**Ph.D. Dissertation Proposal: Paul Mendoza**

**Dissertation Title:** Experimental Characterization of Pu Separation by PUREX Process on a Low-Burnup, Pseudo-Fast-Neutron Irradiated DUO2 for Product Decontamination Factors and Nuclear Forensics

1. **Introduction**

In the wake of the Iran deal, North Korea’s pursuit of nuclear weapons, and the onset of the Islamic State of Iraq and Syria, nuclear proliferation concerns remain relevant. A nonproliferation focal point is the control and accounting of weapons usable material, which has been the responsibility of the International Atomic Energy Agency with the goal of promoting the safe and peaceful use of nuclear technologies1. Although these efforts, backed by an “atoms for peace” mentality and the treaty on the non-proliferation of nuclear weapons, have hindered the development of weapons in some states2, efforts beyond safeguards prevention are necessary due to “the awful arithmetic of the atomic bomb”3. An effort some steps after, and potentially outside of safeguards, but before detonation, is interdicted material origin attribution.

Material origin attribution, in this context, applies to deducing history of nuclear material, specifically weapons usable material. The importance and time sensitivity of which varies widely in different circumstances, but is fundamentally an inverse problem, which are difficult to solve. For example, if a purified sample of plutonium were interdicted at a border between states, information from a wide variety of sources will be used to determine a likely hypothesis for where the sample came from. This hypothesis, is an informed, studied, and tested conclusion, but is only one possible explanation for the history of the sample.

The point is not to say the exercise is meaningless, but difficult and multi-layered. Multi-layered in the sense that there are many different sources of information and an infinite realm of possibility for hypothesis. This study proposes merely to provide another source of information for this complex problem coupled with a nuclear forensic analysis of uniquely irradiated nuclear material.

Previously, computational studies have indicated that analysis of contaminants in Plutonium Uranium Recovery by Extraction (PUREX) processed plutonium could give indications of material origins.4 Unlike enrichment of 235U, 239Pu “enrichment” involves neutron irradiation, which introduces radioactive fission products and hence, purification by some means. Purification by PUREX is most common for low enriched uranium fuel5 - important because 238U converts to 239Pu upon neutron capture. Material attribution is complicated by purification due to varying and unknown elemental decontamination factors (DFs, a measure of purification) for different PUREX procedures.

The problem of attribution for unpurified material has been previously studied4, 6, 7, ideally, if elemental DFs for interdicted plutonium were determined, then these previous methodologies could be used to narrow material origins by applying these correction factors, assuming DFs for different isotopes of the same element are equal. This is visually represented in Figure 1, where the initial plutonium composition is estimated through DFs, and attribution analysis ensues with this estimate.

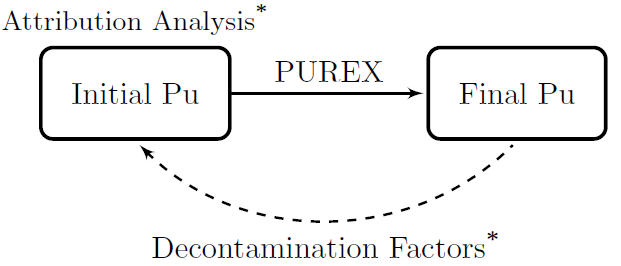


Figure Proposed research areas for irradiated fuel.

1. **Objectives**

The objective of this research is to determine DFs and distribution coefficients (DCs, the ratio of concentrations between organic and aqueous phases) for a developed benchtop scale PUREX process for important attribution elements noted in previous research (Cs, Eu, Rb, Sr, Nd, Pm, Sm, U, and Pu).4 Both DCs and DFs will be determined for this process so that the two parameters will be experimentally connected to the specific PUREX process utilized. This establishment is important because mathematically, DC values, coupled with process information, can be used to calculate a reasonable estimate of a DF8-11, but experimentally, this connection has never been publicly discussed for the PUREX process.

This is probably due to complications in bridging the gap between controlled experiment and practice. Most reported DCs from experiments are for steady state, equal contact volumes systems. Some practical reprocessing plants designs (example: counter current) have constantly changing concentrations and non-equal volumes, which makes mathematically determining DFs from DCs for systems difficult. Reprocessing plants usually measure DFs from initial and final solutions.

This above goal will be met by analyzing mass, gamma, and alpha spectroscopic results from the process steps of a four extraction three back-extraction PUREX process run in triplicate. Each step of the process will be analyzed for DC values, and the overall process will be analyzed so that the DF values will be determined through initial and final solutions and calculated through individual DCs.

Further, several forensic analyses will be undertaken on the sample itself. Among them will be burnup, fluence, initial enrichment, and fuel age calculations in order to determine the applicability of utilizing this information for forensic purposes the uncertainty on the above values will be determined from the three experiments, and attribution analysis . This will be determined by taking a standard deviation of the three different he uncertainty in the DCs and DFs will be estimated, and second, uncertainty in the depletion calculations that arises from thefor the irradiation have a myriad of applications, but on the research purposes to determine the uncertainty in the production of these elements in a thermal system.

1. **Present Status of the Question**

Summarize your literature review. What is the pertinent previous research in this field? Include citations.

While DCs for the various process steps of PUREX have been previously reported, details about elemental DFs for PUREX cycles have been largely limited to the major activity contributors, such as 106Ru and 95Zr12, or the heavy metal elements (Th, U, Pu)13.

1. **Procedure**

Describe your general solution method. If your work is experimental, give the nature of the data you will collect and how you will analyze it. If your work is computational, include a description of how you will verify your methodology (test cases, simulations, sensitivity analysis, etc.).

1. **Expected Results**

Include work already done and what you expect to see in the remaining work. Also talk about risk management – if something doesn’t work as expected, are there alternative soluitons?

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