Investigating the Effects of Sunscreen of the Marine Environment

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Problem

Water has a trickling effect on much of our community. More than ⅔ of the Earth is covered by water, and it definitely impacts everyone on this planet. People have started many conservation and purifying programs in regards to protecting our water. All living things need water to survive, and the environment relies heavily on it. Water acts as a habitat for many organisms, as well as a food and drinking source. It also provides protection, is used for sanitation, and triggers important chemical reactions.

Our team attempted to rectify the issue of polluting one of our primary sources of life. After much background research, we read that sunscreen appeared to have a negative effect on the ocean waters and marine life (Welch, 2015). There have been many tests and experiments performed to ascertain the impact of sunscreen. Sunscreen was found to kill off coral reefs, contaminate the ocean water, and put certain sea organisms at risk (Than, 2008). Additionally, we found that certain changes in the water particularly affected the marine environments.

We read that carbon dioxide released into oceans is a major source of greenhouse gases. It enhances the unwanted changes in ocean acidity due to atmospheric increases in CO_2. These changes impact commercial fish and shellfish populations (Sunda, 2012). Also, we saw that decreasing pH in water interferes with the ability of certain marine animals, such as corals and other calcifying marine organisms to make their skeletons and shells from calcium carbonate minerals. Other marine species that may be affected include lobsters, snails, starfish, oysters, clams, and various species of phytoplankton, which are species that occupy vital spots in the global-ocean food web (Bradshaw, 2007). The effects of sunscreen on these underwater species have adverse effects all over the world, especially in the tourism and fishing industries. In addition, lower dissolved oxygen concentration in water was shown to provide evidence for excessive algae growth in water (caused by nutrients in sunscreen). This meant that oxygen would be depleted for other marine organisms, such as fish. (Risberg, 2009) This is all due to the harmful chemicals that are commonly found in these sunscreens. Some of these chemicals include oxybenzone, benzophenone-2, and methylisothiazolinone. One interesting thing we noted was that biodegradable sunscreen was accepted to be the "healthiest and safest" sunscreen for the ocean water (Bernard, n.d.) . This led us to create our two key questions: What are the harmful effects of sunscreen on the marine environment? Which type of sunscreen is the least damaging to our oceans?

We wanted to find the effects of different types of sunscreens on ocean water. This would help us to pinpoint which sunscreen in particular had a more significant influence on the water. This problem is crucial to our community because while sunscreens are essential to sun-protection for humans, they can greatly pollute the water. Not only that, but sunscreen is an extremely common topical product, especially for our community as it is located on the coast. This well-used commodity is altering our necessary water source, and this issue needs to be addressed. We have to raise awareness and show the community what sunscreen actually does to our marine environment.

We consulted a wide variety of resources as we were performing research prior to the start of our experiment. We visited various websites and read both general and scholarly articles. They are listed below:

Bernard, M. (n.d.). Biodegradable Sunscreen. Retrieved January 18, 2016, from http://greenliving.lovetoknow.com/Biodegradable_Sunscreen

Danovaro, R., Astolfi, P., Bongiorni, L., Corinaldesi, C., Damiani, E., Giovannelli, D., Greci, L., Pusceddu, A. (2008). Sunscreens cause coral bleaching by promoting viral infections. Environmental Health Perspectives, 116(4), 441-447, doi: 10.R89/ehp.10966.

Donovoro, R. Corinaldesi, C. (2003). Sunscreen products increase virus production through prophage induction in marine bacterioplankton. Microbiol Ecology, 45 (2), pg 109-118, doi: 10.1007/s00248-002-1033-0

Lyons, P. (2008, May 23). Sunscreen in Sea Water May Harm Coral. *New York Times*. Retrieved from http://thelede.blogs.nytimes.com/2008/05/23/sunscreen-in-sea-water-may-harm-coral/

Sanchez-Quiles, D., & Tovar-Sanchez, A. (2014) Sunscreens as a source of Hydrogen Peroxide Production in Coastal Waters, Environ. Sci. Technol., 48 (16), 9307-9042, doi: 10.1021/es5020690 Retrieved October 20, 2015 from www.pubs.acs.org/doi/abs/10.1021/es5020696

Tabor, A. (2013) Sunscreen, while protecting skin, pollutes water. Retrieved October 18, 2015 from http://www.mysciencework.com/news/10431/sunscreen-while-protecting-skin-pollut es-water

Than, Ker (2008). Swimmers' sunscreen killing off coral. National Geographic News, Jan 29, 2008, doi:10.1038/news.2008.537

Tibbets, J. (2008). Bleached, But Not by the Sun: Sunscreen Linked to Coral Damage. Environmental Health Perspectives, 116 (4), A173-A173. doi: 10.1289/ehp.116-a173b. Retrieve October 21, 2015 from www.ncbl.nin.gov/pmc/articles/PM2291012/

The Trouble With Sunscreen Chemicals | EWG's 2015 Guide to Sunscreens. (n.d.). Retrieved October 20, 2015, from http://www.ewg.org/2015sunscreen/report/the-trouble-with-sunscreen-chemicals/

Welch, C. (2015, May 14). Do Sunscreens' Tiny Particles Harm Ocean Life in Big Ways? *National Geographic*. Retrieved from http://news.nationalgeographic.com/2015/05/150514-sunscreen-nanoparticle-nanotechnology-oceans-marine-beach-boat-toxic/

Trover-Sánchez A, Sanchéz-Quiles D, etol. (2013) Sunscreen products as Emerging pollutants to coastal waters, P105 One 8(6), doi: 10.1371/journal.pone.0065451

In addition, we reached out to various experts via email. We contacted Kate Bradshaw, a researcher who conducted a study on the effect of carbon dioxide on marine environments, as well as Murrye Bernard, an author who wrote an article on the benefits of using biodegradable sunscreen. We also communicated with Badger Balm and Aveeno, both of which are companies that produce and sell sunscreen. In both cases, we received responses detailing the company's products and the various ingredients that go into producing their sunscreens.

