RESEARCH ARTICLE

Leachable Xenoestrogen Contaminants in Commonly Used Plastics and How High School Students Feel About This

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ABSTRACT: Potential health risks are associated with plastic use, one of which is the inadvertent consumption of the xenoestrogen contaminants Bisphenol A and phthalates. Xenoestrogens include industrial compounds that are byproducts of plastic manufacturing, and they are known to have development-altering potential. The purpose of this project was to (1) qualitatively analyze commonly used plastic food and drink containers for xenoestrogen content and to (2) use a survey to educate high school students about the scientific knowledge concerning the potential health risks of xenoestrogens. The Experimental component of this project analyzed the presence or absence of xenoestrogens in water and isopropanol extractions of the plastic samples. In the survey, high school students were queried before and after discussing the experimental data to assess whether the knowledge was likely to decrease individual plastic consumption. The project found that some plastics leached xenoestrogens and that students who had achieved a better understanding of xenoestrogen contamination indicated that they would either use the same amount of plastic or less in the future. The survey did not find a direct correlation between the amount of knowledge and plastic consumption; however, it successfully provided high school students with information to educate them about the health risks associated with xenoestrogens.

KEYWORDS: Earth and Environmental Sciences; Environmental Effects on Ecosystems; Plastic Consumption; Xenoestrogen Contamination; Bisphenol A.

Introduction

Plastic has become a massive part of the modern world. Various plastics are used in construction, food packaging, healthcare materials, and transportation.[1] However, the increase in plastic production has resulted in a plastic waste crisis. Today, the United States generates more than 258 million tons of solid waste each year, with only about 34.6% being recycled and the rest sent to landfills.[2] Americans use so much plastic daily, but many people do not necessarily know what goes into the production of plastics.

Every plastic product has a recycling symbol to identify the chemical type of plastic it contains; however, not all of these are recyclable or reusable, despite what the symbol implies.[3]

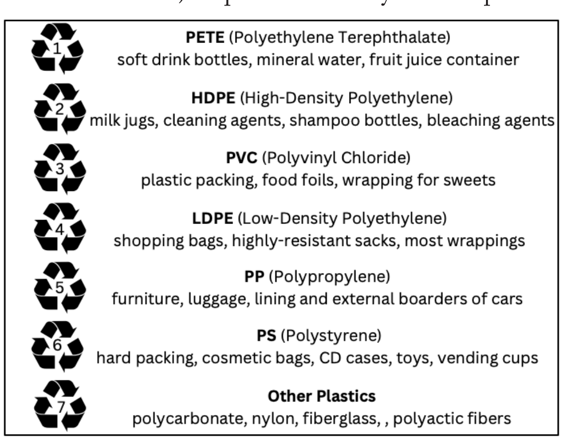

Figure 1: Plastic recycling numbers; the table shows the type of plastic associated with each number and gives examples of each type.[3]

Each plastic number is made of different materials that have different characteristics, and many different purposes. For example, polyethylene terephthalate (PETE) used in Type 1 has very different uses than polypropylene used in Type 5 plastic, as shown in Figure 1. The purpose of having plastic numbers on materials is to inform workers and consumers what type of plastic the material is so the material can be appropriately sorted for recycling, and they can be processed correctly.[3] While the recycling symbols help provide people with this information; many people do not understand what they mean. The L'Oreal Paris Elvive cosmetic company conducted a survey that showed that people want to recycle to prevent plastic pollution. However, only 37% of people correctly identified what the recycling symbols represent.[4] This means that the majority of people do not understand what the recycling numbers represent. People want to help the environment, but cannot know the best way to do so without understanding the differences between plastic types.

Plastics are mostly made from raw materials based on fossil fuels, such as crude oil, natural gas, and coal, but many chemicals are also used in their production.[5] One of these chemicals is Bisphenol A or BPA. BPA is an industrial chemical found in polycarbonate plastics and epoxy resins that are used in food and beverage packaging and to coat the inside of metal food containers.[6] Environmental conditions such as drastic weather changes and UV light, as well as time, can cause the BPA in the plastic to leach into the substances that are being stored. While BPA helps to create food packaging, it is considered to be an endocrine disruptor that can affect how estrogen acts

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in the body, and it disrupts the normal hormonal balance.[7] The FDA-acceptable dose limit of BPA is 23 micrograms per pound of body weight, but BPA can be even more toxic in smaller doses due to the way it interacts with body receptors.

