Effectiveness of Chemical Sunscreen versus Mineral Sunscreen in Water

I. Introduction

As summer approaches, it is increasingly important to apply sunscreen to protect yourself from the sun's harmful UV rays. The sun emits UVA and UVB rays, which penetrate into skin and can cause damages to DNA, resulting in skin cancer. Thus, when choosing a type of sunscreen, it is important to consider many factors. One factor is the SPF (sun protection factor), and it indicates the percentage of UV light blocked by the sunscreen. Unfortunately, some people mistakenly believe they need to apply sunscreen just once a day if it has a high SPF rating, but the effectiveness of sunscreen can wear off very easily over time. One of the most important factors that cause sunscreen to wear off is exposure to water. Many people apply sunscreen before swimming or entering water with the belief that it will stay on, but no sunscreen is water-proof. Sunscreens are labeled as water-resistant, which lasts only 40 to 80 minutes on wet skin. Commonly, there are two types of sunscreen that are water-resistant: chemical and mineral sunscreen. Chemical sunscreens don't sit on the skin or block rays. Instead, they feature active ingredients that absorb UV rays before your skin can soak them up, such as oxybenzone or avobenzone. Mineral sunscreens work by creating a physical barrier on the skin that shields it from the sun's rays. However, the water-resistance level of mineral vs. chemical sunscreen has not been tested before.

In this experiment, I will be testing two popular brands of sunscreen, Sun Bum sunscreen, which is chemical, and Blue Lizard sunscreen, which is mineral, to determine if their claim of 80 minutes of water-resistance is valid.

II. Statistical Question

Is there a significant difference between the effectiveness of chemical sunscreen and mineral sunscreen after 80 minutes in water?

Hypothesis:

$H_0: \mu_1 - \mu_2 = 0$	μ_1 = the mean numerical effectiveness of chemical sunscreen after 80 minutes in water
$H\alpha: \mu_1 - \mu_2 \neq 0$	μ_2 = the mean numerical effectiveness of mineral sunscreen after 80 minutes in water

III. Data Collection

There were two treatment groups of 30 UV detection stickers each. One treatment was Sun Bum Original SPF 50 chemical suncreen, and the other treatment was Blue Lizard Sensitive SPF 50 mineral suncreen. Both sunscreens indicated water-resistance of 80 minutes. The samples were 60 UV detection stickers. The stickers used in this experiment are clinically proven UV detection stickers with skin mimicking technology that interacts with sunscreen like skin. When the sticker is covered with sunscreen, it will turn clear, and when the sunscreen wears off, it will turn purple again.

To randomly assign the treatments, I used the hat method. Each sticker was assigned a number from 1-60, and I wrote the numbers 1-60 on separate, equally sized pieces of paper and placed them in a hat. For the first treatment, I randomly picked 30 slips of paper without replacement; the corresponding 30 stickers were assigned to be covered in chemical sunscreen. As the stickers were picked, each sticker was placed in a flat, large bowl in a 5 by 6 rectangle arranged so that the stickers were equally distributed. For the second treatment, I randomly picked 30 another slips of paper without replacement; the corresponding 30 stickers were assigned to be covered in mineral sunscreen. As the stickers were picked, each sticker was placed in a flat, large bowl in a 5 by 6 rectangle arranged so that the stickers were equally distributed.

For the first treatment, a syringe containing mineral sunscreen was used to carefully squeeze 0.25 ml of sunscreen on top of each sticker. Q-tips were used to spread the sunscreen equally across on the area of the 30 stickers in the bowl for mineral sunscreen. This procedure was repeated with the chemical sunscreen. I purchased a large UV lamp that emitted both visible light, UVA, and UVB in order to simulate sunlight. The UV lamp was secured around 1 foot above the bowl, and the bowl was positioned on top of a shoebox. This ensured that each sticker received very similar levels of UV light. To remove glare in pictures, two lights were placed on either side of the shoebox for surround lighting. A tripod was used to fix a phone above the bowl in order to take pictures with the same orientation and position. This indoor setup minimizes experimental error and reduces variability, controlling for UV light intensity, location, and outside environmental factors.

Fig. 1. The experimental setup.

The following procedure was completed for both groups. First, following the instructions for the UV stickers, the stickers covered in sunscreen were exposed to UV light for 10 minutes until the stickers turned clear. Next, 0.5 cups of water was carefully poured into the bowl from the side and a timer was started. A picture was taken right after water was added, and every 5 minutes afterward for 90 minutes.

