Thesis Project Portfolio

Production Plant of Nanoparticle Mineral Oxide Sunscreen

(Technical Report)

Exploring Barriers to Sunscreen Development in the United States

(STS Research Paper)

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Sherie Rillera

Spring, 2025

Department of Chemical Engineering

Table of Contents

Executive Summary

Sunscreen use has evolved from a seasonal ritual to a year-round practice, driven by increasing awareness of sun exposure risks. In the United States (U.S.), sunscreens are regulated by the U.S. Food and Drug Administration (FDA) and must follow strict guidelines to ensure consumer safety while providing sun protection. However, these guidelines shape and limit the type of sunscreens that reach consumers. This raises the question: *How do regulatory guidelines affect sunscreens in the U.S.?* With few approved active ingredients, manufacturers must either innovate within strict confines or pursue a time-consuming and costly approval process to introduce new components. This paper explores the issue through two lenses: the technical topic examines the development of a nanoparticle-based sunscreen plant that operates within FDA restrictions. The STS research investigates the broader systemic barriers that hinder sunscreen development in the United States.

The technical project presents a design proposal for a production plant that manufactures nanoparticle-based sunscreen. Two of the most common UV filters in sunscreens are metal oxides, or more specifically, zinc oxide and titanium dioxide. However, these ingredients can leave a white cast on the skin, a white residue. This is because the popular ingredients are solids and are naturally white. This issue can be eliminated by making the ingredients nanoparticle-sized or invisible to the human eye. The product plant involves synthesizing both metal oxides in-house through direct precipitation, followed by several steps to isolate and achieve the desired nanoparticles, forming powders. They are then incorporated during the mixing and emulsification to create the final sunscreen. The plant is designed to produce 5.2 million fluid ounces per year. The expected annual revenue is roughly $52.5 million from the wholesale of the

sunscreen and isopropyl alcohol (or rubbing alcohol), a byproduct of the titanium dioxide process.

The STS research project investigates barriers to sunscreen development in the U.S. While sunscreens should offer UV protection and pleasant textures, U.S. formulations lag behind those in other countries, leading to sunscreens that leave a white cast or a heavy feeling on the skin. When looking for why this is, focus is often placed on the FDA. The FDA classifies sunscreen as an over-the-counter drug, unlike other countries, where they are classified as cosmetics. This classification poses more rigorous testing and longer approval processes. Congress passed several acts to attempt to speed up the process, but they have had little success. Some acts include the 2014 Sunscreen Innovation Act and the 2020 Coronavirus Aid, Relief, and Economic Security Act. Additional barriers include scientific uncertainties, such as the systemic absorption of ingredients and environmental impacts. While there is no conclusive evidence that there are health risks from systemic absorption, skin cancer remains one of the most common cancers in the U.S. This creates a tension between the need for sun protection and a precautionary stance around the unknown risks. These conflicting considerations influence consumer behavior, product availability, and the sunscreen market. By examining multiple perspectives, this research highlights the different factors that influence sunscreen development.

Both projects were successful in achieving their goals. The technical project provided insight into industrial equipment and process development. Although the project is based on small, lab-scale experiments, it would benefit from more testing at larger scales to ensure they are viable. The STS project deepened my understanding of sunscreen regulations and how the different barriers are interconnected. However, the analysis was relatively broad due to the wide scope of topics. Future work would benefit from more in-depth research, such as conducting case

studies around different specific acts by Congress or an investigation into the health risks of sunscreen usage. These experiences highlighted the importance of technical validation and sociotechnical analysis when addressing real-world challenges.