Through our research, we learned about the different types of sunscreens and their effect on the marine environments. We discovered that a variety of sunscreens, including traditional and water-resistant, contain chemicals and nanomaterials that cause the rapid growth of algae, depleting oxygen concentration and reducing the number of organisms that can live in an underwater region (Risberg, 2009). We also discovered that these sunscreens can disable defense mechanisms that marine life use to protect their embryos, leaving them more susceptible to toxic pollutants (Welch, 2015). We also found that sunscreens contain chemicals that can increase the level of carbon dioxide in the water. This causes an unwanted change in ocean acidity, which impacts shellfish populations by leaving them unable to develop the shells they need for protection and growth.

Finally, we found that biodegradable sunscreen is thought to be the best type of sunscreen by the general public, as it has been created solely for the purpose of providing skin care while protecting marine environments. Biodegradable sunscreen contains minerals and organic ingredients that are converted to basic elements when they biodegrade, becoming reusable by biological systems (Bernard, n.d.). After deliberating all this information, we were able to develop our hypotheses.

Hypothesis

After deciding the main problems that we would be approaching and conducting research, we carefully chose three specific hypotheses to test. We decided to compare different types of sunscreens and conduct an experiment to see how each affected the ocean water in regards to the carbon dioxide concentration, dissolved oxygen concentration, and the pH level of the water.

Our first hypothesis was that if biodegradable 30 SPF sunscreen is used, then the carbon dioxide concentration will increase as opposed to when traditional 30 SPF sunscreen is used. We chose 30 SPF for our sunscreens because we discovered in our research that is the most common SPF bought in stores.

Since it is an accepted idea that biodegradable sunscreen is generally the healthiest sunscreen for the environment, we hypothesized that it would be more likely to cause the carbon dioxide concentration to decrease than the traditional 30 SPF sunscreen (and the 30 SPF water resistant sunscreen). Decreased carbon dioxide level is better because carbon dioxide can increase both the temperature and acidity of oceans, which can have harmful consequences for marine organisms (Bradshaw, 2007) cite. The independent variables for this hypothesis were the different types of sunscreen, which in this case, were the biodegradable 30 SPF sunscreen and the traditional 30 SPF sunscreen. The dependent variable was the carbon dioxide concentration of the water after each sunscreen was put into the water. We measured the validity of our first hypothesis by using Bromothymol blue indicator and seeing whether the blue indicator changed the color of the sunscreen.

Our second hypothesis was if 30 SPF biodegradable sunscreen is used, then the dissolved oxygen concentration will increase as opposed to when traditional 30 SPF sunscreen is used. We predicted this because traditional sunscreen contains chemicals such as oxybenzone as well as nanometals (Welch, 2015), which linger in oceans for long periods of time and spur rapid algae growth. The algae use a great deal of oxygen, decreasing the amount available for other underwater organisms. This is also the case for water-resistant sunscreen. The independent variables for this hypothesis were the different types of sunscreen, which were the biodegradable and traditional sunscreens. The dependent variable was the dissolved oxygen concentration of the water. We measured the validity of our second hypothesis by using a dissolved oxygen test kit, which came with a color scheme strip that we compared the colored water with, and we matched the colors to find the oxygen content (mg/L) of the sea water.

Finally, our third hypothesis was that if water resistant 30 SPF sunscreen is used, then the pH level will decrease as opposed to when biodegradable sunscreen is used. We predicted this because water resistant sunscreen contains chemicals such as benzophenone, which can cause an increase in carbon dioxide concentration, as well as decreasing pH level. This is also the case for traditional sunscreen. Our independent variables were the different sunscreens, which were the water resistant and biodegradable sunscreens. Our dependent variable was the pH level of the water after each sunscreen was mixed into the tanks. We measured the validity of our third hypothesis by using pH strips that had a color scheme to match with. The matched colors showed the pH of the substance; we used these to find the pH of the ocean water.

Overall, we expected to find data that supported the idea that biodegradable sunscreen was the best of the three sunscreens we tested in terms of environmental health. These hypotheses were created to see whether biodegradable sunscreen would truly demonstrate to be the superior choice in sunscreens.

All our hypotheses demonstrated validity, as they were capable of being tested by our experiment. Our first hypothesis was valid because in our study, we tested the carbon dioxide level in water with 30 SPF biodegradable sunscreen added in and in water with 30 SPF traditional sunscreen added in. Our second hypothesis was also valid because we tested for dissolved oxygen concentration for both these sunscreens. Our final hypothesis was valid because we were able to test the pH level of both water with water resistant sunscreen dissolved in it and water with biodegradable sunscreen dissolved in it. This demonstrates that all three of our hypotheses showed validity.

