**Background Research:**

**Section 1: Basic Information (Plastics, Environment):**

Plastic is a synthetic substance that is made which can be molded into a soft material which is used for many purposes. This involves toys, bottles, utensils, tools, etc. Considered convenient because of its shatter resistance, (containers do not break when knocked over or dropped). Moreover, this material is preferred due to its low weight, durability, and ease of manufacturing. Tailored to have specific properties revolving around durability and strength. Furthermore, plastics are affordable and accessible.

While convenient, accessible, and resourceful, plastics form a significant risk to the environment. These risks may differ between plastic types including PET (Polyethylene Terephthalate), PVC (Polyvinyl Chloride), PS (Polystyrene), etc. Mainly speaking, issues regard their biodegradability – generally, plastics take nearly 1 000 years to begin biodegrading however, specific timing differs among different types of plastic. Here is a breakdown:

**PET**: This plastic is particularly resistant to biodegradation in natural environments. It has been shown to persist for hundreds to a thousand years – some cases show more. Although natural biodegradation is slow, certain microorganisms have been identified to speed up the biodegradation process of PET.

**PVC:** This plastic is also highly resistant to natural breakdown taking nearly 100 to over 1000+ years to biodegrade, again due to its persistence coming from chemical additives which will be explained later.

**PS:** This plastic has a tendency to break down nearly 500 years after exposure to environment due to exposure such as UV radiation. All three plastics listed are proved to biodegrade mainly due to UV radiation, etc.

\*It is important to note that specific biodegrading time is impacted by environmental conditions.\*

With activities such as poor handling and littering, plastic has been shown to accumulate in the environment particularly forming microplastics over time. This accumulation can reach a peak over time when it affects multiple life forms such as sea life, land life, and plant + soil life.

Chemical additives used in the formation process have certain properties and toxicities which can cause plants to exhibit certain effects such as reductions in root growth, plant vigor, etc. These additives such as plasticizers also tend to affect the soil as well. (More detail will be provided later).

Plastic is a growing concern in the environment due to other reasons combined with the ones listed above compared to the plastic production. With recycling considered, the industrial production simply surpasses.

Just in 2023, an estimated 400 000 000 metric tons of plastic was produced globally. In that, 9% of it was estimated to be recycled and the rest 91% ended up in other places such as environments. (Ex. Great Pacific Garbage Patch, Plant Ecosystems).

**Microplastics:**
Plastics form microplastics through mechanical and chemical breakdown processes. These processes include UV radiation and physical abrasion.

**Mechanical Breakdown:** Can be exposed to wind and water which may carry larger fragments. This transfer may cause physical stress on the plastics through abrasion. “Abrasion is the process in which larger fragments or pieces rub against different surfaces including jagged or sharp causing impact, either breaking down or causing damage.” Over time, constant rupture against multiple surfaces may cause plastic to break down into smaller pieces, particularly 5mm or under to be considered a microplastic.

**Chemical Breakdown:** Adding to the abrasion breakdown processes, UV radiation plays a role. Prolonged exposure to UV radiation causes strong chemical bonds in plastic to break down over time. Exposure causes the long chains to break apart into smaller and weaker chains, resulting in smaller pieces. Moreover, this process is known to release the various chemical additives used in the formation process of these plastics. As the chains break, the strength of the plastic reduces and becomes brittle.

**Section 2: Plastic Information:**

Among the multiple types of plastics, there are mainly three that are being analyzed: PET, PVC, and PS foam plastic. Here is some basic information of their uses:

**PET:** Is a flexible and useful plastic. One of the most common types of plastics used in day to day lives: It is a very abundant polymer and approximately 56 million tons of PET is produced worldwide. Has uses such as single use packaging material involving plastic bottles, etc. This polymer is also involved in processes of creating products such as polyester.

**PVC:** PVC is rather rigid in structure. Common used plastic for its durability and strength. Somewhat abundant. Used in pipes, flooring etc. This plastic accumulates for 10% of the global production. Has uses such as long lasting plastic and also used in vinyl.

