The Fireproofing Abilities of Sodium Polyacrylate in the Form of a Gel, Water Based Paint, and Spray

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In light of recent events, finding more methods of making homes and buildings more fire resistant is important. A method of making homes and buildings more fire resistant is using fire and heat resistant coating and applying them to the surfaces of these structures. While other types of coatings have been widely researched and are currently used, there is little research on how superabsorbent polymers can be used to protect against heat and flame. Sodium polyacrylate is a super absorbent polymer that turns into a gel. Sodium polyacrylate has been observed to have heat resistant properties due to the chemical orients with water. The sodium polyacrylate was tested in 3 different forms along with a control with no form of the chemical. It was tested in the form of a gel, a sprayable liquid, and mixed in with a water based paint. It was hypothesized that the material tested with the sodium polyacrylate in the form of the gel would prevent more of the testing material from being burned than the material tested with sodium polyacrylate in the form of a liquid, mixed in with a water based paint, or the control. The samples had their own respective coatings placed on them and were burned for 2 minutes. The mass in grams of each sample was measured before testing and then the remaining material was measured after testing to record the amount lost. 15 of each variable, including the control, was burned for a total of 60 samples. An ANOVA was conducted after experimentation to test the significance of the data. The ANOVA showed that the data were significant and rejected the null hypothesis with a p- value <0.001. A post hoc Tukey test showed that there were significant differences between the gel and every variable except for the sodium polyacrylate combined with the water- based paint. Further analysis showed that the gel and the paint did not yield statistically different results. The test also revealed that the spray was only statistically different from the control in terms that it prevented most of the surface from burning

Introduction

According to the National Fire Protection Association, approximately 374,000 homes in the US are destroyed due to fires each year. Additionally, there was recently a large forest fire in California, reminding the public of the relevance and always present dangers these fires can bring. These events have led to discussion over methods of making homes fire resistant in order to protect them from fires. Some of these methods include applying different coatings to the outside surfaces of homes. Many fire resistant coatings are intumescent that swell when introduced to heat in order to protect the surface below and while these coatings are effective, little research has been conducted on the effects of different fire resistant substances.

Other fire resistant substances include super absorbent polymers. Super absorbent polymers are polymers that can absorb liquids and promptly turn into a gel. These super absorbent polymers have been observed to absorb immense amounts of water and other liquids. Along with their ability to absorb mass amounts of water, these polymers also have fire resistant qualities[1]. [2]stated "It is well known that moist fire protection materials have good fire resistance characteristics." These fire resistant properties are thought to be the effect of how these polymers orient themselves in and with water[2]. When introduced to water, the polymer turns into a gel and forms bubble-like structures.

These bubbles, along with the polymers alone, have been observed to be able to withstand high temperatures. It was found that another fire resistant polymer was able to withstand temperatures as high as 700 degrees celsius[3]. It was stated "this fact [the results] confirms a synergistic effect of G-MMT and APP on flame-retarding P(BA-VAc), which indicates G-MMT was essential in producing solid residues at high temperature[3]." The results of the experiment showed that the polymer was effective in protecting from flame and high temperature.

Sodium polyacrylate is another form of a super absorbent polymer. This polymer is commonly used in diapers due to its ability to absorb up to 500 times its weight in water. Along with the ability to absorb mass amounts of water, it has also been observed to have fire resistant properties[5]. Due to its fire resistant properties, sodium polyacrylate has been used to protect actors in movie scenes that deal with flames. While the fire and heat resistant properties have been observed they have not been widely researched or experimented with.

While there is research on the properties of fire resistant polymers, there is minimal research on their effectiveness in different forms. Although these polymers are typically a powder that turns into a gel, they can be used in the form of a liquid. This experiment focused on using sodium polyacrylate in the form of a gel, liquid, and mixed in with a water based paint. There has been minimal research on the use of fire resistant polymers in the form of liquids or when mixed in with other substances. Therefore it is relatively unknown whether these different forms have a substantial effect on fireproofing different substances.

