ALUMINUM SACRIFICIAL PAINT WITHOUT HEXAVALENT CHROMIUM

AN EXPLORATION OF THE HINKLEY WATER CONTAMINATION CRISIS

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Material Science and Engineering

By
Marcus Dupart

November 8, 2024

Technical Project Team Members:
Katie Anderson and Jesper Bradley

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor guidelines for Thesis-Related Assignments.

ADVISORS

Benjamin Laugelli, Department of Engineering and Society
James Fitz-Gerald, Department of Material Science and Engineering

Introduction

Air pollution is an important factor that influences the World Health Organization's Sustainable Development Goals (SDGs); with it having a direct role in the outcome of Health and Wellness (SDG 3) and Affordable and Clean Energy (SDG 7) while also having an indirect effect on the status of many more which include SDG 11, 12, 13, and 15 (Clean Air Fund, 2023). The United States has invested heavily in its infrastructure to help meet the ambitious goals set out within the SDGs. Legislation such as the Bipartisan Infrastructure Law has increased the resources available to reduce toxic pollutants; with a focus on providing those resources to underserved and overburdened communities, including $100 million for the Pollution Prevention (P2) Grant ("Investments in Pollution Prevention," 2021). Legislation ,such as the P2 Grant, has led to the banning of harmful chemicals that affect the cleanliness of the air by regulatory bodies such as the European Chemical Agency (ECHA) with the Registration, Evaluation, Authorisation ,and Restriction of Chemicals (REACH) set of regulations. One such example of a recently banned chemical is hexavalent chrome (hex-chrome). The California Air Resources Board (CARB) has taken drastic action by banning hex-chrome usage for decorative plating in 2027, and industrial plating common in the aerospace industry by 2039 (Hughes, 2023). Hex-chrome is considered to be a carcinogen and mutagen making the ban necessary due to harmful emissions from the plating process disproportionately endangering the health of people living in disadvantaged communities ("Chromium (VI) compounds," 2023; Hughes, 2023). This has left aerospace companies such as Rolls Royce (RR) actively seeking safer alternatives to hex-chrome in anticipation of impending regulatory bans by CARB and the EU.

For this reason, my capstone group and I have been tasked to find a viable alternative to hex-chrome containing coatings by RR. In collaboration with Luna Labs, we have created a non hex-chrome-containing coating matrix out of two pre-existing options from industry. Throughout this investigation, the corrosion and thermal resistance of these coatings will be tested and compared to that of hex-chrome. Inherently, this project has many technical factors that need to be understood before experimentation. Such as how the coatings would adhere to each other as well as the surface of the substrate. However, there are also many social, political, and economic considerations that are key to understanding why hex-chrome is being banned worldwide. An example of this occurred in the town of Hinkley, California. Where a local gas and electric company called the Pacific Gas and Electric Company (PG&E) dumped hex-chrome wastewater into the drinking water of the local town. To analyze this case, I will draw on the STS framework of actor network theory (ANT) to investigate how non-human actors overwhelm human actors culminating in policy changes.

If companies like PG&E focus only on dumping waste in the most convenient way possible, without addressing the community that it can potentially affect, then they risk perpetuating key social factors that contributed to the health degradation of 650 community members in Hinkley by failing to inform them of the dangers present in their drinking water (Baker, 2015). Because the challenge of eliminating the use of hex-chrome is socio-technical in nature, it requires addressing both the technical and social aspects of hex-chrome to discontinue the chemical successfully. In what follows, I set out two related research proposals: a technical project proposal for finding an existing industry alternative to hex-chrome and an STS project proposal for examining the adverse health effects that have led to hex-chrome being banned.

Technical Project

Hex-chrome has been used as a corrosion inhibitor within the aerospace industry for 70+ years (Pennigton, 2021). At RR, hex-chrome is used within aluminum sacrificial paints to protect steel shafts, gears, and structures from corrosion and thermal oxidation (Wiley & Golden, 2024). These paints are a layer of inorganic polymer that holds aluminum particles within their matrix (Wiley & Golden, 2024). Hex-chrome is a key component in this class of paints and serves two purposes: an inorganic polymeric binder system and provide a passivation action to the surfaces of the aluminum particles, held within the coating. The presence of hex-chrome in these paints represents a hazard due to it being a carcinogen, mutagen, and reproductive toxin (Wiley & Golden, 2024). Due to this, it is at the highest levels of visibility to regulatory bodies such as CARB and ECHA. These regulatory bodies have put pressure on RR to find a suitable alternative to hex-chrome within aluminum sacrificial paints (Wiley & Golden, 2024).

