# Forever Chemicals & Temporary Stand-Ins:Effects of a Chemical Surfactant on Chlorophyll Production in Lettuce Plants

Grades 11 & 12

Class Project

20 February 2026

## Abstract

Per- and polyfluoroalkyl substances (PFAS) are a forever chemical that have greatly impacted the Southside of Tucson. PFAS are held together by a Carbon-Fluorine bond that can make products stain-resistant, water-resistant, and heat-resistant, which is very attractive and makes people want it more. Since PFAS do not break down naturally and bioaccumulates in humans which leads to health risks and makes it life-threatening. We were inspired by a news article in “Time” online publication titled “EPA Embraces PFAS Pesticides”. We were surprised given all the known negative outcomes associated with PFAS. As we knew we couldn't use the forever chemical PFAS we used Sodium Lauryl Sulfate (SLS) as a substitute as it causes the same stresses on the plant and is safer. We conducted a stress study on lettuce plants that targeted photosynthesis and chlorophyll production. We prepared four different stress level groups using different concentrations of SLS powder mixed with water; high, medium, and low contamination groups. We measured the levels of relative fluorescence–which measures the unused energy because photosynthesis wasn't able to happen efficiently because of the contamination–from each group. On our second test date, day 13 of the investigation, the contamination group with the highest level of fluorescence was the group with the most SLS contaminant. We originally thought and predicted the relationship would be in an indirect relationship, as contamination increased across test groups, the chlorophyll fluorescence would decrease. However, we did more research to better understand our results. It turns out healthy plants use light energy to make food which produces less fluorescences. When a plant is stressed it can't use all the light energy which produces more fluorescences. We concluded that PFAS isn't safe to use as a pesticide because it doesn't allow proper photosynthesis to occur.

Acknowledgments

This research was conducted with our women in STEM Club during the 2025–2026 academic year as part of our environmental science investigations into PFAS-related impacts on plant systems as well as our wider community.

We would like to express our sincere appreciation to the director of Tucson Water John Kmic for sharing his expertise on Tucson Water's PFAS monitoring and treatment efforts. Additionally, we would like to thank Sofia Forier-Montes from the University of Arizona's Southwest Environmental Health Science Center for providing valuable insight on farming and how PFAS affects crops during her guest presentation. We are also grateful to Tina Fingesi, PhD candidate, for discussing her blood-PFAS health study and expanding our understanding of PFAS exposure pathways. Special thanks are extended to Adelita Grijalva, Arizona's first Chicana Congresswoman for her guidance and support as a guest speaker. She shared her personal and family journey with water contamination through trichloroethylene. We would also like to thank Governing Board Member Beki Quintero for inspiring this project by sharing the news article regarding the EPA's approval of PFAS-containing pesticides, which inspired the direction of our research question. We are grateful for the financial support of our community's non-profit organization, established in 1991 by local district graduates, which funded essential project materials including soil, seeds, greenhouses, and molecular modeling sets.

Finally, we acknowledge the support of our science instructor and peers for their commitment and collaborative work in the laboratory and guidance throughout the planning and execution of this investigation.

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Class Science Fair Project

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# Introduction

Per- and polyfluoroalkyl substances (PFAS) are synthetic chemicals that have been used since the 1940s and are known for their persistence in the environment and ability to bioaccumulate. Although major compounds such as PFOA and PFOS have been phased out, PFAS are still commonly found in water, soil, air, food, and consumer products, leading to widespread human exposure. This exposure has been linked to health concerns, including reproductive issues, increased cancer risk, and immune system disruption, especially in vulnerable populations like pregnant women and children (U.S. Environmental Protection Agency, 2023). Despite these concerns, there is limited research on how PFAS affect soil and plant systems (Forier-Montes, 2026), particularly processes such as chlorophyll production. Because PFAS are too toxic to be used in a high school laboratory, this investigation uses a proxy contaminant with similar properties. This research is especially important as recent government policy changes may reduce protections that limit exposure to environmental contaminants. The problem we aim to address is the need for continued research and regulation to protect environmental and human health.