The purpose of this experiment was to determine if there is a difference in using sodium polyacrylate in the form of a gel, liquid, and mixed in with a water based paint. The purpose of this project is that fires cause damage to property, property loss, and multiple deaths a year and to find a more efficient way to make substances more fire resistant. This polymer could be a solution to numerous losses due to fires. It was hypothesized that the gel would have better fireproofing abilities than the water based paint and the liquid forms of the polymer but the water based paint would have better fireproofing abilities than the liquid. It was hypothesized that the gel would have better fireproofing abilities than the liquid form or the water based paint due to the polymer being in its most natural state. It was hypothesized that the water based paint solution would have better fireproofing abilities than the liquid form due to the water in the paint allowing the polymer to retain its properties.

Methods

The sodium polyacrylate was bought from an online retailer. The cardboard samples used were cut from cardboard boxes. The cardboard samples were approximately 54cm^2 with a length of 9cm and a width of 6cm. All of the cardboard samples were the same thickness. The gel form of the sodium polyacrylate was made by taking 1g of powdered form of sodium polyacrylate and adding 206mL of water and stirring until the gel was formed. The drops of water were added using a beaker and pipette respectively. The liquid form was made by taking 1g of salt and adding it to the gel form of the chemical. The salt did not interfere with the properties of the chemical but it did transform the chemical from a solid to a liquid. The

liquid formed was placed into a spray bottle and sprayed on to the cardboard samples. Water- based paint was used instead of other forms of paint to ensure that the sodium polyacrylate retains its properties. The water- based paint compound was made by taking water based paint and adding the liquid form of sodium polyacrylate to the paint. The liquid form of the sodium polyacrylate was made in the same manner as made for the sprayable liquid form.

A random number generator was used to assign the cardboard samples to each variable. Cardboard samples assigned the number one were used to test the gel form of sodium polyacrylate. Cardboard samples assigned the number two were used to test the sprayable liquid form of sodium polyacrylate. Cardboard samples assigned the number three were used to test the water- based paint form of sodium polyacrylate. The gel form of the sodium polyacrylate was applied to one flat side of the cardboard sample. The gel was applied using a spatula. The gel was applied 3mm thick and covered the entire side of the sample. The sprayable liquid form of the polymer was applied to one flat side of the cardboard sample. Five pumps of a finger pump spray bottle were applied to each sample. Considering that one pump is approximately 10mL, then 50mL were applied to each sample. The water-based paint was also applied to one flat side of the cardboard sample. The paint was applied using a paint brush. An even, thick layer of paint was applied to each sample so that the cardboard can not be seen through the paint. The painted samples were allowed to dry for 12 hours to make sure the paint is completely dry before testing. A control set of cardboard samples did not have anything applied to their surface.

Experimentation took place in a fume hood. Proper safety procedures were followed including the use of goggles, gloves, and an apron. At the start of testing, the selected sample was placed at a diagonal up against a brick with the appropriate form of the sodium polyacrylate facing down. An already lit tea- light candle was placed up under the cardboard sample so that the flame is touching the sample. Below is a diagram of the testing design along with the experimental diagram. Each sample was allowed to burn for 2 minutes before the flame was extinguished. Once the flame was extinguished, a scale was used to find the mass of the sample after testing. The amount remaining was subtracted from the starting mass and the difference was recorded. This was repeated for each sample. Following experimentation, data were collected and statistical analysis was completed. Figure I, located in Appendix B, shows the testing set up for experimentation. Figure II, located in Appendix B, shows the experimental diagram for the experiment.

Results

The data and results of the experiment were gathered by taking the mass of the samples before experimentation and taking the mass of the samples after experimentation, then subtracting the mass after experimentation from the mass before experimentation. This method allowed for a correct reading of how much of the testing material remained after testing. It also allowed for a correct reading of how well the variable tested protected the cardboard surface underneath. Data were analyzed using the masses after experimentation and running tests to see if these masses had any significant differences. The raw data for the experiment can be seen in appendix A tables 1, 2, 3, and 4.