To address these impending regulations, a plethora of different approaches have been taken to try and eliminate all uses of hex-chrome. The most common way is to synthesize a new coating that does not have a carcinogenic chemical in it. Graduate students as well as companies have developed potential formulations for their coatings. For example, a Charlottesville-based company called Luna Labs is currently developing solutions toward this issue called Blockade HT. They currently offer coatings such as Blockade GC and Gentoo that are ready for widespread adoption in industry. Blockade GC is a coating synthesized from smaller molecules to create a larger solution also known as the sol-gel methodology (Shah et al., 2023). This leads to a final material that is high in purity and uniformity; which is great for a coating because it ensures consistent performance that is also predictable. Gentoo is a hydrophobic coating that offers abrasion-resistant fluid repellency on numerous surfaces (“Gentoo Hydrophobic Coatings,” 2022). Both coatings offer great protection against corrosion to temperatures up to

250-275 degrees Celsius (“Blockade GC™ Protective Coating,” n.d.; & “Gentoo Hydrophobic Coatings,” 2022). Another solution comes in the form of the SurTec 643 which is a pretreatment created by the German-based company SurTec. A pretreatment goes onto the substrate before the coating is applied to ensure good adhesion for the layers to come. Therefore it can be said that SurTec 643 provides excellent corrosion protection and paint adhesion (SurTec, n.d.). The final approach is to take a coating that has been created by a third party (Luna Labs for example) and to apply it to a specific use case. For example, RR used the inorganic coating Alseal 5k on various low-carbon steel substrates to see how it performed when put under rigorous corrosion and thermal testing.

The primary challenge with replacing hex-chrome coatings lies in the lack of alternatives that match its corrosion and thermal resistance. This makes it difficult for engineers to adopt non-hex-chrome options, as current substitutes do not perform as effectively. RR has identified and tested an existing industry coating, Alseal 5K, but it did not progress beyond Technology Readiness Level 4 (TRL-4). TRLs, ranging from 1 to 9, measure a technology's maturity level (Manning, 2023). Testing was unable to progress past validation within a real environment or TRL-5 due to the coating not being able to survive a more extreme test environment as well as protect substrates of a more complex geometry such as a curved substrate. Another problem is that it is difficult to develop a coating with the necessary corrosion resistance while also not degrading at high temperatures. For example, Blockade GC is only rated for 250-275°C which is not high enough for the need of RR which is much closer to 700°C.

Due to the lack of suitable alternatives available, my capstone group decided it would be best to create a coating matrix that combined two industry offerings. The topcoat would be Blockade HT, a high-temperature coating currently in development by Luna Labs that is at a

TRL-2 level. Luna Labs is still finalizing the formulation, however, they are estimating that it could withstand up to 1100°C. Blockade HT lacks any inherent corrosion inhibitors, therefore it is necessary to include a base coat that is made to protect against corrosion. For that reason, we selected Zinc Clad II Plus from Sherwin Willaims. This coating was also selected because it has been previously used by Luna Labs with their Blockade GC product with no adhesion problems. Both of these coatings will be applied to AISI 1010 steel, a low-carbon steel substrate. Once this process is complete, we will collect corrosion data using a salt fog machine following ASTM B117 and thermal cycling data using a method previously used by RR when testing the validity of Alseal 5K. I aim to use key skills such as corrosion to refine the experimental design.

STS Project

Between 1952 and 1966, PG&E used hex-chrome to mitigate corrosion in cooling water towers ("PG&E Hinkley Chromium Cleanup," n.d.). The wastewater from the towers was discharged to unlined ponds at the site which directly led to a dramatic increase in hex-chrome concentrations. ("New science informs extent of hexavalent chromium groundwater plumes in Hinkley Valley," 2023). This large amount of hex-chrome then entered the local aquifer and later infected the groundwater as well. This culminated in a direct-action arbitration lawsuit against PG&E in 1996 which resulted in the largest payout ever at the time for that type of case at $330 million (Genecov, 2019). This led to Hinkley becoming a ghost town due to buyouts from PG&E with the few remaining members of the community still fighting to have clean water. In 2019, hex-chrome levels still peaked at over one thousand parts per billion, 100 times the state's maximum contaminant level for the chemical compound.

The current discourse about the water contamination crisis focuses on the difference between naturally occurring hex-chrome versus the amount of hex-chrome that was polluted into

the waterways by PG&E. A study conducted by the United States Geological Survey (USGS) found that the amount of hex-chrome ranged from 2.8-4.8 micrograms per liter with the area of Hinkley being naturally low in chromium ("New science informs extent of hexavalent chromium groundwater plumes in Hinkley Valley," 2023)). One of the goals of this study was to determine if the amount of chromium increased or decreased with time which was used in conjunction with the other research goals to create an updated map of the human-introduced hex-chrome.

