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Title:

Pollution Prevention Benefits of Non-Hazardous Shielding Glovebox Gloves – 11000

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ABSTRACT

Radiation shielding is commonly used to protect the glovebox worker from unintentional direct and secondary radiation exposure, while working with plutonium-238 and plutonium-239. Shielding glovebox gloves are traditionally composed of lead-based materials, i.e., hazardous waste. This has prompted the development of new, non-hazardous shielding glovebox gloves. No studies, however, have investigated the pollution prevention benefits of these new glovebox gloves. We examined both leaded and non-hazardous shielding glovebox gloves. The nonhazardous substitutes are higher in cost, but this is offset by eliminating the costs associated with onsite waste handling of Resource Conservation and Recovery Act (RCRA) items. In the end, replacing lead with non-hazardous substitutes eliminates waste generation and future liability.

INTRODUCTION

Chemical and metallurgical operations involving plutonium and other nuclear materials in support of the U. S. Department of Energy's (DOE) nuclear weapons program account for most activities performed at the Los Alamos National Laboratory's Plutonium Facility (TA-55). To preclude uncontrolled release, gloveboxes are used to confine plutonium during laboratory work. Gloveboxes used for radioactive materials are maintained at a lower pressure than the surrounding atmosphere, so that microscopic leaks result in air intake rather than hazard outflow. From a structural design standpoint, glovebox gloves are the weakest part of the glovebox system and more susceptible to failure from mechanical, chemical, radiological, and thermo stressors than the glovebox walls or windows. Recognizing this vulnerability, the Glovebox Glove Integrity Program (GGIP) was developed at TA-55 to minimize and/or prevent glovebox glove events. Previous accomplishments of this program have been reported [1]. A key element of the GGIP is the proper selection of glovebox gloves. The low energy and moderately penetrating gamma and X-ray radiation from plutonium easily penetrate the rubber gloves in a glovebox, resulting in a radiation dose to the hands, i.e., extremity dose. Glovebox gloves with a layer of radiation shielding reduce this extremity dose.

Due to its high density, lead has been used for shielding against primary gamma and X-rays. Previous studies have shown lead to be an excellent shield against this type of radiation [2]. Leaded glovebox gloves used for radiation shielding (hereafter referred to as *leaded gloves*) are a commercially available item produced by North Safety by Honeywell. These leaded gloves made from Hypalon® were for many decades the primary glovebox glove of choice for the TA-55 programmatic operations and represented over 75% of the glovebox gloves used (8300 in total). Recent improvements in the Hazard Control System of glovebox operations, i.e., switching from leaded gloves to unleaded glovebox gloves for most non ^{238}Pu operations, have lowered this number to 25% [3]. This has resulted in a reduction of about 3 m^3/yr of mixed transuranic (MTRU) waste, as well, as a reduction in ergonomic injuries.

Since used leaded gloves are considered hazardous waste, i.e., Resource Conservation and Recovery Act (RCRA) items [4], new, non-hazardous shielding glovebox gloves have been developed and are commercially available from Piercan U.S.A. These non-hazardous shielding gloves are composed of three different and inseparable layers: polyurethane, a shielding layer, and Hypalon. Polyurethane provides superior protection against mechanical risk including tears, puncture, cuts, and wear. While the exact formulation is proprietary, the components of the shielding layer consist of bismuth, tungsten, and lanthanum. The dose attenuation properties of these non-hazardous shielding gloves as they compare to leaded ones has recently been reported [5]. In this study, the risks associated with leaded gloves are assessed and the pollution prevention benefits of switching from leaded to non-hazardous shielding gloves are discussed.

RISKS ASSOCIATED WITH LEADED GLOVES

- **RCRA Issues** Leaded gloves are hazardous waste when discarded, and mixed-waste is created when this material becomes contaminated with radioactive material. Thus, discarded but not yet disposed of leaded gloves represent a RCRA liability, as shown in Figure 1 [4].

Figure 1. Recently Replace Glovebox Gloves

- **Mechanical Properties** Leaded gloves are constructed of a layer of lead oxide (Pb_3O_4) dispersed in a Neoprene elastomer, bound between inner and outer layers of Hypalon. Hypalon with its exceptional chemical resistance to acid and alkali products, protect glovebox workers from chemical hazards inside the glovebox. However, the Hypalon layer exposed to the glovebox environment is only 0.2 mm thick. Once this Hypalon layer is worn through, degradation due to chemical, radiological, and mechanical stressors accelerates. An example is shown in Figure 2.