The boxplot showing the masses after testing for the sodium polyacrylate gel can be seen in figure 1 in appendix C. The descriptive statistics of the data, shown in table 1 in appendix D, shows that there was a mean difference of 0.6760 grams in the masses before and after testing. The boxplot showing the masses after testing for the sodium polyacrylate spray is shown in figure 2 in appendix C. The descriptive statistics of the data, shown in table 2 appendix D, shows that there was a mean difference of 1.52 grams in the masses before and after testing. Figure 3 in appendix C, displays the mass differences after testing for the sodium polyacrylate combined with the water based paint. Table 3 of appendix D shows that the mean difference in the masses after testing for the sodium polyacrylate combined with the water- based paint was 0.8367. Figure 4 in appendix C, displays the mass differences after testing for the control samples. Table 4, in appendix D, shows that the mean difference in the masses before and after testing the control samples, with no form of sodium polyacrylate on them, was 2.1720.

The box plot compares the mass after testing for the sodium polyacrylate gel, spray, water- based paint, and the control can be seen below in figure 5 of appendix C. This comparison of the data from each variable shows the difference performance levels for each of the variables in comparison to one another. The boxplots show that the sodium polyacrylate gel and the sodium polyacrylate combined with the water- based paint had similar performance and resulted in smaller mass differences..

An ANOVA was conducted using the mass differences for each of the variables to verify the significance of this data. The results of the ANOVA proved to be significant with a p- value less than 0.001 with an alpha of 0.05. The data from this ANOVA rejects the null hypothesis. This suggests that there is a significant difference in the masses after testing the sodium polyacrylate gel, the sodium polyacrylate spray, the sodium polyacrylate combined with the water- based paint, and the control. The results of the ANOVA can be seen in table 5, appendix D.

Considering that the ANOVA rejected the null hypothesis, a post hoc Tukey test was conducted. The post hoc Tukey test was conducted to identify where the significance in the data lies. Figure 6 in appendix C shows the results of the Tukey test. The interval plot of the data shows that the sodium polyacrylate gel has the lowest mean mass differences while the control has the highest mass differences. The interval plot can be seen in figure 7 in appendix C. In respect to the sodium polyacrylate gel, the post hoc Tukey test showed that there was a significant difference between the gel and the sodium polyacrylate spray. There was also a significant difference between the sodium polyacrylate gel and the control. In terms of the sodium polyacrylate spray, there were significant differences between the spray and the paint, the spray and the gel, and the spray and the control. In terms of the sodium polyacrylate combined with the water-based paint, the Tukey test showed that there was a significant difference between the paint and the sodium polyacrylate spray and the paint and the control. In terms of the control, the tukey test showed that there was a significance in the mass differences between the control and the gel, the control and the spray, and the control and the paint. However, the results did not show a significant difference between the mass differences for the sodium polyacrylate gel and the sodium polyacrylate combined with the water- based paint. Figure 7 shows the graph comparisons between the different forms of sodium polyacrylate.

Discussion

The purpose of this study was to investigate different forms of the chemical sodium polyacrylate and their fire resistance. Considering recent events, there has become more of a need to find ways to protect different objects from fire such as homes and buildings. Because there has been much discussion to find fire resistant coatings to protect these different surfaces. For this reason, sodium polyacrylate, a heat resistant chemical, was tested. The chemical was tested in the form of a gel, a liquid form that was applied using a spray bottle, and mixed in with a water- based paint, control samples were tested without any form of the chemical.

A one- way ANOVA was used to analyze and determine if there was significance in the data. The ANOVA was run at a 95% confidence level with an alpha of 0.05. The ANOVA p- value of <0.001 revealed that there was a significant difference between the means. This result rejected the null hypothesis. This means that at least one of the means for the different forms of sodium polyacrylate were significantly different from the other

means. Although the ANOVA showed that there is a significant difference in the means, it does not show where the differences lie. For this reason, a post hoc Tukey test was conducted.