A study published in Environmental Health Perspectives in 2015 tested BPA concentrations in urine samples of 2,517 participants and found that BPA was detected in 92.6% of the participants, and the concentration of BPA ranged from 0.4 micrograms/liter to 0.149 milligrams/liter.[8] BPA has been linked to many different health problems, specifically reproductive, immune, and neurological problems, as well as increasing the risk of cardiovascular disease and breast cancer.[7] While plastic producers do not intend for the chemicals to leach into the foods or beverages stored in these plastics, they are still using them and thus increase the risk of people ingesting these toxic chemicals. People could avoid ingesting toxic chemicals by reducing their overall plastic use and avoiding storing plastic in conditions that are known to cause BPA to leach from the plastic. Examples of these conditions are extreme temperatures or keeping the containers for long periods of time.[9]

Another type of chemical that is used in the manufacturing of plastics is phthalates. Phthalates are used as plasticizers and are added to many plastics, mainly to soften polyvinyl chloride (PVC) plastics, in order to increase flexibility, durability, transparency, and longevity.[10] Phthalates are similar to BPA because they are also hormone-disrupting chemicals. However, it is unclear what damage phthalates cause to the human body at low doses. In high doses, phthalates have been found to cause harm to many organs, such as the liver, kidneys, and lungs, as well as to the reproductive system, especially in young infants.[11] There are many health hazards associated with plastics. However, they can be avoided if plastic is used in safe conditions.

While most people do not know what BPA is, it is not unknown to everyone. The FDA conducted a study where they used two different methods to determine the amount of BPA that leaches from different types of baby bottles.[12] The importance of determining the amount of BPA in baby bottles is that BPA has a strong effect on the infant brain, impairing babies' learning ability and memory and having a lasting impact on their behavior.[13] The FDA analyzed three different types of baby bottles using both the standard HPLC method and the UHPLC method to determine the leaching concentrations of BPA. The FDA analysis showed that different amounts of BPA were detected in the three types of baby bottles, and if an infant were to drink 250 mL of liquid from the baby bottles, they would consume 0.1 μg/kg of BPA, which caused some concern in many studies.[12] The FDA determined that many different types of baby bottles contained BPA and pose a risk to infants. As a result of this study, the FDA banned the use of BPA in baby bottles and other baby products.[12] While BPA is not widely known; the FDA has extensively studied BPA in an effort to protect people's health. In response to the FDA ban, plastic manufacturers have begun using different plastic types for their products or replaced BPA with BPF or BPS, which are less studied.

It can be difficult to determine if a substance contains BPA since it is present in low concentrations, dissolves in many organic solvents and acids, and is only slightly soluble in water.[14] The tool used to overcome this limitation and determine the presence of BPA was Gas Chromatography Mass Spectrometry or GC-MS. The GC-MS combines two microanalytical techniques to determine each component's identity and its concentration in the samples. The gas chromatograph separates the components of a mixture in time, and the mass spectrometer provides the information to help identify and quantify each component.[15]

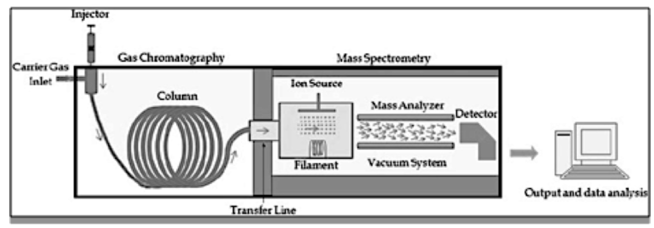

Figure 2: Principal components and setup of the GC-MS instrument.[16] https://www.researchgate.net/figure/Schematic-plot-of-the-main-components-of-GC-MS-instruments_fig1_273955959.

As shown in Figure 2, a sample is injected into the gas chromatograph and enters as a gas into an analytical column, a narrow 25-meter-long glass capillary with a wax coating on the inside. The analytical column is gradually heated to about 300˚C to separate the chemical components based on their differential solubility in the gas and wax coating phases. The separated components then exit the column and enter the mass spectrometer. The components are ionized to form fragments and molecular ions. Mass spectrometry detects each component by the mass-to-charge ratios of their ions and displays the data for each ion in a chromatogram. The mass spectrometer computer provides a NIST library that stores the chemical properties of compounds and can determine (i) what compounds are present, (ii) the amount of each compound that was identified in the sample, and (iii) the probability that it is that specific compound. The GC-MS can specifically identify most compounds in a sample, which is helpful for experimental studies.

If Americans were more educated about plastics, the health risks associated with the toxins in plastics would be more familiar to many, and the amount of plastic that people use might decrease. The gaps in this research are how much Americans know about plastics and how more knowledge can change their perspectives on plastics. The second part of this research surveyed how high schoolers' opinions of plastics would change after receiving data from the experimental study on randomly selected food container plastics. The popular plastics chosen included many different products that many people use daily; examples of this are plastic water bottles and epoxy-coated soup cans. This project aimed to determine how and where BPA is found in randomly selected plastics and to educate young adults about plastics.