PFAS are human-made “forever chemicals” used in products like non-stick pans, waterproof clothing, and firefighting foam. They don't break down and can build up in people and the environment (Environmental Working Group, 2025). PFAS are extremely stable

because of their chemical structure. They are synthetic chemicals made of strong carbon–fluorine (C–F) bonds. These bonds allow PFAS to resist heat, water, and oil, which is why they are used in many everyday products (Levy, 2020). However, the same strength that makes PFAS useful also makes them persistent in the environment. Scientists are researching better ways to remove or destroy PFAS, such as using activated carbon or high-temperature incineration. Today's PFAS widespread global contamination has fingerprints back to just a couple of companies, Dupont and 3M (Veritasium, 2025).

## Impact of the Problem

USGS and EWG data show PFAS in tap water, wells, soil, rivers, landfills, military bases, and industrial sites. Over 9,000 U.S. locations have confirmed contamination (Environmental Working Group, 2025). Wilbur Tennant's experience in West Virginia, where his cattle died after being exposed to PFAS contamination from DuPont, led to a major legal case and brought national attention to "forever chemicals." The case resulted in large settlements, important health studies like the C8 Health Study, and increased public awareness of PFAS (Veritasium, 2025). These events, shown in the film *Dark Waters*, highlight the serious health effects on people living near the chemical plant (Veritasium, 2025).

Given our community's history with environmental justice, this is a topic of great concern to us. Trichloroethylene (TCE) was knowingly dumped into unlined ponds by the Hughes Aircraft Company for over 40 years, resulting in groundwater contamination and many deaths and illnesses for the predominantly Hispanic community on the southside of Tucson

Arizona. The health effects are still felt today and the cleanup continues, the Environmental Protection Agency (EPA) designated this site within our district boundaries, a SuperFund Site in September of 1983. This history of TCE water contamination fits the criteria of environmental racism as it disadvantaged a community of color and the agencies contaminating ground water knew of the health hazards associated with the TCE plume (Dominguez, 2022).

This is a topic of great importance to us. When the director of Tucson Water visited our class, we learned that the two largest sources of PFAS in Tucson are located near our school. The two major sources of PFAS are the Tucson International Airport and Davis Monthan Airforce Base. This is because airports practice fire drills often and PFAS are commonly found in firefighting foams (Kmiec & DeRoock, 2026).

Because of our community's history with water contamination, and because we live and attend school so close to two of the major contamination sources, we invited more guest speakers to understand this environmental issue. Another of our guest community speakers informed us that Arizona's economy is heavily dependent on agriculture, specifically cotton and citrus (Forier-Montes, 2026). When we learned that the EPA approved PFAS pesticides, we knew we needed to learn more and test our ideas.

## Research question

How will increasing the concentration of sodium lauryl sulfate (SLS) in water affect the production of chlorophyll in lettuce plants?

## Hypothesis

Increasing the concentration of SLS will decrease the amount of chlorophyll in lettuce leaves.

## Materials & Methods

The materials we used were Black Seed Simpson lettuce seeds, soil, water bottles, greenhouses, rubbing alcohol (91%), filters, plastic bags, and Sodium Lauryl Sulfate (SLS), our PFAS substitute contaminate. We used small beakers with 50mL of water to effectively water the plants with equal amounts of water and the Vernier Spectrovis Go Plus spectrophotometer and LabQuest 3 to measure and read our results for chlorophyll production.

We started planting our seeds, planting 24 lettuce plants for each group (including the control group), and watered them with 50mL of uncontaminated water every 3 days. The plants received 14 hours of sunlight each day. Two weeks after planting, the plants were grown enough to begin contaminating with different amounts of the Sodium Lauryl Sulfate. Each batch of our watering substance had 3,000mL of water and contained 0.03 grams of SLS for our low batch, 0.15 grams of SLS for our medium batch, and 0.30 grams of SLS for our high batch. Our plants were separated by group and labeled to ensure that each batch was being watered with the correct SLS-water mixture.