The results of the Tukey test showed which of the different variables had a significance between the means. In terms of the sodium polyacrylate gel the Tukey test showed that the gel had a significant mean from spray and the control. Considering that the gel had a mean mass difference of 0.6760g and the spray had a mean mass difference of 1.52g, the gel was significantly better at protecting the surface underneath than the spray. The control had a mean mass difference of 2.1720g therefore implying that the gel was also significantly better at protecting the surface underneath than the control. Regarding the sodium polyacrylate combined with the water- based paint, the Tukey test showed that there were significant differences between the paint and the spray and the control. Considering that the paint had a mean mass difference of 0.8367g and the spray had a mean mass difference of 1.52g, the data indicate that the paint was significantly better at protecting the surface underneath than the spray. Also considering that the paint had a mean mass difference of 0.8367 and the control had a mean mass difference of 2.1720g, the data indicate that the paint was significantly better at protecting the surface than the control. In concern to the sodium polyacrylate spray, the Tukey test showed significant differences between the spray and the gel (as mentioned above), paint (as mentioned above), and control. Considering that the spray had a mean mass difference of 1.52g and the control had a mean mass difference of 2.1720g, the spray was significantly better at protecting the testing surface than the control.

Overall, the data indicate that the sodium polyacrylate gel and the sodium polyacrylate combined with the water- based paint were better at protecting the testing surface than the sodium polyacrylate spray and the control. It was originally thought that the gel would outperform that paint however this did not occur. This is thought to be because of the water in the paint allowing the sodium polyacrylate to keep its structure and heat resistant properties. The same reason is why it is thought that the sodium polyacrylate gel protected the surface to the capacity it did. The water along with the gel allowed the chemical to keep its structure and fire resistant properties. The spray and the control performed as expected. The spray was thought to perform better than the control due to the presence of the sodium polyacrylate than compared to it not being present. It was also expected that the spray would not perform as well as the gel or the paint due to the fire being able to evaporate the water combined with the chemical and breaking down the fire resistance. In conclusion, the data and results of this experiment highlight that the gel and paint forms of this chemical could be useful in making different surfaces more fire resistant. In the future their application to different surfaces could prove to be beneficial.

There are several venues for future research using this chemical. For instance, there are numerous other fire resistant chemicals that sodium polyacrylate could be mixed with to increase the amount of fire resistance. This could be accomplished using sodium silicate. Another method for future research could be to test the chemical using different amounts of water to make the chemical in different consistencies. The recommended amounts are 1g of sodium polyacrylate to 824mL of water, however the chemical could be tested to see how different amounts of water affect the results.

Acknowledgements

I would like to acknowledge Mrs. Michelle Spigner for helping me through the course of this experiment and its planning. I would also like to thank her for allowing me to use the fume hood in her classroom when needed. I would also like to thank my family and friends for their support during this process. Thank you to Mrs. Shawna Moore and Dr. Brenda Mack for allowing me to use Mrs. Moore's fume hood at Ridge View High School as well.

Notes and References

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Appendix A

Raw data for sodium polyacrylate gel

Trial	Starting Mass	Ending Mass	Difference
1	18.3g	17.9g	.4g
2	19.4g	19.2g	.2g
3	20.2g	19.3g	.9g
4	21.3g	19.9g	1.4g
5	17.8g	17.1g	.7g
6	20.5g	20.1g	.4g
7	19.68g	18.56g	1.12g
8	19.16g	18.59g	.57g
9	19.99g	19.13g	.86g
10	20.92g	19.51g	.41g
11	20.22g	19.59g	.71g
12	18.39g	17.84g	.51g
13	23.06g	22.58g	.48g
14	19.32g	18.45g	.87g
15	20.97g	20.31g	.66g

Raw Data for sodium polyacrylate spray

Trial	Starting Mass	End Mass	Difference
1	3.66g	1.52g	2.14g
2	4.78g	2.78g	2.00g
3	3.70g	2.18g	1.52g
4	4.36g	2.28g	2.08g
5	4.4g	3.15g	1.25g
6	4.04g	2.79g	1.25g
7	3.99g	2.47g	1.52g
8	4.11g	2.71g	1.4g
9	4.96g	2.70g	2.26g
10	4.01g	3.65g	.36g
11	4.36g	3.03g	1.33g
12	4.60g	2.71g	1.89g
13	4.03g	2.51g	1.52g
14	3.68g	2.23g	1.45g
15	4.18g	2.62g	1.56g