■ Methods

This study had a mixed-method approach, consisting of an experimental laboratory study and a survey. This allowed for both analytical and survey data to be collected on the amount of BPA found in plastic materials and how high school students' perspectives might change if they were more aware of plastic contaminants. This will determine what effect knowledge about plastic may have on individual plastic use. The overall goal of this project was to increase awareness about the health risks of the chemicals in plastics and to determine if plastic use would decrease if more people were aware of the health risks associated with those chemicals.

Authentication of methods for assessing Bisphenol A and phthalates leached from plastics –Standard Curve:

Before the experimental study was conducted, pure standard BPA was purchased from Sigma Chemical Co. this standard was analyzed and authenticated by GC-MS. A standard response curve was established to determine if the methods were sensitive enough to observe compounds leached from small amounts of plastics (e.g., a single plastic water bottle and a single soup can). Pure standard BPA was mixed with dimethylformamide (DMF) to create six concentration levels to inject into the GC-MS. These samples included 500-fold, 1,000-fold, 1,500-fold, 2,000-fold, 2,500-fold, and 3,000-fold dilutions of a solution containing 6 micrograms of BPA per milliliter. The purpose of these dilutions was to determine the abundance of BPA in each sample. This data was then used to find the approximate linear curve for three concentrations in the range that might be found in plastic leachates.

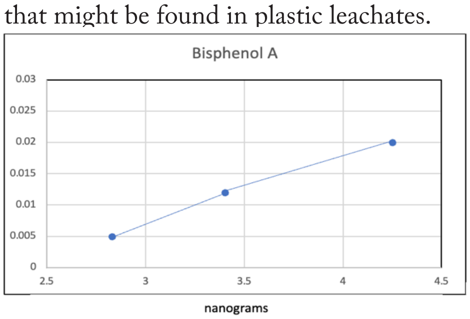

Figure 3: The approximate linear relationship for the three highest concentrations of BPA used for the standard curve; the y-axis represents abundance, and the x-axis represents nanograms of BPA.

As shown in Figure 3, the GC-MS computer library could recognize BPA at different concentrations and find the abundance of BPA in these dilutions. This was important because it proved that the GC-MS analysis could identify BPA that was present in sample leachates, and quantitative data could be obtained. It was not possible in this study to compare quantitative data for all different plastics tested because the types of plastics differed in density and other properties. Our purpose was to determine qualitatively whether Bisphenol A and/or phthalates were present in leachates from the 22 randomly selected plastic types. In cases where xenoestrogens were found, further work beyond the scope of this project will be needed to obtain replicate data and the concentration of BPA - micrograms of Bisphenol A per milligram of each particular plastic.

The 20 types of plastic analyzed:

The products that the samples were created from were (1) plastic water bottles, (2) pieces of PVC pipe (as found in household plumbing), (3) a DVD, (4) a frozen Shrimp container, (5) store thermal receipt paper, (6) a plant growth container, (7) an empty soup can, (8) Milli-Q water, (9) Gorilla glue dried on paper, (10) plastic wrap, (11) a ramen noodle package, (12) an oatmeal cookie package, (13) distilled water, (14) a hard candy wrapper, (15) a fresh Mexican blueberry container, (16) plastic wrap for sausages, and (17) a typical restaurant take-out container. All these plastics were obtained from grocery stores. The Milli-Q water and the distilled water were included as controlled samples because it was expected that there would be no BPA present in the samples.

Procedure for leaching BPA from plastics:

The popular plastic products used in the experimental study, except for the plastic water bottles, were cut into approximately 2 cm by 2 cm squares, submerged in 100 ml of water, and placed in an oven and heated at 75˚C for approximately 48 hrs. The water bottles were split into two separate groups: 235 ml of the water was stored at room temperature, and 235 ml of the water was placed in the oven at 75˚C with the other samples. The samples were heated to allow the plastic to release the BPA faster if present. For each sample, the pieces of plastic were removed from the water which was then lyophilized (freeze-dried) to concentrate the chemicals leached into the water. Chloroform was then added to the lyophilized samples to dissolve the BPA, the chloroform was evaporated, and the samples were suspended in a minimal amount of DMF for injection into the GC-MS. This process is relevant because it collects the BPA from the plastic with minimal loss and the final solution is a nonpolar (water-hating) solvent that the GC-MS can tolerate.