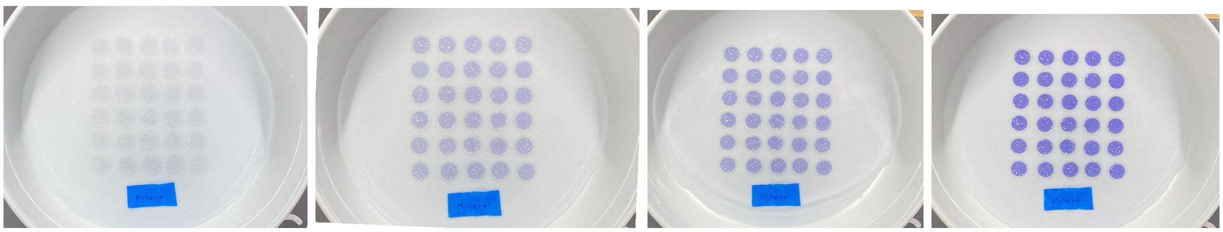

Fig. 2. Four pictures of the UV stickers covered in mineral sunscreen turning purple over time.

In order to convert the color of each sticker into numerical values, I used the ImageJ program. I used the functions convert to 16-bit image, threshold, set measurements, and analyze particles, and then I filtered by area. The mean gray value was determined for each sticker for a total of 38 pictures (19 pictures per treatment). Higher values correspond to a higher intensity of white, which meant that the sunscreen was more effective. Thus, the numerical intensity of white is proportional to the effectiveness of sunscreen and was used for analysis.

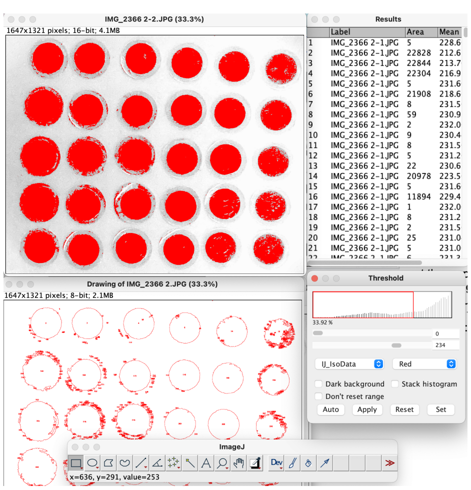

Fig. 2. A screenshot of the ImageJ results and processing windows.

V. Data Display

	Intensity of white	
Sticker	Mineral	Chemical
1	147.402	201
2	149.235	191.921
3	152.04	191.902
4	148.115	192.637
5	150.249	196.835
6	150.066	195.68
7	149.287	194.765
8	154.228	201
9	145.199	200.5
10	145.593	200.5
11	145.889	200.5
12	143.814	192.343
13	150.465	196.393
14	142.3	191.053
15	151.76	200.625
16	143.209	192.749
17	142.922	193.079
18	139.815	200.8
19	155.132	195.809
20	152.34	199.455
21	146.576	200.667
22	144.58	198.079
23	146.7	199.679
24	143.206	200.667
25	155.72	197.615
26	146.462	199.19
27	151.21	201
28	148.406	200
29	145.942	196.686
30	148.431	192.072

	Mineral	Chemical
Mean	147.8764333	197.1733667
SD	3.967705084	3.528808673
N	30	30
Min	139.815	191.053
Q1	145.2975	193.5005
Median	147.7585	197.847
Q3	150.411	200.5
Max	155.72	201

Fig. 3. Data table and summary statistics of the intensity of white after 80 minutes in water for mineral vs. chemical sunscreen.