Experimental Design

Traditional sunscreen (30 SPF)

Water resistant sunscreen (30 SPF)

Biodegradable sunscreen (30 SPF)

Micro Essential Lab Hydrion Single Roll pH test strips

Four 35,000 mL tanks

Salifert O2 Profi Test

0.2 Micrometer filter

Yosoo 6V DC DIY Peristaltic pump

6 test tubes

Latex gloves

Graduated cylinders

Bromothymol blue indicator

Pipette

Excel

Statistical Package for the Social Sciences (SPSS)

Experimental Methods

For our experiment, we tested four different groups. For phase 1, all four tanks were filled with 9,000 mL of seawater. For phase 2, all four tanks were filled with 21,000 mL of seawater. Our other constants were the amount of light exposure, the water source, the SPF of each type of sunscreen, the location the tanks were held in, the tank size, and the time sitting in between tests. In addition, all four tanks experienced the same temperatures, as they were all in the same room. No sunscreen was present in our control group, and our experimental groups each had 10 mL of a respective type of sunscreen in phase 1. In phase 2, no sunscreen was present in our control group, and our experimental groups each had 50 mL of a respective type of sunscreen. The different types of sunscreen we used in our experiment were traditional, biodegradable and water-resistant sunscreen. We determined how much sunscreen to put into each tank by researching the average amount of sunscreen people apply before visiting the beach, and then calculating how much we should insert in proportion to the amount of water in our tanks. For our water collection, we went to Oyster Bay for phase 1 and another local beach for phase 2. We used a peristaltic pump to transfer water from the ocean into a containment unit.

In order to prevent rapid changes in temperature or carbon dioxide, we brought it to an enclosed area to filter with our 0.2-micrometer filter and the peristaltic pump. The water used in phase 2 was not filtered.

For phase 1, first we filled four 35,000 mL tanks with 9,000 mL of filtered seawater each. Next, we put 10 mL of traditional sunscreen into one tank, 10 mL of biodegradable sunscreen into another tank, and 10 mL of water-resistant sunscreen into the third tank. We did so by squirting the sunscreen into a beaker to get more accurate measurements and then putting it into the tanks by putting the beaker in the water and stirring the beaker with a glass rod until all the sunscreen was out. We then took a 50 mL test tube sample of the water from each tank from the bottom of the tank as that was where the greatest concentration of sunscreen was present. Then we tested each water sample for the pH level using pH test strips. We did so by dipping a pH strip into the water for two seconds, and then allowing ten seconds for a color change. We then compared the color of the strip to those on the container, disregarding any color changes after 30 seconds, as instructed by the directions. In order to determine the most accurate result, each member of the team read the pH strip and the average pH value was the one accepted.
We also tested the water for carbon dioxide concentration using the **B**romothymol blue indicator. We added three to four drops of the indicator into an uncovered test tube filled with a 20 mL water sample and then allowed ten seconds for a color change. We then tested the water for dissolved oxygen concentration using the dissolved oxygen concentration kit. We did so by adding 5 mL of water to the test vial provided by the dissolved oxygen concentration kit and adding 5 drops of O2-1 and swirling gently for 20 seconds. We made sure not to shake the test vial too much since this could change the oxygen content of the water. We then added 5 drops of

O2-2, also provided by the kit, and swirled gently for 15 seconds. Next, we allowed it to stand for 3 minutes, as directed by the instructions. Following the three minutes, we added 5 drops of O2-3 and swirled for 5 seconds after each drop. Then, we allowed 1 minute for color development. Next, we placed the test vial on a white part of the color scheme that was provided by the kit and compared the colors. An intermediate color corresponds to an intermediate oxygen content. The values on the color chart provided from the kit are in mg/L (ppm) oxygen. To increase interrater reliability, we had each team member determine what they thought the appropriate value was and the average was accepted. We then repeated the pH, carbon dioxide, and dissolved oxygen concentration tests on water from each of the tanks immediately after putting the sunscreens in, and once every day at the same time each day for four days afterwards. All our testing took place over the course of five days.

For phase two, we chose a testing period of two weeks, allowing us to determine the more long-term effects of sunscreen on our oceans. We collected ocean water from another local beach but did not filter it in order to preserve any microscopic marine organisms present in the water. We again used the same four tanks, but this time filled them with 21,000 mL of water rather than 9,000 mL. We added 50 mL of 30 SPF traditional sunscreen to the first tank, 50 mL of 30 SPF water-resistant sunscreen to the second, and 50 mL of 30 SPF biodegradable sunscreen to the third. Once again, the fourth tank remained devoid of sunscreen in order to serve as our control group. We chose a greater amount of sunscreen in proportion to the increased amount of water. Another differentiating factor between phase one and phase two of our experiment was that we tried to more closely simulate ocean conditions by adding a wave making pump to each tank in order to circulate the water and allow the sunscreen to diffuse throughout. We conducted the same three tests, testing for carbon dioxide level, pH, and dissolved oxygen concentration, in the same manner for the second part of our experiment. We tested first for Day 0 right after putting adding the sunscreen, and then continued to collect data every three days for 12 days.

Data Collected

For phase one of our experiment we collected data regarding the water quality on a daily basis including data regarding pH level, dissolved oxygen concentration, carbon dioxide concentration. We measured the pH level on a scale of 1 to 14 and entered it into the statistics program as numeric data. We measured the dissolved oxygen level on a scale from 0 to 15 milligrams per liter. This was also entered as numeric data. Carbon dioxide did not have a specific measurement and only showed whether the gas was present or not present so the data was entered as a nominal variable. Additionally, we collected other information such the whether or not sediments were present in the tanks and the color of those sediments. Both were imputed as nominal variables where the sediments are present or not present and colors was orange, white, or clear. We collected this data a total of five different times for each group. The first time was directly after we added the sunscreen and was imputed as ‘Day 0’. More data were collected for the following four days. The raw data collected can be seen on the next page.

For phase two of the experiment, we collected the same data regarding the water quality, but had different testing intervals. Instead of collecting data daily, we collected data every three days, with four testing days spread out over a course of twelve days.