These current perspectives fail to mention the long-lasting impacts that hex-chrome has had on the policy that has been developed in recent years. My argument showcases that non-human factors such as hex-chrome, groundwater data, and technological tools (such as water testing equipment), act as critical mediators for the creation of new policy. By not acknowledging the critical side effects of hex-chrome, a key part of its current power over policy is being missed. The main takeaway is that non-human actors play a very large role in policy because they have a large role in our everyday lives. To frame my analysis of the Hinkley Water Crisis, I will draw on the science, technology, and society (STS) concept of ANT. Developed by scholars such as Michel Callon and Darryl Cressman, this framework claims that engineering projects can be seen as a technological network made up of actors of varying backgrounds brought together by a network builder to accomplish a set goal. These network builders construct heterogeneous networks that consist of human and non-human actors that work in conjunction to accomplish a goal set out by the network builder. In this case, the technological network is the PG&E natural gas pipelines that are in the city of Hinkley, with the bad actor being the hex-chrome. A key portion of ANT is that it considers both human and non-human factors (Cressman, 2009). I will use evidence from regulatory bodies such as CARB and geological data

from USGS to showcase the non-human actors. Stories from the people of Hickey were published in Grist to showcase the human actors.

Conclusion

The technical design aims to aid RR in finding a suitable alternative to hex-chrome coatings. The STS portion of the proposal aims to examine the Hinkley water contamination crisis and how non-human actors, such as hex-chrome, can cause a network to fail which culminates in a change in policy. This will be analyzed using the STS framework of ANT with the goal of showing how much nonhuman factors can destabilize an existing network.

Word Count: 2002

References

Baker, C. (2015, July 5). *Hinkley Groundwater Contamination — How Pacific Gas & Electric Avoided Negotiation: A Reassessment of the Changing Scope of Historical Mass Tort Cases*.https://www.cschs.org/wp-content/uploads/2014/03/2016-Writing-Competition3-Baker.pdf

Blockade GC™ protective coating. (2024, March 20). Luna Labs. https://lunalabs.us/product/blockade-gc-corrosion-resistant-fasteners/

California Water Board. (n.d.). *PG&E hinkley chromium cleanup*. Lahontan Regional Water Quality Control Board. Retrieved October 29, 2024, from https://www.waterboards.ca.gov/lahontan/water_issues/projects/pge/

Clean Air Fund. (2023, July 12). *Sustainable Development Goals and air pollution*. Clean Air Fund. https://www.cleanairfund.org/news-item/sustainable-development-goals/

Cressman, D. (2009, April). *A Brief Overview of Actor-Network Theory: Punctualization, Heterogeneous Engineering & Translation*.

Environmental Protection Agency. (2021, November 5). *Investments in pollution prevention*. US EPA. https://www.epa.gov/infrastructure/investments-pollution-prevention

European Chemical Agency. (2023, May 19). *Substance information*. ECHA. https://echa.europa.eu/substance-information/-/substanceinfo/100.305.315

Genecov, M. (2019, January 29). The ‘Erin Brockovich’ town is still toxic (and nearly abandoned). *Grist*. https://grist.org/Array/the-true-story-of-the-town-behind-erin-brockovich/

Gentoo hydrophobic coatings. (2022, August 19). Luna Labs. https://lunalabs.us/product/gentoo-hydrophobic-coatings/

Hughes, E. (2023, July 21). *Proposed EU chrome-plating ban isn't quite what it seems*. Magneto. https://www.magnetomagazine.com/articles/proposed-eu-chrome-plating-ban-isnt-what-it-seems/

Manning, C. G. (2023, September 27). *Technology readiness levels*. NASA. https://www.nasa.gov/directorates/somd/space-communications-navigation-program/technology-readiness-levels/

Pennington, T. (2021, October 3). *Aerospace making progress on switch to cr3*. FinishingandCoating.com. https://finishingandcoating.com/index.php/conversion 837-aerospace-making-progress-on-switch-to-cr3

Shah, V., Bhaliya, J., Patel, G., M., Popaliya, M., Mishra, A., & Patel, P., R. (2023). *Biodegradable polymer nanocomposites as electrode materials for electrochemical double-layer capacitors and hybrid supercapacitor applications*. ScienceDirect. https://www.sciencedirect.com/science/article/abs/pii/B9780323916967000192

SurTec. (n.d.). *SurTec 643*. SurTec. Retrieved October 29, 2024, from https://www.surtec.com/en/products-services/surtec-643/

SurTech. (n.d.). *SurTec 643 Sales Sheet*. SurTec.

United States Geological Survey. (2023, April 26). *New science informs extent of hexavalent chromium groundwater plumes in Hinkley Valley*. U.S. Geological Survey. https://www.usgs.gov/news/state-news-release/new-science-informs-extent-hexavalent-chromium-groundwater-plumes-hinkley

Wiley, B., & Golden, R. (2024). *UVA MSE Capstone Project Submission 2024*.