STUDENT SUMMER INTERNSHIP TECHNICAL REPORT

Mercury Abatement via Strippable Coating Technologies

DOE-FIU SCIENCE & TECHNOLOGY
WORKFORCE DEVELOPMENT PROGRAM

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ABSTRACT

Idaho National Laboratory (INL) is one of the nation's leading laboratories dedicated to research and development in sectors such as nuclear energy, national security and environmental sciences. In an effort to execute effective decontamination while keeping risk at a minimum, INL has been conducting research that would diverge from the conventional method of manual application of decontamination gels and strippable coatings. During his summer 2015 internship at INL, and in collaboration with Dr. Rick Demmer, Mr. Stephen Reese and Mr. Don Fox, DOE Fellow Janesler Gonzalez was tasked with the assignment of evaluating the capacity of commercial strippable coatings to be atomized. This scope of work included optimizing the dilution of four commercially available strippable coatings with either water or ethanol, observing differences in consistency after the addition of particular adsorption additives, and studying the effects of the coating under different conditions.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

Because of its properties, mercury has been used for centuries for innovations such as barometers and thermometers, dental amalgams, batteries, fungicide resistant paint, vapor lamps and several other applications. However, due to the toxicity of mercury in all of its three forms, its use is being curtailed as much as possible and actions such as the Minamata Convention on Mercury have been executed in order to eliminate the anthropogenic release of mercury. The Agency for Toxic Substances & Disease Registry (ATSDR) has registered mercury as third on its Substance Priority List (SPL), a list that outlines the potential for human intoxication based on toxicity and potential for exposure. Mercury poisoning, most commonly through inhalation of toxic vapors, illustrated in Figure 1 (left), has been correlated with neurodegenerative processes and damage to other vital organs.

In the case of a mercury spill, the current methods of decontamination include the use of a special mercury vacuum cleaner and/or mercury decontaminant as shown in Figure 1 (right). These are both very affordable and safe alternatives, but are not without their drawbacks. Mercury vacuums can be effective but can worsen the situation in some cases if it spreads the mercury vapor. This makes it a dangerous practice when dealing with porous surfaces such as concrete and granite. An ideal form of mercury decontamination would be one that keeps personnel at the lowest risk possible, contains the spill in lieu of potentially spreading it, doesn't produce any secondary waste, can be used for non-ideal situations, and makes the waste easier to dispose of.

Figure 1. Mercury vapors exposed under ultraviolet light (left) and hazardous spill team responding to a mercury spill in a school (right).

2. EXECUTIVE SUMMARY

This research work has been supported by the DOE-FIU Science & Technology Workforce Initiative, an innovative program developed by the US Department of Energy's Environmental Management (DOE-EM) and Florida International University's Applied Research Center (FIU-ARC). During the summer of 2015, DOE Fellow Janesler Gonzalez spent 10 weeks doing a summer internship at Idaho National Laboratory under the supervision and guidance of Stephen Reese. The intern's project was initiated on June 1, 2014, and continued through August 6, 2015 with the objective of conducting research on polymer solutions designed to abate mercury.

3. RESEARCH DESCRIPTION

Mr. Gonzalez worked in a laboratory setting under the guidance of Dr. Demmer, Mr. Reese and Mr. Fox with the objective of researching an innovative method for mercury decontamination. Considering that current methods of cleaning up this hazardous substance are not optimal, research and development dedicated to improving these technologies and methods must be emphasized.

Taking place in the Water Chemistry Laboratory at the Materials and Fuels Complex of INL, the scope of work included the evaluation of commercial strippable decontamination gels and coatings before and after dilution and being combined with a small ratio of specific additives. The gels and coatings are listed and categorized in Table 1 below.

Table 1. Gels and Coatings Used for Testing

Product	Chemistry	Viscosity (cP)	Density (lbs/gal)
A: Stripcoat TLC Free	Acrylic	-	9.52
B: Encor 449	Acrylic	600	8.7
C: Carboset 441	Acrylic emulsion	40-125	8.93
D: DeconGel 1108	Mixture	8,000-18,000	8.35-8.65

Because of their adsorption properties and known uptake capacity, activated carbon and elemental sulfur were used as chemical additives to enhance the capability of the coating to abate mercury. In particular, a ratio of 0.0035:1 was used and strictly abided by. The solutions were used to coat coupons of porous material like concrete and granite, as well as non-porous coupons of plastic. Among the equipment used were the proper personal protective equipment, a heavy-duty spray bottle, a laboratory spatula, and a precision balance. The testing that developed within the span of the 10 weeks did not involve any exposure to mercury. Instead, the research entailed 1the evaluation of the integrity of the strippable coatings after being modified. The procedure is outlined below.

