**Contract No:**

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*LDRD-2021-00228*
*LDRD External Report Summary*

**Title of Project**
Microbially Influenced Separation of Uranium Isotopes

**Project Start and End Dates**
Project Start Date: October 2021
Project End Date: October 2022

**Project Highlight**
This project explores the use of microorganisms to separate uranium-236 from spent nuclear fuel through metal reduction processes.

**Project Team**
Principal Investigator: Beth Lewczyk
Team Members: Robin Brigmon, David DiPrete, Lisa Ward
External Collaborators (all external collaborators and their respective organizations that participated in this project: Ken Czerwinski (UNLV)

**Abstract**
The US nuclear industry is on the cusp of significant growth in the areas of advanced reactors, SMRs, and microreactors. The existing commercial nuclear reactor fleet is considering expanding the life of the reactor cores by slightly increasing enrichment of their fuel. The common thread is the demand for High Assay Low Enriched Uranium (HALEU). A technical challenge exists with a blend down of Highly Enriched Uranium (HEU) from spent nuclear fuel (SNF) to meet the American Society for Testing and Materials (ASTM) and the "Y12" specifications. U-236 impacts reactor performance and is not desired in fresh fuel cores. In order to meet tight specifications, U-236 must be diluted by addition of fresh HEU. Fresh HEU is highly sought after and not plentiful in the US. A solution to this issue lies in the application of a technology to selectively remove the U-236 with non-hazardous microorganisms, which will be evaluated in this project by experimentally separating different isotopes of uranium.

**Objectives**
- Explore an alternate method of isotopic separation of uranium through microorganisms
- Use microorganisms with planned application to HALEU production by looking to remove U-236 from SNF

**REVIEWS AND APPROVALS**

**1. Authors:**

___Beth Lewczyk___________________________________________

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Name and Signature                                                                 Date

**2. Technical Review:**

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Name and Signature                                                                 Date

**3. PI's Manager Signature:**

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Name and Signature                                                                 Date

**4. Intellectual Property Review:**

This report has been reviewed by SRNL Legal Counsel for intellectual property considerations and is approved to be publicly published in its current form.

**SRNL Legal Signature**

______________________________________________________________________________

Name and Signature

**Introduction**

Currently many studies of uranium isotopic separation focus on the separation of U-235/U-238 without taking into consideration U-236. By looking at separating U-236 there is added technical difficulty as U-236 is generally seen concentrating alongside U-235 and U-233 as well as U-234 and U-232. Additionally, U-236 is found only in SNF and reprocessed uranium, giving the Savannah River National Laboratory (SRNL) a unique opportunity to use its available reserve of materials to perform microbiological separations of U-236 from SNF.

The methods for uranium isotopic separation currently in place are not expected to have commercial availability until 2023-2024, while demands for HALEU expecting to reach almost 600 MT by 2030 as shown in Figures 1 and 2. Having an additional method of HALEU production is imperative for SRNL as the electrochemical processing is only estimated to deliver approximately 5 MT of 19.75% U – 10Zr fuel by 2023, and by 2020 the hybrid zirconium extraction process (ZIRCEX) is only at a ¼ scale facility, leaving a wide margin of need left unfulfilled. Currently, the H-Canyon processes SNF to eventually create a uranyl nitrate solution. Bioremediation has been used extensively to reduce uranium in environmental applications for soil, sediments, and groundwater. If applied here, microorganisms in a bioreactor would be able to work with an already dissolved form of uranium to begin an isotopic separation and partially purify the uranyl nitrate from the U-236 poison. The utilization of microorganisms in order to separate uranium isotopes is a way to help alleviate the increasing need for HALEU production while advancing SRNL's potential in the field of microbial heavy metal reduction, by looking specifically at U-236, then applying the process to reactor fuel production.

**Approach**

In the first phase of the project, microorganisms have been cultured and media obtained and formulated for the metabolic needs of each microorganism to allow for the most optimal metal reduction environments. The microbial cultures have successfully been maintained such that live cells are always available for testing. Once the capabilities of these microorganisms are assessed in initial trials of uranium metal reduction, the approach will be refined to observe the potential for isotopic separation of U-236 in SNF.

The second phase of the project includes the isotopic analysis of the media. It is expected based on previous evidence that the microorganisms will successfully reduce soluble uranium into an insoluble form, creating a precipitate. The precipitate should have a different concentration of uranium isotopes than in the original solution, therefore demonstrating a microbially influenced separation of uranium isotopes to be analyzed by Inductively Coupled Plasma Mass Spectrophotometry (ICP-MS).