Only a few samples showed the presence of BPA in the water because BPA is only slightly soluble in water, so the samples were reused in another trial where they were extracted with isopropanol (rubbing alcohol) instead of water. Isopropanol was used because it is a solvent that BPA is readily soluble in. The plastic samples were submerged in isopropanol at room temperature for 48 hours, after which the pieces of plastic were removed, and the samples were evaporated and processed for injection into the GC-MS. The data collected from the water and isopropanol leachates were recorded in charts to keep the results organized and make it easier for people to understand the overall results.

Surveys:

The survey aimed to determine how high school students' plastic use might be affected when they were provided with more knowledge about what can leach from plastic food containers. The survey was sent to high school students at Lafayette H.S. in Lexington, KY. It was completely anonymous so that the students would be more comfortable answering the questions and to respect the privacy of minors. It also included a “choose-not-to-answer” option on every question in case some students felt uncomfortable answering the question. The goal of the survey was to find the percentage of students' opinions that changed after they were given information from my experiments and if it would change their future plastic use or how they use/store plastic. A survey is the best way to achieve this goal because it can collect data from a wide variety of students and be anonymous to ensure the participants’ privacy.

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Survey Procedure:

The survey consisted of three parts: (1) the initial questionnaire, (2) the informative section, and (3) the final questionnaire. In the initial questionnaire, students were asked about their current plastic use in order to estimate how much plastic they use every day, how often they reuse plastic products (e.g., water bottles), and how often they heat food in plastic serving containers. They were then asked how much information they currently know about plastics and human health, specifically how much they know about BPA and other leachable contaminants and how well they understand the differences between plastic types. It is essential to know how much of the information is widely known to assess how much it will impact the students' opinions. In the informative section, the survey explains important information about BPA along with information from other sources that discuss the different chemicals found in plastics and their health risks. The information that was given to the students is as follows:

Bisphenol A, or BPA, is an industrial chemical that is found in polycarbonate plastics and epoxy resins, and it is used in food and beverage packaging and to coat the inside of metal containers. BPA has the ability to leach into the food or beverages from the container, which is an issue because BPA is a hormonal disrupter, which can affect the brains of young children and has been linked to increase blood pressure, type 2 diabetes, cardiovascular disease, breast cancer, and other diseases.

It is important to note that the FDA has stated that the current levels of BPA in plastics are low enough not to cause harm when it has been exposed to people. To indicate potential BPA usage in plastics, the FDA added resin codes on all plastic products. High resin codes, such as a 6 or a 7, indicate that BPA may have been used in its production while low resin codes, such as a 1 or a 2, indicate that there is a very low probability that BPA was used in its production.

If you are interested in learning more about BPA, the following sources can explain more:

https://www.insider.com/what-is-bpa

https://www.mayoclinic.org/healthy-lifestyle/nutrition-and-healthy-eating/expert-answers/bpa/faq-20058331

https://www.npr.org/2012/03/30/149668771/how-much-bpa-exposure-is-dangerous

The survey then provided the students with the data tables from the experimental study. After receiving the information, the students were asked quiz-like questions about the information provided to determine whether the students were reading the information. The quiz-like questions are important because students must read the information for the results to be accurate. In the final questionnaire, the students were asked a series of questions about their potential future plastic use. They were asked to estimate the amount of plastic they might use in the future, whether they will reuse or refill plastic products in the future, and if they have a better understanding of BPA and phthalates after reading the information in the informative section. The responses to the survey are organized in pie charts to easily visualize the percentage of students who chose each answer to the questions (Figures 6-13). The survey was sent out through social media to request students to respond to the survey voluntarily. The number of people that received the survey is approximately 130 people, the exact number is unknown because the survey was posted on an Instagram story and was removed around 24 hours later. There was a total of 77 responses to the survey.

Results and Discussion

Experimental Study Data:

The data collected in the experimental study was organized into tables. Table 1 shows the data collected from all the samples extracted in water, Table 2 shows the data collected from all of the samples extracted in isopropanol, and Table 3 shows the data from the samples where BPA and/or phthalates were detected. The water and the samples of interest tables each have five columns. Table 2 does not include a temperature column because isopropanol evaporates quickly at high temperatures. To prevent this, all the isopropanol samples were extracted at room temperature.

In the experiment, each sample was first incubated in water for 48 hrs at different temperatures and then incubated in isopropanol for 48 hrs at room temperature. The (√) in the BPA and phthalate columns indicates that those chemicals were found in that sample. An asterisk (*) in the recycling number column indicates that those samples are not made from plastic. However, they do contain an epoxy resin that may contain BPA. The ** indicates control samples or samples that were not expected to contain any BPA.

Table 1: Plastic samples that were extracted in water.