To get an idea of the original composition of each coating, their physical properties and curing times, each coating was sprayed onto a porous coupon and a non-porous coupon and allowed to dry, which involved periodic monitoring of the sample. At the same time, different solutions were produced and also sprayed onto similar coupons. The solutions used are shown in Table 2.

Table 2. Additives and Solutions for Testing

Nomenclature
AC-activated carbon
ES-elemental sulfur
Mixture-diluted Coating X (40:60/ 80:20; water)

Solution 1	100 mL of Product + 3.5g AC + 3.5g ES
Solution 2	100 mL of Product + 3.5 g AC
Solution 3	100 mL of Product + 3.5 g ES

Figure 2. Granite coupon sprayed with solution (left) and pulling off the cured coating (right).

Typically, the samples were allowed to dry under an inert atmosphere in a fume hood. In one case, however, coupons were subjected to environmental conditions to evaluate the consistency of the fixative had it been used on a surface outside or in a hot environment.

4. RESULTS AND ANALYSIS

Since this research is still at its very early stages, the results are not conclusive enough to warrant any governing decisions about the project. The conclusions that were made from the experimentation were observational but nonetheless empirical. Outlined below are the hypotheses and outcomes of testing.

Product A

As per the procedure, Product A was first sprayed without any additives onto a non-porous and porous coupon to generate a reference for future comparisons. Product A was diluted with water at a 60:40 ratio. It is also important to note that the coating was applied with over 15 layers of spray. Curing time for the diluted solution was ~3 hours.

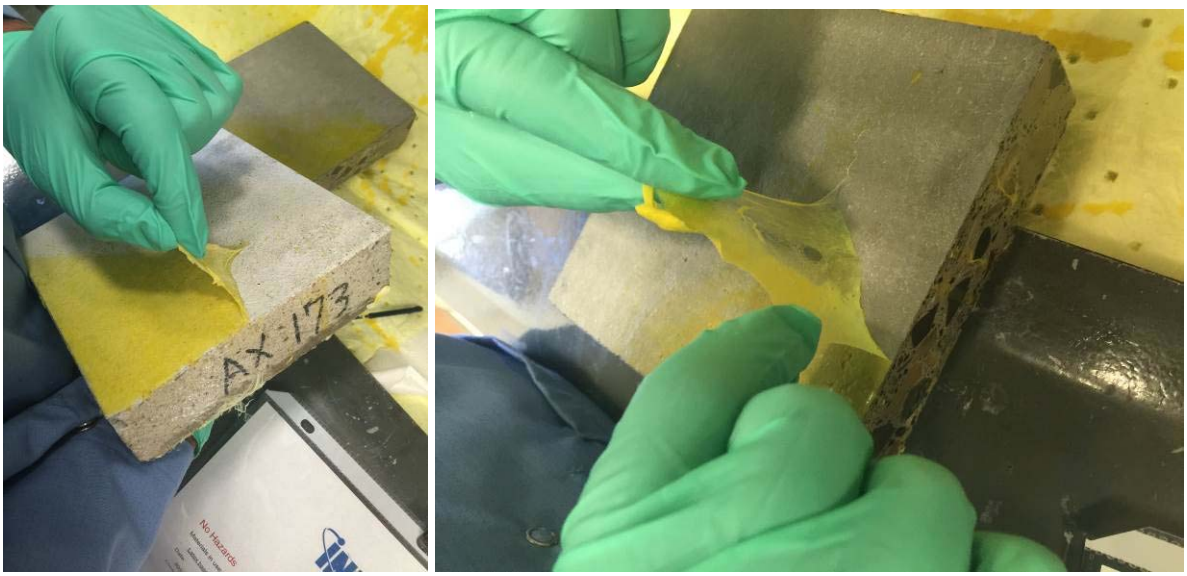

Figure 3. Display of Product A consistency.

The resulting final consistency after drying was tacky, with a very high tensile strength. Most importantly, it was inarguably strippable by hand from a porous surface. When combined with the additives, activated carbon and elemental sulfur, the solution was far too thick to spray using a heavy-duty spray bottle and was applied by means of spreading. Shown in the figure below is Product A containing the additives.