Data Analysis

We analyzed our data using the statistics program SPSS. When comparing the pH and oxygen levels between the different types of sunscreen, we ran an ANOVA. An ANOVA analyzes sample variances to draw inferences about population means. We made the decision to run an ANOVA because we were looking for the effect of a nominal variable with four levels (biodegradable, control, traditional, and water resistant) on interval/ratio varaibles (oxygen and pH). The formula used for this test is: $F = \frac{\text{between-group variability}}{\text{within-group variability}}.$. The between-group variability is defined as: $\sum_i n_i(\bar{Y}_{i\cdot} - \bar{Y})^2/(K-1)$, while the within-group variability is defined as: $\sum_{ij}(Y_{ij} - \bar{Y}_{i\cdot})^2/(N-K),$.

In addition, we used Tukey Kramer post hoc tests to compare each of the different sunscreens to all the others in terms of pH and oxygen concentration. The formula for this test is: $\frac{M_1 - M_2}{\sqrt{MS_w\left(\frac{1}{n}\right)}}$. M is defined as the group mean and n is defined as the group.

Due to the fact that we needed to compare two nominal variables (carbon dioxide concentration and sunscreen), we decided to also run a chi square test. The formula for a chi-square is: $\chi^2 = \sum \frac{(O-E)^2}{E}$. In this case, the O stands for the observed value, while the E stands for the expected value. Therefore, the numerator $(O-E)^2$ is essentially the square of the expected value subtracted from the observed value. Our first hypothesis, 'If traditional sunscreen is used, then the carbon dioxide concentration will increase as opposed to when biodegradable sunscreen is used, was proved incorrect by our data from phase one. There was no change in the carbon dioxide, as there was none present in any of the water samples, including the control. Our second hypothesis, ‘If biodegradable sunscreen is used, then the oxygen concentration will increase as opposed to when traditional sunscreen is used, was also proven incorrect by the data. The p value recorded was 0.8, which is well above the accepted 0.5 that is required for statistical significance. Our third hypothesis, ‘If water-resistant sunscreen is used, then the pH level will increase as opposed to when biodegradable is used,’ also had an p value that was not significant. All results from phase one of our experiments would lead us to adopt a null hypothesis that sunscreen does not affect pH, oxygen, and carbon dioxide level of ocean water.

Raw Data for Phase 1

Control

	Day 0	**Day 1**	**Day 2**	**Day 3**	**Day 4**
Ph	6.5	7	6	7	6.5
Carbon Dioxide	Negative	Negative	Negative	Negative	Negative
Oxygen	6	4	2	7	8
Sediment	Negative	Negative	Negative	Negative	Negative
Color	None	None	None	None	None

Traditional

	Day 0	**Day 1**	**Day 2**	**Day 3**	**Day 4**
Ph	7	6.5	6.5	6	6.5
Carbon Dioxide	Negative	Negative	Negative	Negative	Negative
Oxygen	6	6	7	8	8
Sediment	Negative	Positive	Positive	Positive	Positive
Color	None	Orange	Orange	Orange	Orange

Biodegradable

	Day 0	Day 1	Day 2	Day 3	Day 4
Ph	7	7	7.5	7.5	8
Carbon Dioxide	Negative	Negative	Negative	Negative	Negative
Oxygen	6	7	8	10	8
Sediment	Negative	Positive	Positive	Positive	Positive
Color	None	White	White	White	White

Water-Resistant

	Day 0	Day 1	Day 2	Day 3	Day 4
Ph	6.5	6.5	7	7.5	7.5
Carbon Dioxide	Negative	Negative	Negative	Negative	Negative
Oxygen	6	6	7	7	6
Sediment	Negative	Positive	Positive	Positive	Positive
Color	None	Orange	Orange	Orange	Orange

Phase two of our experiment was performed with some alterations to our experimental method. Testing occurred over a longer period of time with a set number of days between each test. Additionally, pumps were also added in to allow the sunscreens to circulate throughout the tanks. We used the same statistical tests, and for this phase, two of our three of hypotheses were supported.

Raw Data for Phase 2

Control

	Day 0	Day 1	Day 2	Day 3
Ph	7.5	7	7	7
Carbon Dioxide	Positive	Negative	Negative	Negative
Oxygen	8	7.5	7	7
Sediment	Negative	Negative	Negative	Negative
Color	None	None	None	None

Traditional

	Day 0	Day 1	Day 2	Day 3
Ph	7.5	6.25	6	6
Carbon Dioxide	Positive	Positive	Positive	Positive
Oxygen	7	5	4.25	4
Sediment	Negative	Positive	Positive	Positive
Color	None	Orange	Orange	Orange

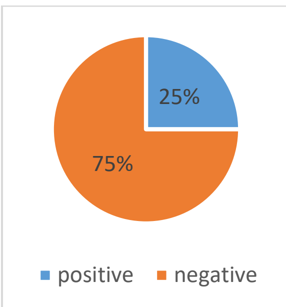
Biodegradable

	Day 0	Day 1	Day 2	Day 3
Ph	7.5	6	5.75	5
Carbon Dioxide	Positive	Negative	Negative	Negative
Oxygen	8	7	7	7
Sediment	Negative	Positive	Positive	Positive
Color	None	White	White	White

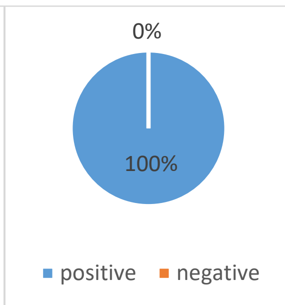
Water-Resistant

	Day 0	Day 1	Day 2	Day 3
Ph	7.5	5.5	5.25	5
Carbon Dioxide	Positive	Positive	Negative	Negative
Oxygen	7	6.5	5.25	5
Sediment	Negative	Positive	Positive	Positive
Color	None	Orange	Orange	Orange