Raw data for sodium polyacrylate combined with water-based paint

Trial	Starting mass	End Mass	Difference
1	3.38g	2.35g	1.03g
2	3.31g	2.17g	1.14g
3	3.38g	2.87g	.51g
4	3.36g	2.11g	1.25g
5	3.54g	2.46g	1.08g
6	3.38g	2.69g	.69g
7	3.46g	2.72g	.74g
8	3.50g	2.44g	1.06g
9	3.27g	2.53g	.74g
10	3.34g	2.47g	.87g
11	3.17g	2.92g	.25g
12	3.28g	2.63g	.65g
13	3.40g	2.62g	.78g
14	3.82g	3.26g	.56g
15	3.48g	2.27g	1.21g

Raw data for control

Trial	Starting Mass	End Mass	Difference
1	2.88g	.8g	2.08g
2	2.9g	.37g	2.53g
3	2.95g	.92g	2.03g
4	2.98g	.66g	2.32g
5	2.86g	1.03g	1.83g
6	2.96g	.91g	2.05g
7	2.88g	.2g	2.68g
8	2.75g	1.1g	1.65g
9	2.86g	.53g	2.33g
10	2.71g	.79g	1.92g
11	2.80g	1.11g	1.69g
12	2.71g	.58g	2.13g
13	2.83g	.48g	2.35g
14	2.82g	.59g	2.23g
15	2.75g	0g	2.75g

Appendix B

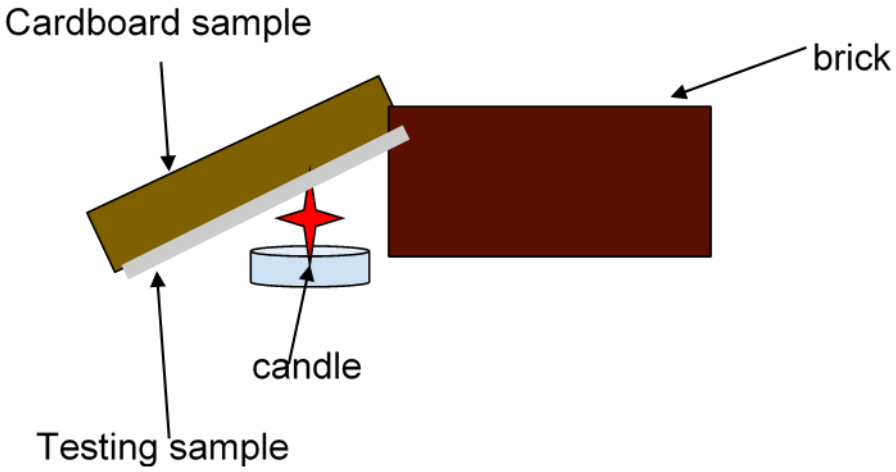


Figure I: This figure shows the testing set up for each of the samples. Including the testing material facing downwards to the flame underneath and the propped up diagonally against a brick.

Figure II: Experimental Design Diagram

Title: The fireproofing abilities of sodium polyacrylate in the form of a gel, water based paint, and spray				
Hypothesis The gel will prevent more off the surface from being burned than the water based paint solution, the spray, or the control				
Independent Variable Gel Water based paint Liquid mixture				
*** Levels of Independent Variable**	Control	Water Based paint	Liquid mixture	Gel mixture
*** Number of Repeated Trials**	15	15	15	15
Dependent Variable The amount of substance burned in centimeters squared				
Constants Source from where sodium polyacrylate is gathered Amount of time each is left to burn Amount of gel on each testing square Amount of spray on each testing square The amount of water based paint on each testing square				
Control The cardboard squares that were burned without any form of sodium polyacrylate				