Sample	Extraction Temperature	Plastic Recycling Number	Contains BPA	Contains Phthalates
1a- Purified Drinking Water	Room Temperature	1		
1b- Purified Drinking Water	Room Temperature	1		
1c- Purified Drinking Water	Room Temperature	1		
1a	75°C	1		
1b	75°C	1		
1c	75°C	1		
Combination of 1a, 1b, 1c	75°C	1		√
A- PVC Pipe	Room Temperature	3		
B- PVC Pipe	75°C	3		
C- PVC Pipe + NaOH base	Room Temperature	3		
D- ½ DVD	75°C	7		
E- Shrimp Container	75°C	6	√	
F- Thermal Paper	75°C	*		
G- Shrimp Container	75°C	6	√	
H- Plant Container from a Plant Lab	75°C	4		
I- Soup Can	75°C	*		
J- Milli-Q Water	75°C	**		
K- Gorilla Glue	75°C	*		√
L- 1997 Saran Wrap	75°C	4		
M- Ramen Noodle Package	75°C	7	√	

N- Distilled H2O	75°C	**		
O- Oatmeal Cookie Package	75°C	4	√	
P- Hard Candy Wrappers	75°C	7		

Table 2: Samples that were extracted in isopropanol.

Sample	Plastic Recycling Number	Contains BPA	Contains Phthalates
1a- Purified Drinking Water	1		
1b- Purified Drinking Water	1		
1c- Purified Drinking Water	1		
A- PVC Pipe	3		√
B- PVC Pipe	3		√
C- PVC Pipe + NaOH base	3		√
D- ½ DVD	7	√	
E- Shrimp Container	6	√	
F- Thermal Paper	*		
G- Shrimp Container	6	√	
H- Plant Container from a Plant Lab	4	√	
I- Soup Can	*	√	
J- Milli-Q Water	**		
K- Gorilla Glue	*		
L- 1997 Saran Wrap	4		
M- Ramen Noodle Package	7		
N- Distilled H2O	**		
O- Oatmeal Cookie Package	4	√	
P- Hard Candy Wrappers	7		
Q- Mexican Blueberry Container	4		√
S- Sausage Tray	6		
U- Take Out Container	5		

Table 3: Summary of plastic samples found to contain extractable BPA and phthalates.

Sample	Extraction Solvent	Temperature	Plastic Recycling Number	Contains BPA	Contains Phthalates
Combination of 1a, 1b, 1c	Water	75°C	1		√
A- PVC Pipe	Isopropanol	Room Temperature	3		√
B- PVC Pipe	Isopropanol	Room Temperature	3		√
C- PVC Pipe + NaOH base	Isopropanol	Room Temperature	3		√
D- ½ DVD	Isopropanol	Room Temperature	7	√	
E- Shrimp Container	Both	Both	6	√	
G- Shrimp Container	Both	Both	6	√	
H- Plant Container	Isopropanol	Room Temperature	4	√	
I- Soup Can	Isopropanol	Room Temperature	*	√	
K- Gorilla Glue	Water	75°C	*		√
M- Ramen Noodle Package	Water	75°C	7	√	
Oatmeal Cookie Package	Both	Both	4	√	
Q- Mexican Blueberry Container	Isopropanol	Room Temperature	4		√

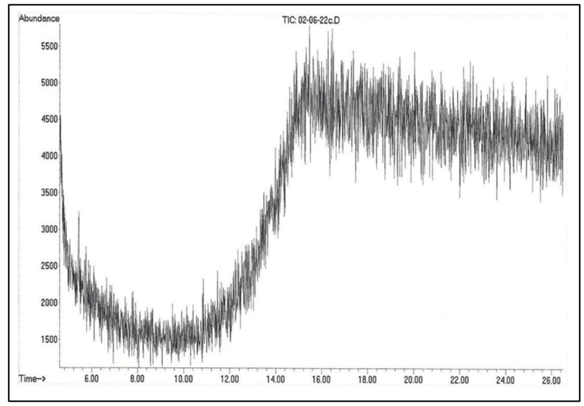

Figure 4: Chromatogram of water extract of sample 1c (no BPA observed).

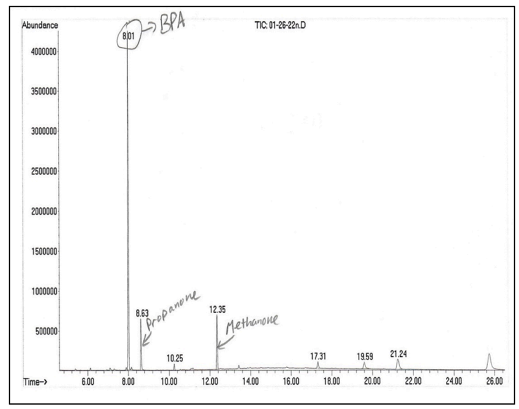

Figure 5: Chromatogram of sample D extracted in isopropanol showing the presence of BPA.