In the span of our three week testing period, we tested the soil fertility of each group and its pH once a week. We didn't see any significant changes within the pH levels of the soil. Mainly, we tested the fluorescence of chlorophyll once a week, using the results to calculate the chlorophyll production from each contaminate. We did this by testing 10 plants from each batch,

obtaining 3-4 small leaves and combining them with around 25 mL of rubbing alcohol and smashed it to release the chlorophyll. After they were mixed, we filtered out the chlorophyll extract and tested it with the spectrophotometer, reading the results off the LabQuest 3.

As we did this as a class, we shared our data using a spreadsheet to easily share all data and results, and to easily calculate our averages. After recording all results, we compared each test group with each other and created a scatter plot of our results to better interpret the data and identified which test group had the greatest amount of chlorophyll production.

## Results

The relative chlorophyll fluorescence of plants was measured over time by using a Spectrovis plus spectrophotometer for four treatment groups: control, low SLS concentration, medium SLS concentration, and high SLS concentration. These measurements were collected across multiple trials for each group and the averages were calculated to summarize the data. Tables 1-3 below, show the summarized fluorescence values for each treatment group across the different testing days. The control group maintained a consistency of high fluorescence values across all the testing periods, averages remained near the upper range of the dataset.

| Spectrovis Data 2/5/26 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Test Group | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Trial 6 | Trial 7 | Trial 8 | Trial 9 | Trial 10 | AVG |
| | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | |
| Control Group | 0.953 | 0.954 | 0.954 | 0.954 | 0.955 | 0.52 | 0.955 | 0.954 | 0.954 | 0.717 | 0.887 |
| Low Contamination SLS | 0.482 | 0.413 | 0.426 | 0.453 | 0.518 | 0.226 | 0.384 | 0.502 | 0.392 | 0.53 | 0.433 |
| Medium Contamination SLS | 0.785 | 0.973 | 0.94 | 0.942 | 0.677 | 0.945 | 0.714 | 0.968 | 0.967 | 0.966 | 0.888 |
| High Contamination SLS | 0.713 | 0.619 | 0.339 | 0.306 | 0.75 | 0.806 | 0.705 | 0.726 | 0.275 | 0.67 | 0.591 |

Spectrovis Data 2/13/26

| Test Group | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Trial 6 | Trial 7 | Trial 8 | Trial 9 | Trial 10 | AVG |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | |
| Control Group | 0.945 | 0.84 | 0.944 | 0.942 | 0.85 | 0.943 | 0.943 | 0.861 | 0.941 | 0.941 | 0.915 |
| Low Contamination SLS | 0.947 | 0.948 | 0.949 | 0.788 | 0.948 | 0.947 | 0.946 | 0.946 | 0.946 | 0.946 | 0.931 |
| Medium Contamination SLS | 0.954 | 0.954 | 0.954 | 0.951 | 0.951 | 0.953 | 0.951 | 0.95 | 0.949 | 0.949 | 0.952 |
| High Contamination SLS | 0.97 | 0.969 | 0.883 | 0.966 | 0.965 | 0.962 | 0.962 | 0.962 | 0.961 | 0.959 | 0.956 |