Appendix C

Figure 1: Boxplot of mass differences for sodium polyacrylate gel

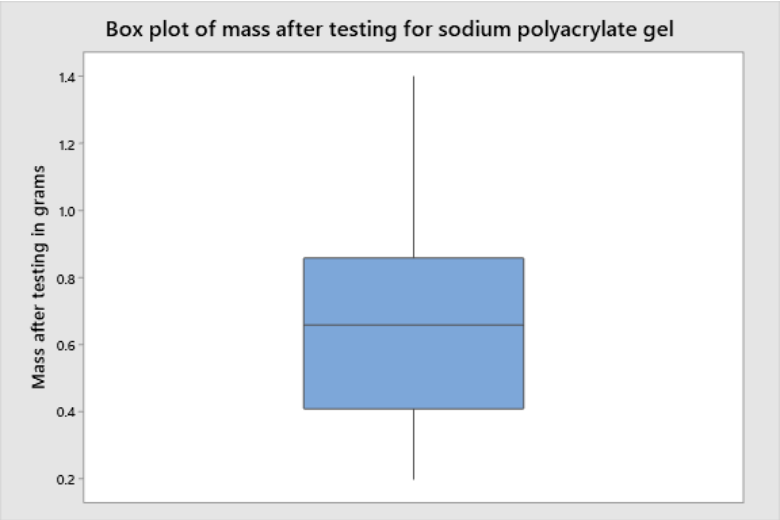


Figure 1: Shows the boxplot for the mass differences for the gel. The range of the mass differences was between 0.2g and 1.4g with a median of 0.66g.

Figure 2: Boxplot of mass differences for sodium polyacrylate spray

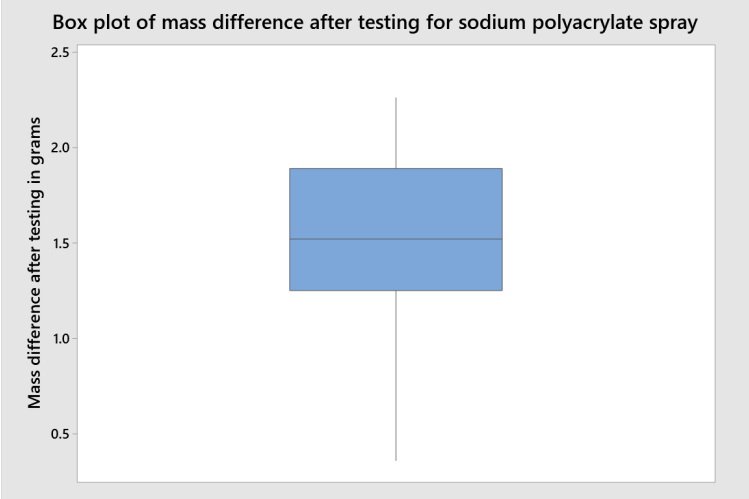


Figure 2: Shows the boxplot for the mass differences for the sodium polyacrylate spray. The range of the mass differences was between 0.36g and 2.26g with a median of 1.52g.

Figure 3: Boxplot of mass differences for sodium polyacrylate combined with water-based paint

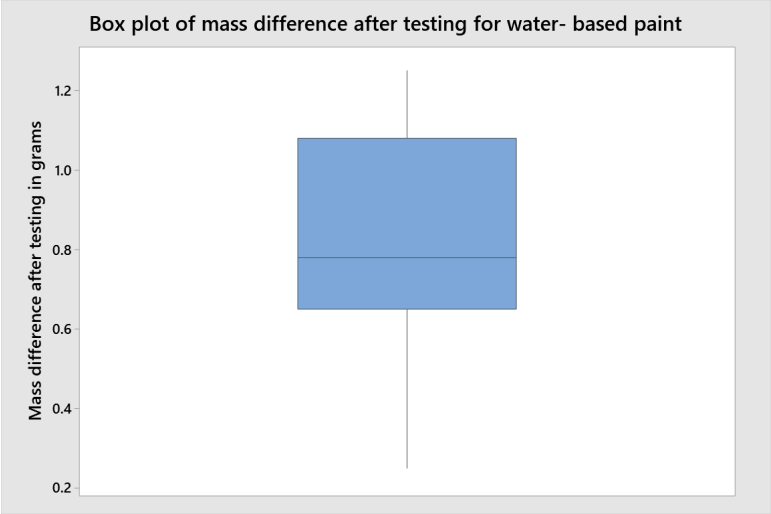


Figure 3: Shows the boxplot for the mass differences for the sodium polyacrylate combined with the water- based paint. The range of the mass differences was between 0.25g and 1.25g with a median of 0.78g.

