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Review

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

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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.

Contents

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1. Introduction

Nuclear fuel treatment (such as reprocessing) and some nuclear accidents liberate radioactive iodine isotopes, principally ^{129}I and ^{131}I, 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 ($t_{1/2} = 1.6 \times 10^7$ y) and high mobility in most geological environments. In fact, ^{129}I 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 (tIHM)$^{-1}$ fuel at the time of discharge from a pressurized water reactor and after 2-y and 5-y cooling. Values are in g (tIHM)$^{-1}$.

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}	–	–

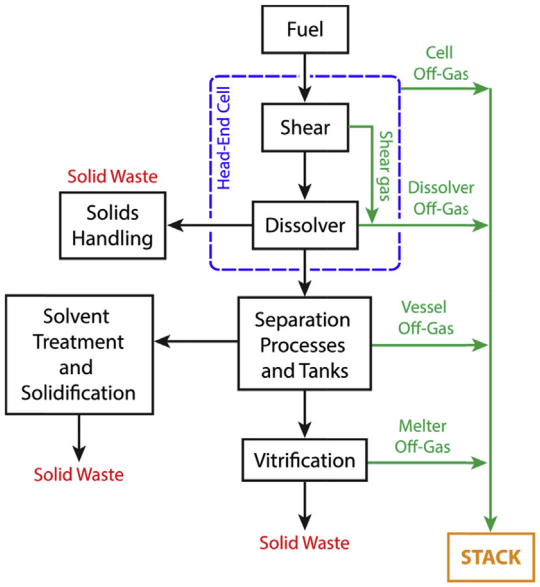

Fig. 1. Schematic of typical unit operations for an aqueous-process-based UNF reprocessing plant from Jubin et al. [24].