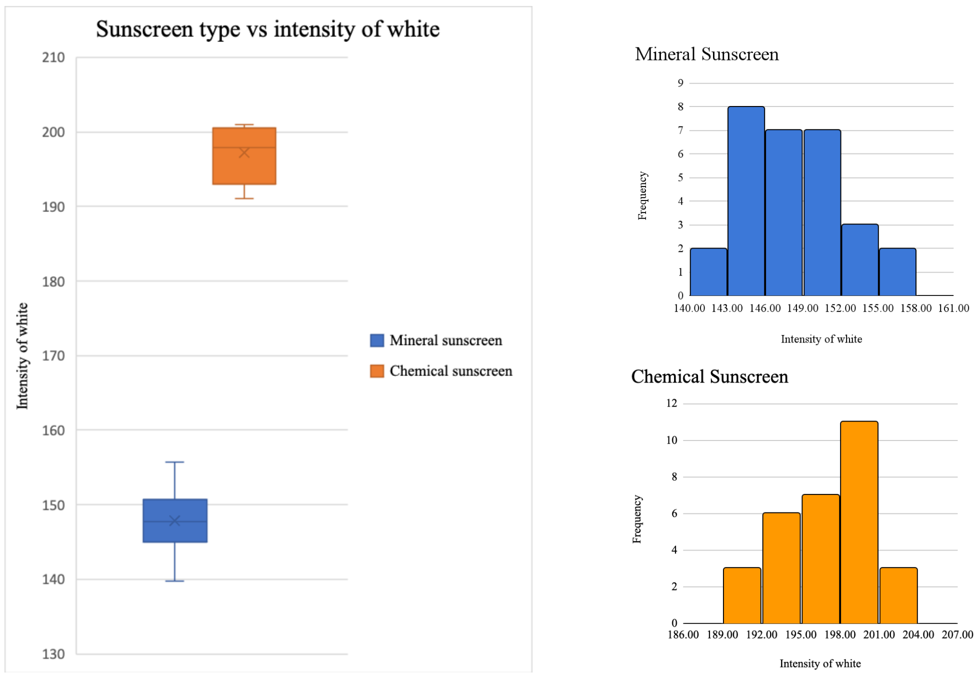

Fig. 4. A box plot and histograms of the data. The sample distribution for the intensity of white for the mineral sunscreen is slightly skewed right, while the sample distribution for the intensity of white for chemical sunscreen is slightly skewed left. There appears to be no outliers in either distribution. The center is larger for the chemical sunscreen distribution, where the median is 197.847 units, compared to the median for the mineral sunscreen distribution at 147.7585 units. The chemical sunscreen distribution has a slightly greater spread, where the IQR is 6.9995 units, while the IQR for the mineral sunscreen is 5.1135 units.

VI. Data Analysis

<u>Assumptions and conditions:</u>

1. **Independence:** Random assignment was used, and the outcome of one UV sticker does not affect the outcome of another UV sticker.
2. **Large/Normal Sample:** A sample of 30 ($n \geq 30$) was used for both treatments. By the Central Limit Theorem, both populations are approximately normal.

3. **Random:** The 60 identical UV stickers were randomly assigned to the two treatments.

The assumptions and conditions are met, so I can proceed with a two-tailed two-sample t-test.

Calculations:

t-statistic = -50.850

p-value = $2.528 * 10^{-49}$

df = 57.221

α =0.05

VI. Conclusion

The p-value is low ($2.528 * 10^{-49} < 0.05$ α level) , so we reject the null hypothesis. There is strong evidence that there is a difference between the mean numerical effectiveness of chemical sunscreen and the mean numerical effectiveness of mineral sunscreen after 80 minutes in water.

VII. Reflection

Overall, my project and experiment went well. I thought it was interesting that there was evidence of a difference in the effectiveness of mineral and chemical sunscreen, and I would like to study this topic further. I was able to design and implement an effective experimental setup, which reduced variability and helped the entire experiment run smoothly. In addition, I was able to quantify the effectiveness of two types of sunscreen using an innovative method of applying them to skin-mimicking UV stickers and computationally analyzing the color of each sticker. During the experiment, I also faced several problems. While I was researching different ways to test the effectiveness of sunscreen, it was initially difficult to find a method that was feasible and sensitive enough. Previous studies have used spectroscopy and other advanced lab equipment, which is too expensive and impractical for the purposes of my experiment, but the advantage is that these methods are highly precise and sensitive. Other studies have used the skin redness of human subjects, which is unreasonable because it is potentially dangerous. I also could not find a relatively inexpensive and reliable UV detector online. Finally, I found the UV stickers that I used in the experiment, and they turned out to be a great method. The only issue is that these stickers may not be as sensitive as other equipment for measuring UV intensity, so my results may not be as accurate. Another problem was that it was difficult to put exactly 0.25 mL of sunscreen on top of each UV sticker with a syringe, as it was hard to squeeze it very precisely. However, due to random assignment, this error is accounted for, and it did not affect my results to a large degree. Another problem was that my results do nto fully reflect real conditions because I conducted the experiment in still water, while most people who use sunscreen in water are active. In the future, I hope to test these sunscreens in continuously circulating water or in chlorinated water or seawater. I also hope to study different types of sunscreen from different brands, as certain brands of sunscreen may be slightly more effective, and the brands I chose are not the only types of chemical or physical sunscreen. I would also like to test spray sunscreen, although it may be more difficult to do so with the UV stickers. In conclusion, I enjoyed conducting this project, and it sparked my interest in the effectiveness of sunscreen or other methods in preventing skin cancer.

VIII. Citations

Timmons, Jessica. "Should You Use Physical or Chemical Sunscreen?" Healthline, Healthline Media, 3 Feb. 2022, https://www.healthline.com/health/physical-vs-chemical-sunscreen#physical-sunscreen.

Don't Forget to Apply Sunscreen before & after Water Fun | Health News ... https://www.usnews.com/news/health-news/articles/2021-08-27/dont-forget-to-apply-sunscreen-before-after-water-fun.