The GC-MS computer system identifies the different substances in the samples and the abundance of each substance in a chromatogram represented by peaks at the time that the ions of that substance hit the detector. The computer library is then able to identify each peak correctly. Figure 4 shows the chromatogram of sample 1c extracted in water, and Figure 5 is the chromatogram of sample D extracted in isopropanol. Figure 4 is an example of a chromatogram that does not indicate any definite substances present because there are no specific peaks, and the graph follows a specific shape over time. This specific shape is called "noise", where there is such a low abundance of substances that it is unlikely for those substances to exist in the sample. Figure 5 is an example of a chromatogram showing that BPA is present in the sample with a strong peak indicating high abundance as well as other substances. The specific shape of a chromatogram, or "noise", is not shown in Figure 5. This is because the substances that the GC-MS found to be present in the sample had abundances higher than the abundance needed for the GC-MS to detect those substances and to show they are part of the sample with accuracy.

Survey Results:

The data collected for the responses to each question in the survey was organized into pie charts. The survey asked various questions about the students' individual plastic use in the initial and final questionnaires. The initial questions in the survey asked about the individual's current plastic use and

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determined how much they already knew about plastic. After they were given the BPA experimental data and background information, they were asked to predict their future plastic use. There was a total of 77 responses to the survey.

Initial Questionnaire:

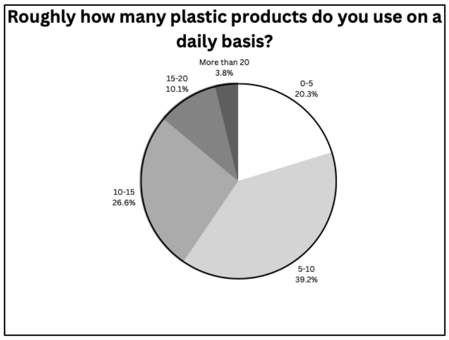

Figure 6: Distribution of the number of plastic products used by the students use every day.

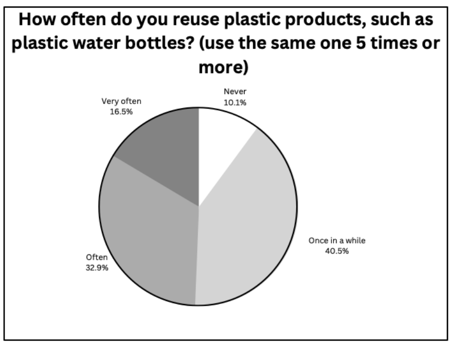

Figure 7: Distribution of how often the students say they reuse plastic products.

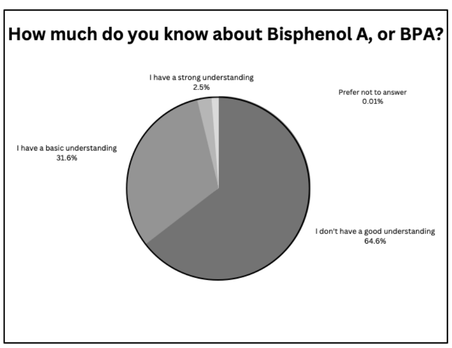

Figure 8: Distribution of how well the students understood the information provided about BPA.

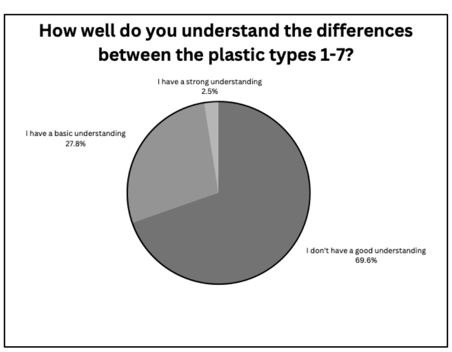

Figure 9: Distribution of how well students understood the difference between the seven types of plastics.

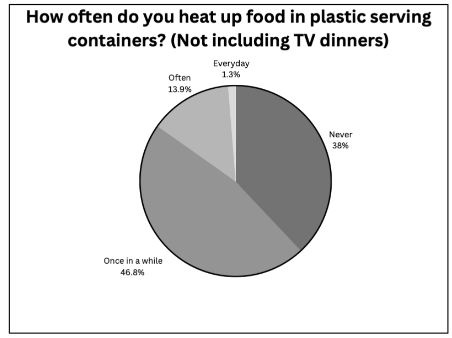

Figure 10: Distribution of how often students heat food in plastic serving containers.