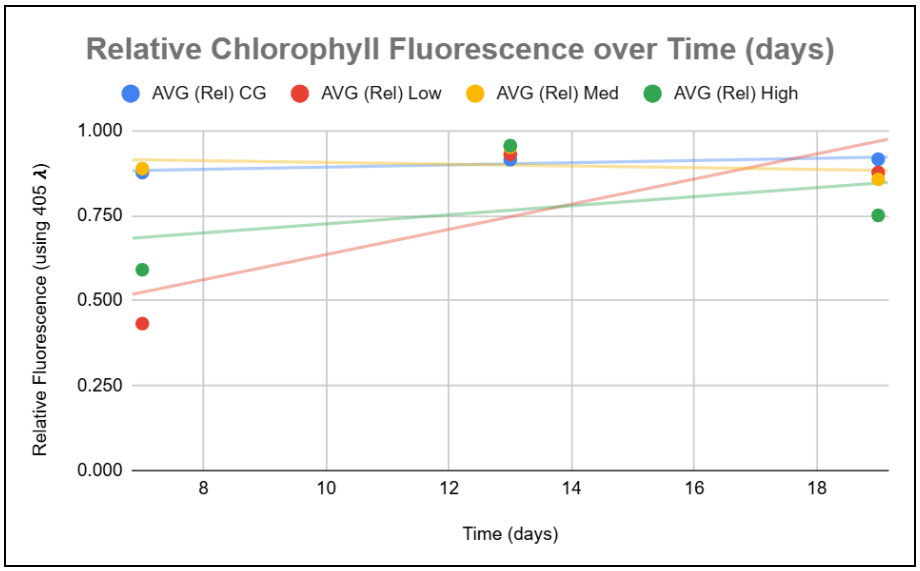
Spectrovis Data 2/18/26

| Test Group | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Trial 6 | Trial 7 | Trial 8 | Trial 9 | Trial 10 | AVG |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | F 405 λ (Rel) | |
| Control Group | 0.996 | 0.82 | 0.834 | 0.942 | 0.995 | 0.996 | 0.836 | 0.997 | 0.751 | 0.997 | 0.916 |
| Low Contamination SLS | 1.001 | 0.998 | 0.915 | 0.556 | 0.882 | 0.827 | 0.998 | 0.999 | 0.805 | 0.787 | 0.877 |
| Medium Contamination SLS | 0.999 | 1.001 | 0.63 | 0.714 | 0.925 | 0.772 | 0.824 | 0.755 | 0.973 | 0.998 | 0.859 |
| High Contamination SLS | 0.933 | 0.686 | 0.458 | 0.736 | 0.579 | 1 | 0.734 | 0.998 | 0.478 | 0.903 | 0.751 |

The low and medium groups showed moderate fluorescence values that increased over time but remained below the control group at the end of the investigation. The high SLS group kept on showing the lowest fluorescence values across trials and testing days, but the trend line showed the steepest slope and increase, showing the most change of all the experimental groups. The second testing period shows the clearest separation and trend among all the treatment groups with the control group having the lowest fluorescence, while the high the SLS contamination increased, so did the fluorescence.

A scatter plot with trend lines shows the relationship between time and relative chlorophyll fluorescence for each treatment group. The plotted data demonstrates the averages that the fluorescence values changed over time for all groups with the control group remaining highest, followed by the medium and low groups, and the high SLS group remaining lowest.

Errors shown among trials was minimal, indicating reliable measurements across trials.




## Analysis

The Spectrovis plus was used because it allowed us to have precise measurement of chlorophyll fluorescence, which is an indicator of plant health and photosynthetic activity. This instrument gave us quantitative data rather than relying only on visual observations. Using this device increased the accuracy as well as reducing human errors, and allowed small differences between treatment groups. It was important because when comparing treatments like different SLS concentrations it allowed us to see the changes that may not be visible to our eyes.

Multiple experimental groups (low, medium and high SLS) were used to show how different concentrations affected the plant rather than relying on a single treatment level. Using three treatment groups allows us to compare across all three, helping with identifying patterns or dose-dependent changes. It may also increase reliability because results that show consistency across multiple groups are more trustworthy than results from only one group. Including a control group is helpful because it provides comparison, making it possible to determine how

much fluorescence changed relative to normal conditions.

The second testing period shows the differences among each group, making it a key data set for seeing these trends. During this period, the separation between control and treated plants was most noticeable, with higher SLS concentrations that corresponded to higher fluorescence values. Because the pattern was clear and consistent across trials, this period showed strong evidence of differences among treatment groups.

The scatter plot with trend lines is the best graph to use because of its visualization between the relationships of the independent variable and dependent variable.

This type of graph was chosen because it shows:

- Trends over time
- Differences between treatment groups
- Patterns in the data (increase, decrease, or stability)
- Relative positioning of groups compared to one another

The line helps show the overall direction of change, making it easier to identify patterns and compare treatments.

From the scatter plot, several key findings were observed:

- Fluorescence values changed over time across all groups.
- The control group and the medium contamination group stayed fairly consistent in its trend over the 18 day testing period, with very little change in fluorescence.
- Increasing SLS concentration corresponded with higher fluorescence values particularly noticeable in the second testing window occurring on day 13 of the investigation.
- Differences within groups were not consistent across measurement days.

These trends show that the treatment groups behaved differently under experimental conditions.

