ^{−11}	—	—

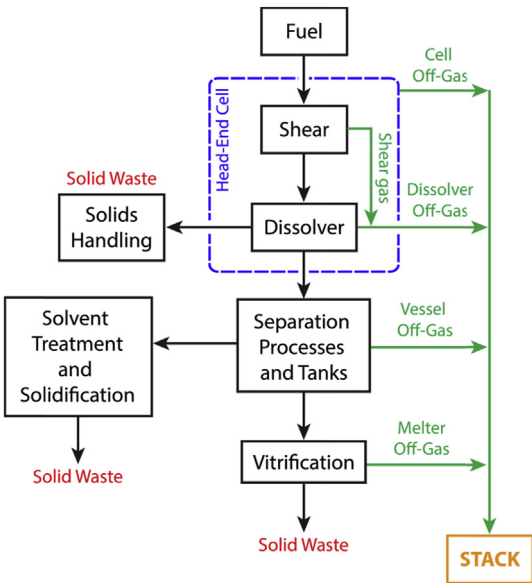


Fig. 1. Schematic of typical unit operations for an aqueous-process-based UNF reprocessing plant from Jubin et al. [24].

Download English Version:

<https://daneshyari.com/en/article/7964529>

Download Persian Version:

<https://daneshyari.com/article/7964529>

[Daneshyari.com](https://daneshyari.com)