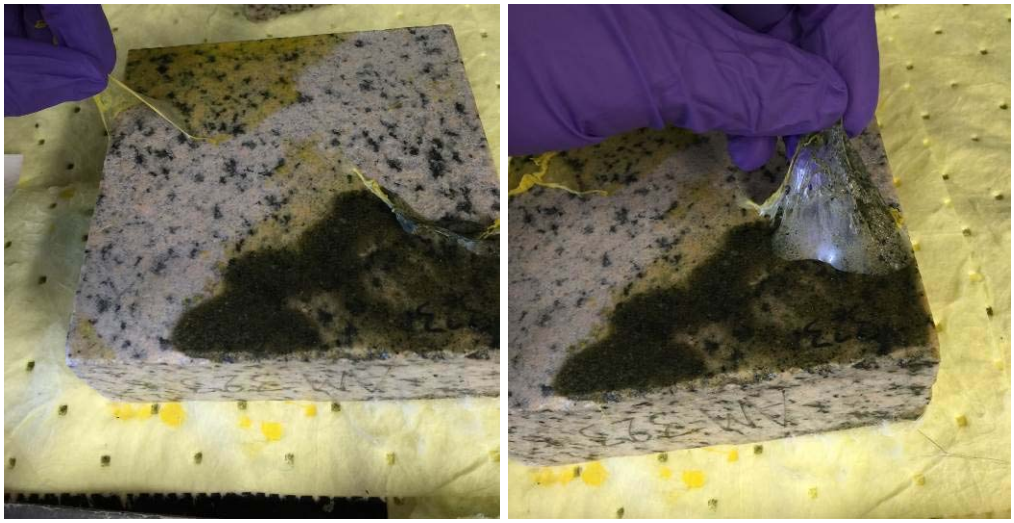

Figure 4. Product A with both additives.

The consistency of the solution with the additives was surprisingly very similar to the original but with added thickness and thus, a higher tensile strength. The additives did not cause a considerable change in curing time, leaving it at approximately the same time, ~3 hours.

To simulate the erosive and/or damaging capacity that environmental conditions would have on Product A, it was applied onto 4 other coupons that were then left outside to cure. The 4 coupons were split into 2 sets; each set had one regular, dry coupon and another that leached water prior to the application of the product. One coupon from each set was placed in the sun to dry and the other coupon from each set was positioned in the shade.

Figure 5. Leached coupon with Product A (left) and non-leached coupon (right).

The effect the sun had on the coatings was directly observable. Not only was the curing time reduced from 3 hours to 1 hour, but the coating lost all cohesiveness and suffered a total loss of tensile strength.

Figure 6. Display of Product A's integrity breakdown in the sun.

As for the coupons that remained in the shade, a surprising mix of results ensued: the curing time was also reduced, this time to approximately 2 hours, but the integrity of the coating was not compromised.

Figure 7. Leached (left) and non-leached (right) coupons cured in the shade (shown once the coating was partially stripped by hand).

Products B and C

In accordance with the same procedure, very different results were obtained for Products B and C. Both products had the ability to be sprayed when diluted with water; the dilutions for Products B and C, respectively, were 60:40 and 80:20. In the images shown below, one can notice the porous coupons have almost totally absorbed the solution. This was the toughest challenge to overcome when trying to peel off the cured solution. In addition, it is important to note that the curing time under the fume hood was reduced more than that of Product A because of this absorption.

Figure 8. Display of thin layer of Product B on porous coupons: thin layer applied to bottom right of coupon (left) and bottom left of coupon (right).

When attempting to remove the coating, we found we were unable to peel it off with our hands due to the thinness of the application and resorted to using a laboratory spatula in order to pry up the corners. Ultimately, the team concluded that Product B was strippable after being sprayed while Product C was too brittle once cured.

Figure 9. Attempts at removing Product C from coupons.

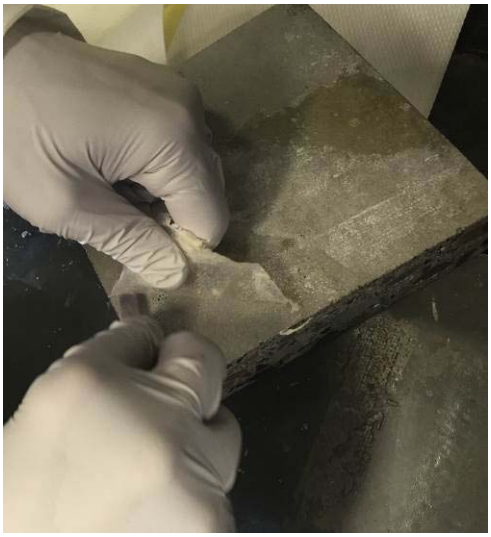

Figure 10. Attempt at removing Product B from coupon.