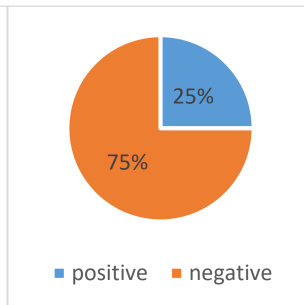
The sunscreen group with little to no deviation from the control group is generally safest for marine environments. In the case of carbon dioxide, the biodegradable sunscreen group differed the least from the control. For both groups, 25% percent of the samples gathered contained carbon dioxide. This is illustrated below in Figures 1A and 1C. As shown, the graphs for biodegradable and control are identical. Additionally, 50% of the samples gathered from the water-resistant sunscreen tank contained carbon dioxide, while 100% of the samples gathered from the traditional sunscreen group contained were positive for carbon dioxide. This demonstrates that the water in the traditional sunscreen group differs most greatly from the control group, thereby making traditional sunscreen the most harmful for marine environments in terms of carbon dioxide and satisfying our hypothesis. However, the data analysis produced no significant results, as the p-value was 0.054, which is slightly higher than the accepted 0.05.



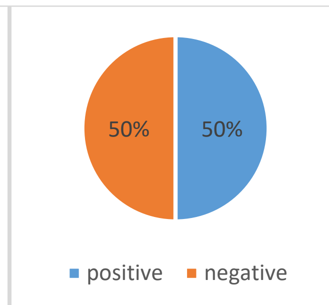
Control - Carbon Dioxide
Figure 1A



Traditional - Carbon Dioxide
Figure 1B

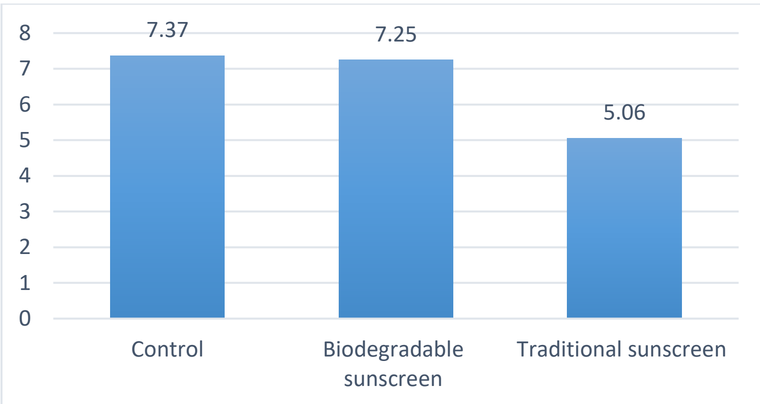


Biodegradable - Carbon Dioxide
Figure 1C



Water Resistant - Carbon Dioxide
Figure 1D

Our second hypothesis, ‘If biodegradable sunscreen is used, then the oxygen concentration will increase as opposed to when traditional sunscreen is used,’ was supported by our data The sunscreen with the least amount of variation from the control is generally considered the best for the ocean in terms of oxygen concentration. The mean for the control group was 7.375, while the mean for the biodegradable group was 7.25. This creates a mean difference of only 0.125, as opposed to -2.31 difference between the control and traditional (as shown in Figure 2). The water resistant and control group had a mean difference of -1.437. This shows that biodegradable differs the least from the control group, supporting our hypothesis and demonstrating that biodegradable sunscreen is the best of these three sunscreens in terms of dissolved oxygen concentration. The greatest variation from the control group was shown by the traditional sunscreen group, indicating that traditional sunscreen is the worst of the three types of sunscreen in terms of dissolved oxygen concentration



Mean of Dissolved Oxygen Concentration

Figure 2

Comparing Biodegradable and Traditional Sunscreen

Mean Difference: -2.188

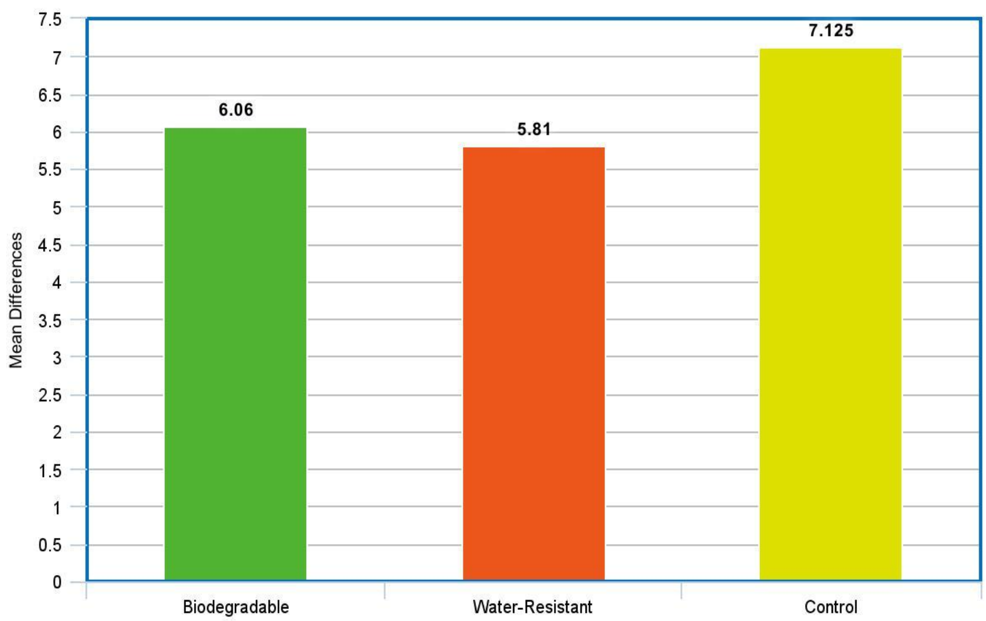
Comparing Control and Traditional Sunscreen