**Accomplishments**

- Microorganisms with previously proven U235/U238 separation have been procured. Additional microorganisms with uranium metal reduction capabilities have been procured for testing
- Microorganisms' viability in testing media has been established for a period of up to 7 days
- Metal reduction testing apparatus has been designed and installed
- Highly Enriched Uranium with the isotopes U-234, U-235, U-236 and U-238 has been procured for testing
- Specialized medium has been prepared for U biotransformations
- Hazard Analysis complete for FY22 isotopic separation experiments

**Future Directions**

- Metal Reduction trials with all procured microorganisms
    - Compare results between microorganisms with previously proven isotopic separation capabilities and untested microorganisms
    - Based on FY22 results evaluate scale-up opportunities
- H-Canyon uranyl nitrate
    - After assessing trials with HEU material, observe potential for isotopic separation with SNF material
- L-Basin microbial consortia
    - Assess uranium metal reduction capability of microorganisms isolated from a nuclear storage basin
    - Samples scheduled for delivery to SRNL in FY22

**FY 2021 Peer-reviewed/Non-peer reviewed Publications**

n/a

**Intellectual Property**

n/a

**Total Number of Post-Doctoral Researchers**

n/a

**Total Number of Student Researchers**

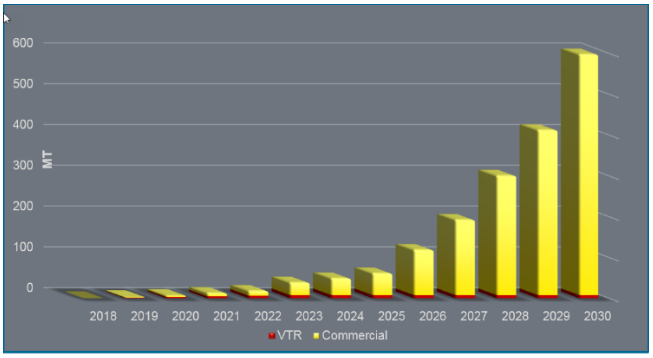
n/a

**Include all images, charts and figures with captions, as shown below.**

| Company | A | B | C | D | E | F | G | H | Total | Cumulative |
|---|---|---|---|---|---|---|---|---|---|---|
| Enrichment Range | 13-19.75% | 19-19.75% | 10-19.75% | 15.5% | 19.75% and 12.6% | 19.75% | 17.5% | 14.4% | | |
| Year | | | | | | | | | | |
| 2018 | 0.001 | | | 0.025 | | | | | 0.026 | 0.026 |
| 2019 | 0.006 | 1.5 | | | | | | | 1.506 | 1.532 |
| 2020 | 0.7 | 1.5 | 0.01 | | | | | | 2.21 | 3.7 |
| 2021 | 0.7 | 2.5 | | | | 1.0 | | | 4.2 | 7.9 |
| 2022 | 0.7 | 3.0 | | | | | | | 3.7 | 11.6 |
| 2023 | 0.7 | 3.5 | 1.1 | | 13.5 | | | | 18.8 | 30.4 |
| 2024 | 0.7 | 5.0 | 1.1 | | | 3.0 | | 0.5 | 10.3 | 40.7 |
| 2025 | 0.7 | 6.0 | 1.8 | 0.4 | | 3.0 | | 0.5 | 12.4 | 53.1 |
| 2026 | 23.3 | 7.0 | 1.8 | 0.4 | | 3.0 | 21.4 | 0.5 | 57.4 | 110.5 |
| 2027 | 35.0 | 9.0 | 1.8 | 0.9 | | 5.0 | 21.4 | 0.5 | 73.6 | 184.1 |
| 2028 | 46.6 | 11.0 | 1.8 | 1.8 | | 25.0 | 21.4 | 0.5 | 108.1 | 292.2 |
| 2029 | 58.3 | 13.0 | 1.8 | 1.8 | | 15.0 | 21.4 | 0.5 | 111.8 | 404.0 |
| 2030 | 70.0 | 13.5 | 1.8 | 1.8 | 61.0 | 15.0 | 21.4 | 1.0 | 185.5 | 589.5 |

https://www.nei.org/resources/letters-filings-comments/nei-letter-perry-need-haleu

Figure 1: NEI Estimated Annual Commercial Requirements for HALEU to 2030 (MTU/yr)




Source for Industry Demand: Nuclear Energy Institute's letter to Secretary Perry, DOE (July 5, 2018)

Figure 2: Estimated Commercial HALEU Market Needs