Final Questionnaire:

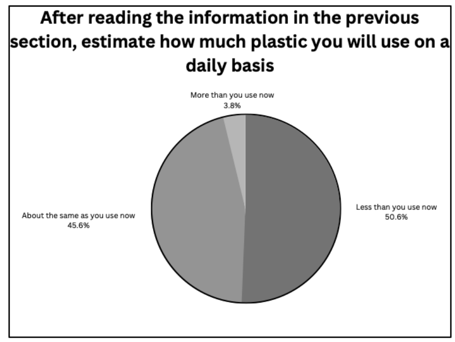

Figure 11: Predicted future plastic used by high school students who read the informative section of the survey.

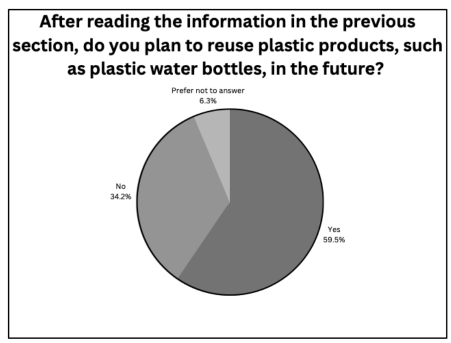

Figure 12: Percentages of students who say that they will or will not reuse plastic products in the future.

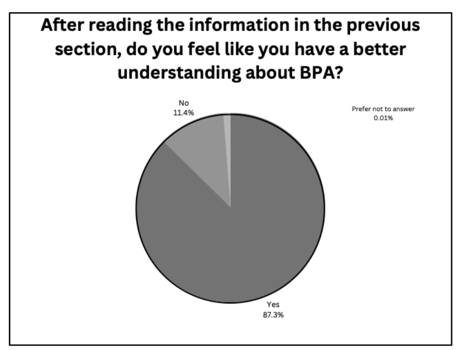

Figure 13: Percentages of students who had a better understanding of BPA vs· those who did not after reading the informative section.

Experimental Study:

The data collected from the experimental study showed that a larger number of samples contained BPA than was initially expected. After first analyzing the data, it was interesting that we also found phthalates in many samples. Phthalates are included in the tables because they are chemically similar to BPA and have similar effects on the human body.

Table 1 shows the results for all the samples extracted in water. Because BPA is only slightly soluble in water, it was expected that there would be few if any samples that showed measurable BPA. While there were far fewer samples showing BPA leached into the water than in the isopropanol, there were still more samples than were expected. Interestingly, the samples containing BPA, samples E, G, M, and O, all involve food substances and contain enough BPA that some could dissolve in the water. Fewer samples contained phthalates than samples that contained BPA. However, it is essential to note that the purified drinking water sample that combined residual water from bottles 1a, 1b, and 1c (water remaining in bottles a, b, and c after initial samples were removed) showed the presence of phthalates. This could be because none of the original samples contained enough phthalates to dissolve in the water. Still, a combination of residual water from all three bottles leached enough phthalates to be detectable in the combined sample. This could also possibly be due to human error (cross-contamination) where phthalates were accidentally introduced into the sample. However, this is very unlikely because each sample was contained in a separate glass beaker. The methodology was planned carefully to avoid using tools or materials that could cause cross-contamination.

Table 2 contains the data from all the samples extracted in isopropanol. BPA is highly soluble in isopropanol, so if there were any BPA or phthalates present in the samples, at least some parts would be dissolved in the isopropanol. Many isopropanol samples contained either BPA or phthalates, and many of those samples included food containers. Some of the samples that initially showed that they had BPA or phthalates in the water extracts did not show BPA or phthalates in the isopropanol extracts, such as samples K and M. This could be because the BPA or phthalates in those samples were entirely or mostly extracted in the water, and not enough remained to be detected in the isopropanol.

Table 3 presents a summary of the samples of interest from Tables 1 and 2, and all the samples shown in Table 3 contained detectable amounts of BPA or phthalates. Samples A, B, and C are different pieces of the same source material, a PVC pipe, and they all show that they contain some phthalates, even though each sample came from a different part of the pipe. This indicates that the phthalates were incorporated throughout the entire material. Samples E, G, and O, showed BPA in both the water and isopropanol extracts; the three materials involve food substances. Sample E was repeated as sample G, which caused more interest because they are from different parts of the same plastic tray, and they both contained BPA. Neither samples I nor K were made of plastic. However, they both have epoxy resin coating the material, and the results indicated that they contain BPA and phthalates, respectively.

In all of the data tables, Table 1-3, the samples included either BPA or phthalates, none of the samples contained both xenoestrogen contaminates. This is because BPA and phthalates affect plastic in different ways, BPA is used in hard plastic while phthalates are used to soften plastic and make the material more flexible.