Mean Difference: -2.31

Comparing Control and Biodegradable Sunscreen

Mean Difference: .125

Our third and final hypothesis, ‘If water-resistant sunscreen is used, then the pH level will increase as opposed to when biodegradable is used,’ was not supported by the data. The p-value was 0.98 which well above the accepted p-value of 0.05. This means that any difference was more than likely due to chance. As illustrated by Figure 3, the means of each sunscreen group also do not vary greatly, with the mean difference being only 0.25. Additionally, the mean difference between water-resistant and control is 1.313, while the mean difference between biodegradable and control is 1.063. It was actually traditional sunscreen that is most similar to the control, with a mean difference of only 0.688. This proves our hypothesis incorrect, leading us to adopt a null hypothesis that states that that states that pH level is not affected by sunscreen. This data also suggest that traditional sunscreen may actually be the least harmful for marine environments in terms of pH. This disagrees with the research we performed prior to the start of the experiment. The research we performed then informed us that the chemicals in biodegradable sunscreen do not dissolve and linger in the water for long periods of time, instead biodegrading to become part of the environment, and therefore should not have much of an effect on water quality (Bernard, n.d). This was shown in the case of carbon dioxide and dissolved oxygen, as there were little changes between the control and biodegradable. However, there is a noticeably larger mean difference between the control and biodegradable in terms of pH, demonstrating that biodegradable sunscreen does cause a change in ocean acidity. This could be because as the minerals in the sunscreen biodegrade, they cause changes in temperature. Temperature changes in turn can cause an increase in pH.

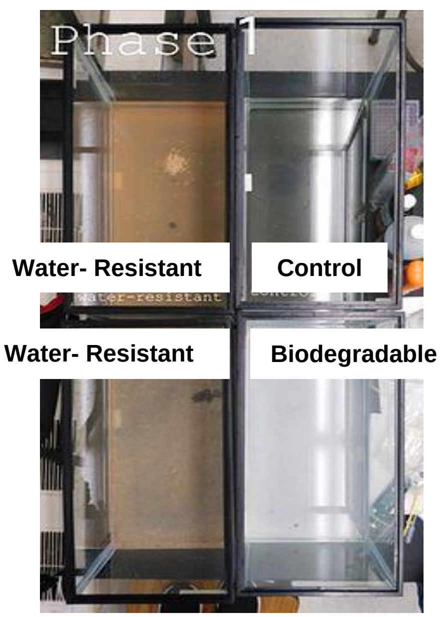


Comparing Biodegradable and Water Resistant Sunscreen

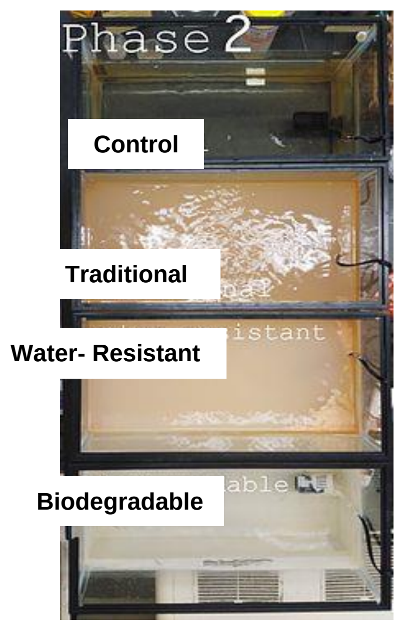
Mean Difference: -.25
p-value: .98

Mean Differences in pH Between Water Resistant Sunscreen, Biodegradable Sunscreen and Control

Several observations were also made during the experiment, and are pictured below. These photos show the visible effects of sunscreen on ocean water. As shown, the water resistant sunscreen and traditional sunscreen cause the water to turn a murky orange-red color, with several sediments settling to the bottom of the tank or adhering to the sides. The biodegradable tank turned a milky white color with white sediments. For all three types of sunscreen, this change occurred very rapidly. Picture 1 was taken during day two of phase one, and as shown, the color change and sediments are already present. Picture 2 was taken during day two of phase two and shows a noticeable change in color, along with the presence of sediments on the sides of the tank.



Picture 1



Picture 2

Sources of Error

Some possible sources of error stem from the accuracy of the pH strips and Bromothymol blue indicator. pH strips have many conditions that need to be met to guarantee absolute accuracy. The most important is that the strips be stored away from direct sunlight and high humidity. Exposure to either direct sunlight or high humidity for long periods of time can cause fading of the color chart, which can compromise the accuracy of the results. In addition, the pH strips have an expiration date that is three years after purchase, and it is recommended that they are kept in temperatures between 50 to 90 degrees Fahrenheit. We had no way of ensuring that this policy was applied to the strips we used in our experiment and this could have affected our results. The Bromothymol blue indicator solution has a shelf-life of two years, and it is possible that the solution used in our experiment could have been older. This could have also impacted the accuracy of our results.

In addition, the environment in which the tests are administered could have changed the results. For pH strips, salt present in the ocean water may change the results. Depending on the type of salt and concentration of salt, it could have skewed the results negatively or positively. This is also true with temperature. Carbon dioxide concentration differs greatly with temperature; as higher temperatures result in greater amounts. Although the tanks were all kept in the same room and the water was collected from the same location, we did not take any measurements of temperature. There could have been changes in the temperatures of the water, which would have influenced our results.

Drawing Conclusions

Our experiment was performed in two parts. Phase one did not yield statistically significant results. All changes recorded in our data were minimal and likely due to chance. However, according to the sources that we read and the research we performed, there should have been a major difference in carbon dioxide concentration, dissolved oxygen concentration and pH level between the different types of sunscreen.