With the addition of the predetermined ratios of activated carbon and elemental sulfur, the team ran into the same issue of not being able to spray the solution because of the overwhelming viscosity. We, again, resorted to spreading the solution onto the surfaces. The result was that neither coating could be removed from the porous subjects once dry because of the lack of tensile strength and thickness; both coatings became extremely brittle when modified.

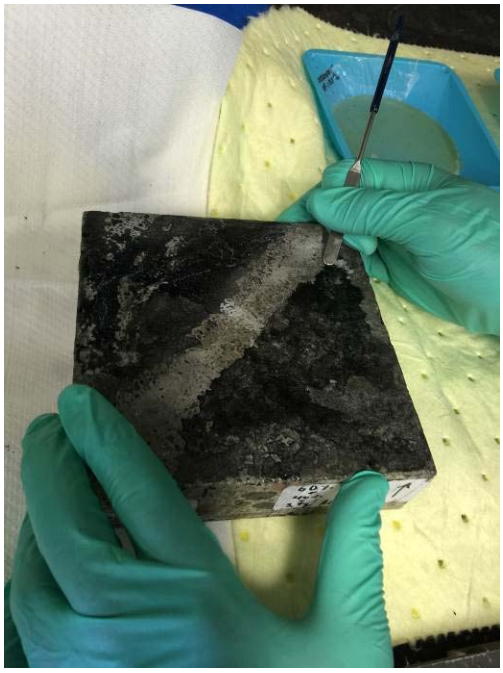

Figure 11. Products B and C were not strippable when combined with additives.

The resolution for this issue could lie in the use of a more effective method of application that would ensure a uniform coating. Making progress towards procuring the technology that can perform at that capacity is urged. The peeling process that requires the use of a laboratory spatula is much more laborious than initially intended.

Product D

Because of the highly viscous nature of this product, a different method of dilution was followed. As a more effective dilution component for Product D, ethanol was used along with water. As an initial reference, the dilution used was 10 parts ethanol, 20 parts water and 20 parts Product D to get a total of 50 mL. Even then, the viscosity of Product D proved to be a bigger issue than expected when attempting to spray it. The solution would spray but would not atomize or release the fluid in a uniform mist but rather as a thick stream. Nonetheless, the team was able to get a uniform coating on the coupon after multiple sprays.

The pictures below display the thickness of the solution and the cohesiveness of the layer after curing. The curing time for this solution was greater than the other products under the fume hood, stabilizing at around ~4-5 hours, but resulted in a more reliable strippable application. More trials need to be done in order to find a better dilution recipe for Product D.

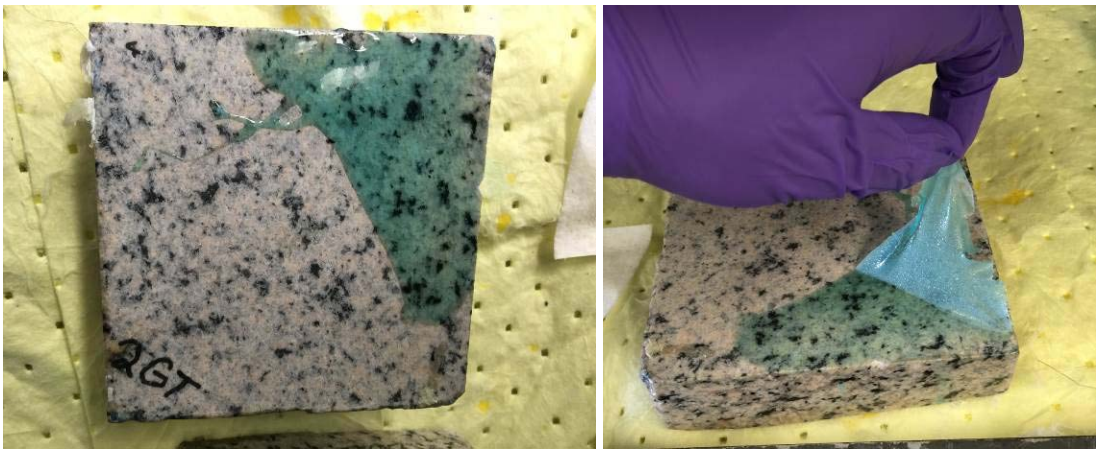

Figure 12. Cured Product D on granite coupon.

5. CONCLUSION

The research Mr. Gonzalez conducted this past summer at Idaho National Laboratory helped advance the progress of technologies that are designed for the abatement of mercury and other hazardous substances. As the early stages of trial and error are complete, progress should be made towards quantifying the results. The next steps to take should be the use of precise measuring tools, more effective forms of atomization, and the incorporation of mercury in small quantities to validate the success of the coatings.

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