Figure 4: Boxplot of mass differences for control

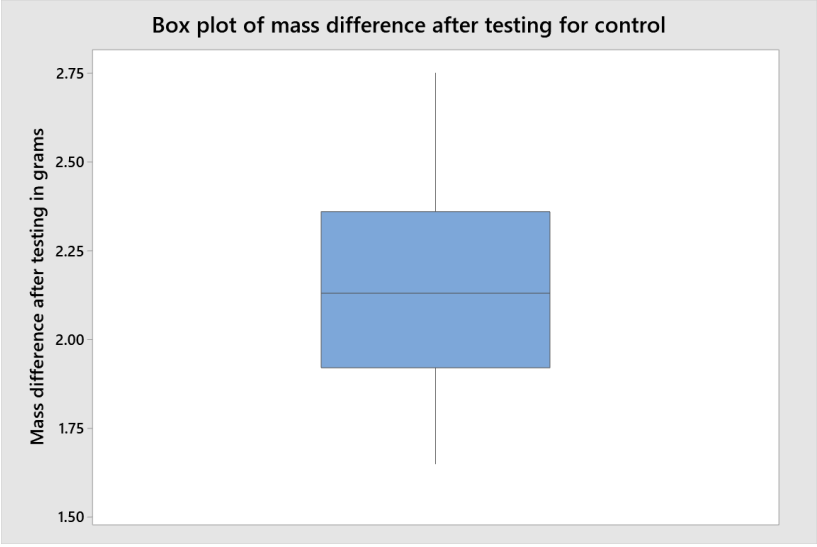


Figure 4: Shows the boxplot for the mass differences for the control. The range of the mass differences was between 1.65g and 2.75g with a median of 2.13g.

Figure 5: Boxplot for the mass differences of the sodium polyacrylate gel, the spray, the sodium polyacrylate combined with the water- based paint, and the control.

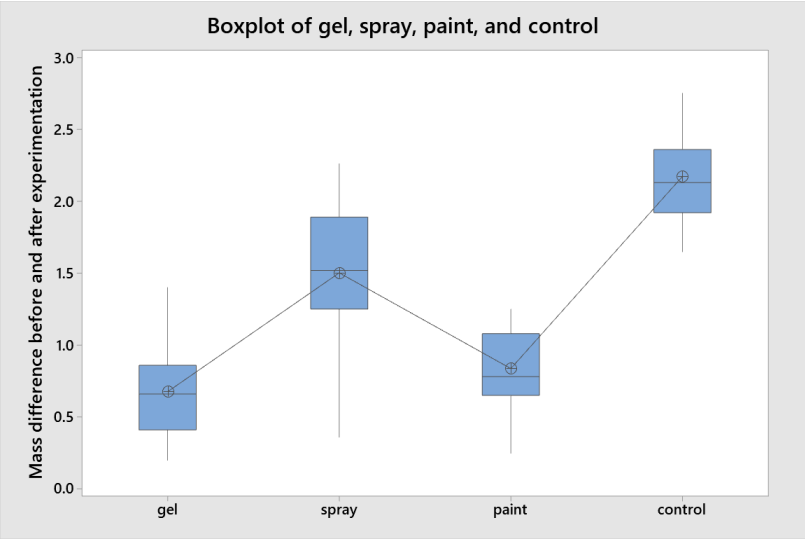


Figure 5 is a box plot comparing the mass differences for the sodium polyacrylate gel, the spray, the sodium polyacrylate combined with the water- based paint, and the control.

Figure 6: Tukey comparison intervals for the means mass differences.