After phase one of our study, we realized we had likely made some errors, which led us to design and conduct phase two. For instance an important goal of our experiment was to test the effects of sunscreens on the marine organisms living in the ocean. Their effects on marine life (particularly algae and shellfish) are the reason we decided to run the dissolved oxygen concentration and pH tests in the first place. However, after we gathered our samples we filtered the water due to the amount of trash and dirt present. As the filters pores were 0.2 nanometers in diameter, this eliminated even any microscopic organisms present in our samples. The filtering turned out to be a mistake as the absence of organisms could have had a drastic impact on our results. As a result, in phase two few did not filter our samples and also collected water from a beach that has a pier that allowed us to stand on high elevation, making it possible to drop tubing into much deeper water than we originally collected from.

Another limitation in the first phase of our study is that we did not to mimic realistic ocean conditions. Realistically, ocean waves cause sunscreen to diffuse throughout the water. Obviously, since we worked out of tanks, this was not the case in our experiment. We squirted the 10 mL of sunscreen into our tanks but did not take any measures to allow it to circulate throughout the tank. Due to this decision, we saw that most of the sunscreen just settled to the bottom of the tanks rather than dissolving in the water. Therefore, it is possible that the water samples we gathered for testing did not contain significant amounts of sunscreen because they were not mixed thoroughly. In phase two of our experiment, we fixed this by using a wave making pump. One pump was placed in each tank, circulating the water throughout the tank. This simulated waves and allowed for the sunscreen to be mixed with the ocean water.

In addition, the ocean is open to fresh air, which causes changes in carbon dioxide concentration. When seawater is exposed to open air at the beach, carbon dioxide can move into the water out of the atmosphere through molecular diffusion (caused by temperature change) between the atmosphere and oceans (Sabine, n.d). Due to the fact we worked inside a closed classroom with the windows shut for both phase one and phase two, the temperature remained constant and diffusion was not possible. This could have resulted in errors in our experimental data.

Another limitation of our study was that our experiments took place over limited time. Phase one took place over the course of one week, with five days of continuous testing. Our results show only the immediate effects of sunscreen on marine environments, rather than the longer-term repercussions. Sunscreens remain in the oceans for a period of up to four weeks after they are first introduced, and their effects are felt consistently.

In regards to the sediments and their color, we could further explore these observations by adding more dependent variables to our experiment and also developing more hypotheses. In addition to our three existing variables, we could test also for turbidity. Turbidity is the cloudiness or haziness of a fluid and is usually caused by a large number of individual particles that scatter light in different ways. It can easily be tested for using either a spectrometer or turbidity meter. If we were to test for turbidity, we would hypothesize that If 30 SPF water resistant sunscreen is used, the turbidity of the water will increase as opposed to when biodegradable sunscreen is used.

Benefit to the Community

Sunscreens contribute markedly to the pollution of oceans around the world (Bradshaw, 2007) and our community is no exception. Long Island is surrounded by water and has a multitude of beaches. These beaches are visited often by residents of our community, particularly in the summertime when it is hot and sunny. Most of these beachgoers wear sunscreen, and most of them use traditional sunscreen, in the highest SPF they find on their drugstore shelf (Griffin, n.d). It is completely reasonable for people to want to shield themselves against UV radiation. However, what most people do not realize is how potentially harmful the sunscreen they wear into the ocean is for marine life. Our experiment is designed to measure the effects on the harmful chemicals found in sunscreens on marine environments and to determine which type of sunscreen is best for combating water pollution.

Discovering which type of sunscreen is best for our oceans this benefits our community because hopefully with this information, people can make the right choices about which sunscreens to use when visiting oceans and interacting with marine life. Their decisions may help save underwater communities all over the world, not just on Long Island. After all, the lives of the underwater organisms are not the only ones at stake. The changes caused by sunscreen due to changes in the levels of dissolved oxygen and concentration can kill off shellfish and large fish populations (Bradshaw, 2007) . When the number of fish, lobsters, clams, and other marine life available goes down, our economy is shaken up as well. The impacts are felt hugely in tourism and fishing industries.

Our experiment also shows how the sunscreens, particularly traditional, contribute to the diminished water quality and appearance of our oceans. Traditional sunscreen caused significant drops in the oxygen concentration of ocean water, which can kill of large fish populations and disrupt many marine ecosystems (Sunda, 2012). Additionally, traditional sunscreen caused a decrease in pH level and an increase in carbon dioxide level, although these changes did not show statistical significance. More data would be needed to ensure this did not occur due to chance. These changes in water quality can have far-reaching consequences on both underwater ecosystems and also our tourism and fishing industries. Sunscreens also greatly increase the sediment content in our oceans. This demonstrates that traditional sunscreen is the most harmful sunscreens for our marine environments. Hopefully, this can influence people to go with the safer choice of biodegradable sunscreen in the future.

Overall, our study concluded that biodegradable sunscreen is the best for marine environments in terms of oxygen concentration, pH level, carbon dioxide level, and ocean appearance. We could look into this further by experimenting with different types of biodegradable sunscreen, such organic versus inorganic or different SPFs. This would allow us to determine what the absolute safest sunscreen for our oceans is. Taking the research on sunscreens further will benefit our community by adding onto our original experiment. Discovering the causes behind water pollution can help our community to try and put a stop to it, which will hopefully lead to cleaner beaches all over Long Island.