## Statistical Analysis

The data was prepared by calculating averages across repeated trials for each treatment group at each time point. Sample sizes for each group included multiple repeated measurements, 10 plants were tested in each group.This helped increase reliability because we could relate trends to true results and less to sources of errors in the investigation.

## Discussion & Conclusions

In our original research question, “How will increasing the concentration of sodium lauryl sulfate in water affect the production of chlorophyll in lettuce plants?” we tried to determine whether PFAS-related compounds, through the stress effects of SLS, negatively impacted the plants we consume or benefit them in the long run. Our investigation goal was to better understand whether increasing SLS concentrations would disrupt chlorophyll production and photosynthesis in lettuce, which we had researched and found at least one other study that confirmed this relationship (Li, et all., 2022). Although our hypothesis predicted that higher concentrations of SLS would decrease chlorophyll levels, our results revealed a more complex response. Our findings revealed that PFAS-related stressors, in this case SLS, can significantly affect plant physiology. Rather than decreasing chlorophyll production as expected, the stressed lettuce plants appeared to have increased chlorophyll levels. Through further research, we learned that when plants experience stress and are unable to properly use the energy generated during photosynthesis, they increase chlorophyll production (Kinhal, 2023). This doesn’t

indicate improved plant health. On day 13 of our experiment, we saw the strongest evidence related to this counterintuitive phenomena. On test day 13, the lettuce plants showed this inefficiency and increase in chlorophyll. This suggests that the stress caused by SLS changed the plant's ability to effectively convert light energy, which would be harmful to plant development and agricultural productivity. The real-world implications of this research are significant. PFAS compounds are widely used in industrial applications and have been associated with long term environmental persistence and bioaccumulation. When used in agricultural settings, such as pesticides they can contaminate soil (Sofia Forier-Montes, 2026), water, and food supplies. Since lettuce and other crops are a main part of the human diet, any disruption in plant health or contamination with PFAS can impact human health as well. Our research supports concerns that the long-term negative effects of PFAS exposure outweigh their benefits, considering their persistence in ecosystems and the risk of accumulation in living organisms.

This research is especially important in light of recent government policy changes that may reduce protections limiting exposure to environmental contaminants. As regulations surrounding PFAS and related substances are debated or potentially weakened, communities could face increased environmental risk. The problem we aim to address is the continued need for scientific research and strong regulation to protect both environmental and human health. By providing experimental evidence that SLS concentrations alter plant physiological responses, our study supports the argument that chemical exposure, even when its effects aren't immediately visible, can mess with the natural biological processes. Continued research and regulation are necessary to ensure that agricultural practices do not compromise long-term

ecosystem stability or public health. Additionally, our study forms new scientific questions. Examples include, “How would longer term exposure to SLS affect overall plant growth, crop productivity, and nutritional value?”

Our final trial also showed an irregular trend in fluorescence production, telling us that additional variables may be influencing the results. In the future we could try to improve our testing process. When we conducted test number two on day 13, we had fewer students collecting samples and extracting chlorophyll. This might have limited errors. We also used only one spectrovis plus and labquest, limiting variance in measuring tools. Other research could include extended experimental timelines, testing multiple plant species. However, after meeting with Tucson Water’s Director, John Kmiec, our women in STEM group has considered conducting a data study on PFAS levels in Tucson water wells, or possibly developing filters and testing the quality of our filters using the spectrovis plus to analyze the filtered water. Whatever we plan to do, we will make sure it advocates for our communities' access to clean water and healthy nutritional crops, free of PFAS.

Overall, our analysis shows that increasing the concentration of SLS did produce a measurable relationship with chlorophyll production in lettuce plants, but not in the way we originally hypothesized. Instead of decreasing in chlorophyll production, higher SLS concentrations were associated with an increase in chlorophyll production, most likely as a stress response. Comparing chlorophyll measurements and fluorescence data across different concentration treatments, particularly noting trends observed by day 13. The relationship was evident; the irregular fluorescence pattern in the final trial suggests that the relationship is

complex and may involve additional physiological factors. Therefore, while our results demonstrate that SLS concentration does affect chlorophyll production, further investigation is needed to fully understand the nature and long term consequences of this relationship.

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