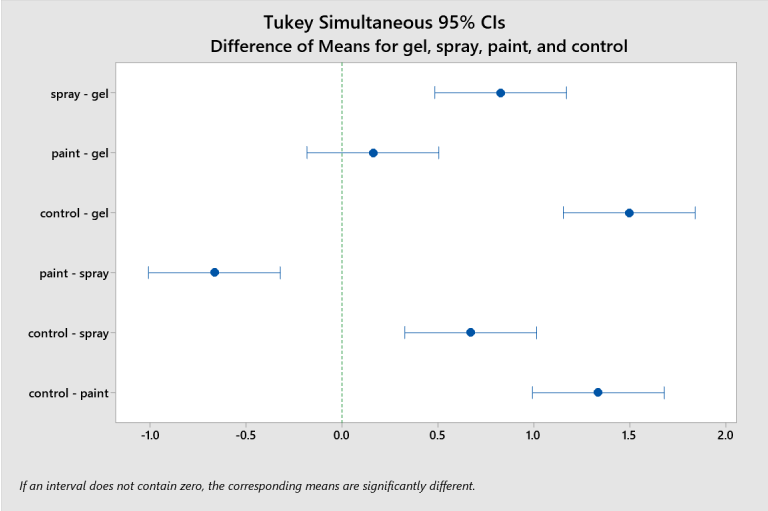
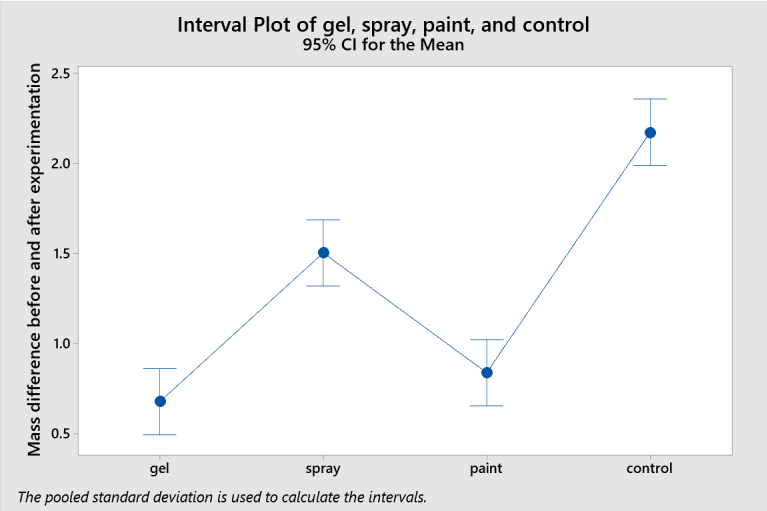


Figure 7: Interval plot of the mean mass differences for the sodium polyacrylate gel, the spray, the sodium polyacrylate combined with the water- based paint, and the control.



Appendix D

Table 1: Descriptive statistics of the mass differences of the sodium polyacrylate gel.

Statistics

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
gel	15	0	0.6760	0.0803	0.3111	0.2000	0.4100	0.6600	0.8600	1.4000

Table 1 shows the descriptive statistics of the mass differences for the sodium polyacrylate gel. The data shows a mean of 0.6760g.

Table 2: Descriptive statistics of the mass differences of the sodium polyacrylate spray.

Statistics

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
spray	15	0	1.502	0.120	0.466	0.360	1.250	1.520	1.890	2.260

Table 2 shows the descriptive statistics of the mass differences for the sodium polyacrylate spray. The data shows a mean of 1.52g.

Table 3: Descriptive statistics of the mass differences of the sodium polyacrylate combined with water-based paint.

Statistics

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
paint	15	0	0.8367	0.0739	0.2864	0.2500	0.6500	0.7800	1.0800	1.2500

Table 3 shows the descriptive statistics of the mass differences for the sodium polyacrylate gel. The data shows a mean of 0.8367g.

Table 4: Descriptive statistics of the mass differences of the control.

Statistics

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
control	15	0	2.1720	0.0855	0.3313	1.6500	1.9200	2.1300	2.3600	2.7500

Table 4 shows the descriptive statistics of the mass differences for the control. The data shows a mean of 2.172g.

Table 5: ANOVA of the mass differences

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	3	21.078	7.0260	55.60	0.000
Error	56	7.076	0.1264		
Total	59	28.154			

Table 5 shows the ANOVA results for the mass differences. The table indicates a significance between the means considering that the p- value is >0.001 with an alpha of 0.05.