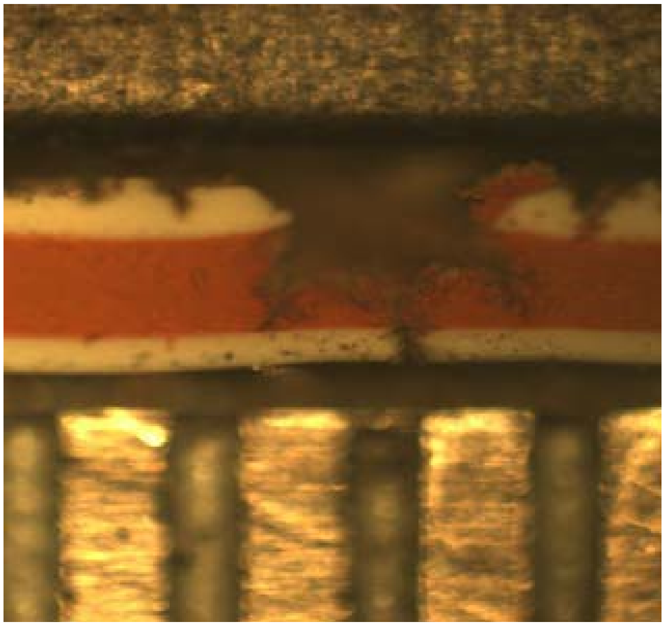

Figure 2. Breakthrough to the Inner Layer

- **Puncture Wounds** Leaded gloves are the least flexible of the glovebox gloves used at TA-55. The lower the flexibility of the glovebox glove, the more likely an injury due to a puncture of the glove will result [6].
- **Ergonomic Injuries:** Leaded gloves increase strain to the upper extremity and back. This is thought to correlate with an increase in ergonomic injuries, particularly injuries resulting from overuse [3].

COST BENEFIT ANALYSIS

Comparison of disposal cost for a variety of radiological waste is shown in Table I.

Table I. Comparison of Radiological Waste Costs.

Waste Type	Unit	Cost per Unit
TRU	m^3	$111K
MTRU	m^3	$111K
MLLW	m^3	$581K
LLW	m^3	$17K

Transuranic (TRU) and Mix transuranic (MTRU) waste cost the same to dispose of; $111K per cubic meter. TRU and MTRU radiological waste costs are the same because of two variances that LANL receives:

- Non-Defense TRU waste is allowed to be buried at Waste Isolation Pilot Plant (WIPP)
- MTRU is being accepted at WIPP

The life cycle costs for a pair of glovebox gloves consist of purchase price and the disposal costs. The cost for a pair of leaded and non-hazardous shielding gloves is $288 and $1100, respectively. TA-55 replaces about 400 shielding glovebox gloves annually. The life cycle costs for year's supply of shielding glovebox gloves are compiled in Table II.

Table II. Annual Life Cycle Costs.

Cost (400 pairs)	Leaded ($K)	Unleaded ($K)
Purchase	115	440
Disposal	872	26
Total	987	466

Leaded gloves and non-hazardous shielding gloves are assumed to be disposed of as MLLW and LLW, respectively. Purchasing non-hazardous shielding gloves cost almost 4 times as much as leaded gloves to buy. Disposal of leaded gloves cost 34 times as much as non-hazardous shielding gloves.

DISCUSSION

No additional hazards are introduced by replacing lead with a tungsten, bismuth, and lanthanum formulation. As previously reported, non-hazardous shielding gloves are a better option from an ergonomic perspective because they have a significantly higher elongation value [5]. These non-hazardous shielding gloves allow for more flexibility and less strain on the upper extremity and the back. This correlates with a decrease in injury, particularly injuries resulting from overuse. In addition, non-hazardous shielding gloves would also be useful for situations in which the use of protective gloves over glovebox gloves is necessary [7]. Loss of dexterity that results when the protective gloves are used is lessened with the use of the more flexible non-hazardous shielding gloves.

Based on radiological waste costs shown in Table I, there is no cost advantage to replacing leaded gloves with non-hazardous shielding gloves. However, if either of the two variances mentioned above were lifted, most leaded gloves would represent mixed waste without a disposal path. The majority of leaded gloves are used in ^{238}Pu operations which for the most are not funded through defense program. If it wasn't for the price incentive of the MTRU disposal costs, most leaded gloves would be disposed of as Mixed Low Level waste (MLLW). Most non-hazardous shielding gloves can be disposed as Low Level waste (LLW).

To supply TA-55 with non-hazardous shielding gloves cost $325K more per year than leaded ones, as shown in Table II. With lead being the fourth most abundant metal, this is not unexpected. Without including disposal cost, leaded gloves are a financially more attractive than their non-hazardous substitute. However, there are significant costs associated with the waste management of leaded gloves. The annual cost of disposing of leaded gloves is $846K more than non-hazardous shielding gloves. From a life cycle prospective, to supply TA-55 with leaded gloves cost $521K more per year to maintain than their non-hazardous counterpart. This adds up to a significant annual expense. One must also consider the regulatory vulnerability that exists when used leaded gloves are left in the glovebox outside of satellite storage area. Intangible costs of occurrence reports and audit findings always make replacing lead with a non-hazardous substitute, a prudent decision in the long-term.

In summary, non-hazardous shielding gloves made from bismuth, tungsten, and lanthanum are equivalent shielding materials and eliminate the toxic and environmental hazards associated with lead without adding hazards. When practicable, complete elimination of lead in the workplace, especially at nuclear facilities, is desired. Onsite waste handling cost associated with leaded glovebox gloves and long-term overhead costs justify these more expensive commercially available non-hazardous substitutes.

CONCLUSIONS

Replacement of leaded gloves with non-hazardous substitutes improves the safety configuration of the glovebox system by reducing MLLW waste generation. Process improvements of this type contribute to an organization's scientific and technological excellence by increasing its operational safety.

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