Survey:

Overall, the questions regarding plastic use in the initial questionnaire had a somewhat even range of responses (Figures 6, 7, and 10). These questions required the background information on plastic use to better understand the results in the final questionnaire and how much high school students understood the essential information regarding plastic use. For example, whether they heat plastic serving containers (Figure 10) or whether they reuse plastic containers, such as plastic water bottles, multiple times (Figure 7). In the initial questionnaire, the questions relating to how much people already knew about BPA or what the different plastic recycling numbers meant were fundamental in understanding how much high school students already knew about plastics and to understand the results from the final questionnaire better. Most high school students (64.9%) said they needed a better overall understanding of what BPA is (Figure 8), or what the different types of plastics are (70.1%; Figure 9). This shows that most high school students are not aware of the potential health risks that plastic could cause when used in an unsafe way.

The final questionnaire gathered the actual results for the research, how high school students' opinions about plastic changed after they were given information about the health risks that plastic could cause if used in an unsafe way, and how they say they will use plastic in the future after receiving this information. As shown in Figure 11, there was almost an equal split in the amounts of plastic high school students expected to use in the future: 49.4% said they plan to continue to use the same amount of plastic they do now, and 46.8% said they plan to reduce their plastic use in the future. Some students may already use very little plastic, and their answers would not have the same impact as those from students who used more. Figure 12 shows that 61% of high school students said they would reuse plastics, while 32.5% said they would not. The informative section of the survey did not go into the consequences of reusing plastic, which helps to explain the answers to of this question.

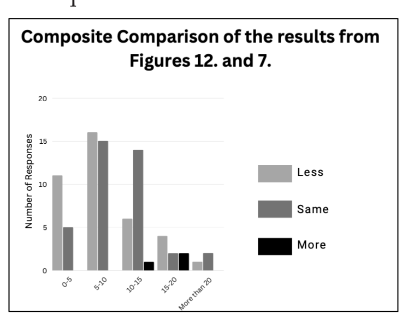

Figure 14: Distribution of results from Figure 12. based on the students response from Figure 7.

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As shown in Figure 14, the students that answered 0-5 or 5-10 for Figure 7 said that they would use less plastic in the future for Figure 12 while most of the students that answered 10-15 for Figure 7 said that they would use the same amount of plastic in the future in Figure 12. This may be because the students that answered 0-5 or 5-10 were already careful of their plastic intake and the informative section could have had more of an impact on their opinion on plastic than the students who answered 10-15 and may not have been careful of their plastic intake. There were not many students that answered 15-20 or 20 or more for Figure 7 and the results of Figure 12 were spread fairly evenly. Most students said they felt like they understood BPA better after taking the survey. Figure 13 shows that 88.3% of high school students said they had a better understanding, and only 11.7% said they felt like they did not have a better understanding of BPA. This shows that, for the most part, the survey successfully provided high school students with information about BPA and the health risks associated with plastics when used unsafely.

Conclusion

A possible limitation of the survey is the number of responses. While the survey yielded 77 responses, more could have given more accurate results. However, it is impossible to know if more responses would have produced a more precise variety. The results depended on each student's opinion and individual plastic use when they answered the survey. Another possible limitation is that some students may have skipped over the informative part of the survey, which was important for them to understand so that their responses to the final questionnaire could be as accurate as possible. However, there were test-like questions in the survey's informative section to ensure that the students at least looked through the information provided. However, it is possible that some students just skimmed through the information to find the answers to the questions. Another potential limitation is human error. Many questions required people to consider how often they use plastic in different situations or in general. Each question that required this had a diverse range of options they could choose from, but if they didn't know their response to the question, it would the results to be less accurate. There is also the possibility of response bias; some students could have answered that they use less plastic or know more information than they really do to have better results. It is hard to prevent this from happening because the survey was anonymous. However, there are ways to reduce response bias, one being to cite an already validated survey to compare data that other organizations have found to the data shown in the survey. This will help to improve the credibility of the survey author and indicate the importance of the survey to the students. Another way is to ensure that the survey is not too long and to make the questions short and direct so that they are easy to understand by the students.

In conclusion, this research did not find a definite correlation between the amount of knowledge that high school students have about chemicals in plastic and how their future plastic use will change based on that knowledge; however, this research did identify a connection. This research did achieve the goal of increasing awareness about contaminant chemicals in plastic, as shown in the question asking how the students' understanding of BPA changed in the final questionnaire of the survey. A large majority, 87.2%, said they better understood BPA after taking the survey. This research can be implemented to help support the idea that more information about health hazards is associated with the types of plastics that students use regularly. However, before this research can be implemented, the experimental study should be repeated with multiple trials and the survey repeated with specific questions to determine how plastic use changed and sent out to more students to get more responses. This would make results much more accurate and reduce potential limitations.

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