In order to inform more people about the dangers of sunscreens to marine environments, and raise awareness about the issue overall, our team has designed a website containing information about our project and the research we performed prior to the experiment. The website was shared via social media and can be easily accessed at: www.jeffreyyu101.wix.com/asquadresearch

Team Collaboration

At the start of our experiment, each member of our team was assigned a role. Jeffrey, who is known for being very strong at math and working with statistics, was given the task of analyzing whatever data gathered in our experiment and running the statistical tests on them. In addition, he and Mayeesa also split up the task of researching sunscreens extensively and figuring out what to hypothesize and test. Because the statistical analysis of the data did not come until much later, this was the first task that Jeffrey completed. He and Mayeesa split the 16 sources that our group had discovered and used them to draw conclusions about the causes of water pollution due to sunscreens. Eventually, through completing even more research on the Internet, they determined what tests the group needed to perform and what sunscreens we were going to use (both our dependent and independent variables). Together, they formulated three hypotheses, which served as the backbone to the experiment. Jeffrey, being the only one of the group to have any experience with engineering, additionally put together a system for water filtration using a peristaltic pump, tubing and a micro filter, which was used in water collection. After our data had been collected, Jeffrey completed his role by entering the information into the spreadsheet and completing the statistical analysis using SPSS.

The job Mayeesa was given in the group was team secretary. This decision was based on her organizational skills. As secretary, her main task was to record exactly what the group accomplished on a daily basis in a log. Each day, she made sure to type up everything that had happened regarding our experiment (including the times outside of class when all members met up or used Google Hangout to discuss our experiment). In addition to working with Jeffrey to determine our hypotheses, Mayeesa was also in charge of the organization of our materials. She researched online and used popular shopping websites to order all our materials, make sure they arrived on time and divided the cost evenly between the four of team members. In addition, Mayeesa kept the group on track so we could complete the study in the time frame we had. Additionally, she did the majority of the editing on the final Mission Folder. Her excellent editorial and writing skills greatly benefited the team in our final write up.

Priscilla and Jasmine were both given the role of experimenter. This means that they performed the majority of the testing while Jeffrey and Mayeesa handled data analysis and organization. Priscilla completed both the carbon dioxide testing and pH testing for all five days of data collection. Prior to this, however, she and Jasmine worked together to formulate the SRC proposal to submit to our school administration for approval. The two of them collaborated on the initial submission and again to correct any mistakes that had been found on the first draft. In addition, Priscilla also devised the procedure, which detailed everything we needed to do to complete our experiment. In order to achieve this, she had to first locate a beach where water collection would be possible and then concoct a collection method. She also had to develop our experimental method, aided by the already developed hypotheses and the tests we'd chosen to run.

In addition to helping Priscilla with the SRC proposal, Jasmine also completed all the dissolved oxygen concentration testing for five days. This test was the most complicated to run because it involved the use of several potentially hazardous chemicals. Due to this, Mayeesa helped her in completing the tests. Jasmine also researched extensively about sunscreens and their harm to the marine environment and used the information she discovered to determine what controls should be present in our experiment. Jasmine also served as the photographer and took several pictures of the sunscreen and the tanks to ensure that the group would have enough to look at for future reference. After the end of testing, Jasmine and Mayeesa worked together to the clean out all the tanks and restore the experiment space to the way it had been prior to the group using it.

For the second phase of the study, the group members split up the tasks just as they had done previously. Jasmine, Priscilla, and Mayeesa completed the majority of the testing while Jeffrey ran the statistical testing once more. Since phase two took place over the course of two weeks, the testing extended into the student's winter vacation. Jasmine, Mayeesa, and Jeffrey visited the school during the break and performed all tests on the four tanks. Additionally, they completed work on the website.

All members of the group played a major role in water collection and filtration, which was probably one of the most important parts of the experiment. All group members were present at the beach when water was collected using tubing and also when water filtration occurred that same day. Another responsibility that the group took on together was the completion of the Mission Folder detailing with the experiment. The group divided the paper into parts so everyone was given an equal amount of work but also collaborated in order to make sure all the information added up. Throughout the experiment, everyone worked to keep each other on track and make sure we all accomplished what we needed to. There was no major conflict and everyone worked together cohesively without much problem. There was no team member who fell behind in his or her designated responsibilities and made someone else cover for them. Everyone put in his or her fair share of effort. All in all, each group member played an integral part in the experiment and completed a substantial amount of work.

Breakdown of Team Responsibilities

Mayeesa Rahman	**Jeffrey Yu**	**Jasmine Ting**	**Priscilla Lee**
Recorded the daily accomplishments of the group in an easily accessible log.	Completed research in order to determine what tests to perform and formulate hypotheses.	Performed the dissolved oxygen testing for five days in a row, with the help of Mayeesa.	Performed all carbon dioxide concentration testing for five days in a row.
Aided Jeffrey in determining what tests to perform, and formulating hypotheses.	Developed a filtration method using a peristaltic pump, tubing, and a micro filter.	Helped Priscilla to devise SRC proposal (both the first draft and the final copy)	Performed all pH level testing for five days in a row.
Determined the costs and where to buy materials. Ordered all materials and made sure they arrived at the correct time.	Kept a careful record of all data as testing progressed.	Determined what controls be present in our experiment by completing research.	Worked with Jasmine to devise SRC proposal (both the first draft and the final copy)
Helped Jasmine to complete oxygen testing.	Entered the data into SPSS and ran the statistical analysis.	Took photographs of the experiment to ensure we had future reference.	Developed procedure by completing research.
Completed water collection and filtration.	Completed water collection and filtration.	Completed water collection and filtration.	Completed water collection and filtration.
Completed her designated portion of the Mission Folder, and completed the majority of the revisions.	Completed his designated portion of the Mission Folder.	Completed her designated portion of the Mission Folder.	Completed her designated portion of the Mission Folder.
Completed work on website.	Completed work on website.	Completed work on website.	Completed work on website.