**PS:** Can be found in two forms: sheets and foam. Commonly used for lightweight and mainly in transportation. This is a thermoplastic polymer – plastic that can be reheated after formation to be left to cool and harden. Solid PS plastic is commonly found to make products involving test tubes or Petri Dishes, but it can also be in household containers such as that of yogurt, or in smoke detectors. Solid form is durable however, foam form (Styrofoam) is lightweight and convenient.

**Section 2.1: Formation Processes:**

Everything is interconnected. To fully understand the composition and descriptions of the plastics, the chemicals and formation processes must be discussed. Here is a brief breakdown:

**PET:** One of the most common sources of plastic, microplastics. PET is a thermoplastic polymer (Polymer that can be softened through heating processes before being processed and left to cool and harden. This class of plastics are known to repeat these heating processes for strength multiple times). This plastic is composed through the process of polymerization – a chemical process which joins smaller molecules known as monomers into larger chains or networks known are polymers. The polymerization of this plastic comes from Terephthalic Acid and Ethylene Glycol. As both derive from petroleum or natural gas, Terephthalic Acid is responsible for the main physical structure of PET. During this process, the monomers of the two chemicals are chemically reacted into chains. Monomers are smaller molecules which bond to create larger and more complex structures. Under intense heat and pressure, long chains are formed over time forming the resins (plastic) of the PET which are sold in pellets. However, to enhance certain properties such as strength or other factors, various chemical additives are used as described prior. As this project mainly focuses on the composition and effects of the plastic, it is essential to understand the chemicals as that is part of the focus:

1. **Catalysts:** Some PET plastics contain substances such as antimony, which is used to speed up the polymerization process. Antimony is a silvery white metal that is found in nature and is used for industrial applicants; polymerization, etc. Has a special chemical structure which causes it to be toxic to multiple biotic factors involving plants and the soil. The presence of this chemical can lead to reduced plant height, photosynthesis, and nutrient uptake. Next, another chemical involved is titanium dioxide which is used to make the PET resins appear whiter, and minimize the impact of UV radiation on PET, although UV radiation still plays a huge impact on the plastic itself. This chemical also serves as a catalyst allows for the acceleration of the polymerization process. Moreover, in context of PET, PET containing titanium has been noted to pose recycling issues. Titanium dioxide particles have been shown to harm plants, although it may be inconsistent. It was concluded that high levels of this chemical has been shown to reduce plant germination in certain cases, chlorophyll content, photosynthesis, and overall plant vigor (including growth, height, development, etc.)
2. **Stabilizers:** Some PET plastics were noted to contain phosphite's, although this is not naturally present as this chemical is added as an additive. Phosphite's are known to be added to PET plastic to enhance certain properties such as biodegradation resistance and flame resistance. This turn positively impacts the plastic’s integrity and resistance which makes it more efficient. Phosphite's are known to be considered somewhat harmful to plants and known for toxicity. The plants are known to be unable to metabolize the phosphite and known to obstruct plant height development (growth) and plant metabolism. They are also easily absorbed by plant roots and are known to induce ROS production (Reactive Oxygen Species). ROS is a defense in the plant which is induced from the cells to attack or neutralize foreign substances or chemicals inside the plant itself.

**PVC:** Another common type of plastic used. This plastic also falls under the umbrella of thermoplastic polymers – can be heated and reheated/reshaped many times without significant chemical degradation. This also enhances strength. Unlike PET, PVC is made from a basis of one chemical rather than two: the vinyl chloride monomer. In the polymerization process, the vinyl chloride monomer is exposed to high temperatures ranging from 40 – 80 degrees Celsius. Furthermore, under a reactor, initiator peroxides are used as a catalyst for the process. Under a reactor, the peroxides help the monomers bond together. As time passes, chains of the vinyl chloride monomer are produced as they grow longer and stronger. As the chains are produced, to remove them from water, a process is used called precipitation which separates the resins. Either non-solvents are applied or the temperature is changed to evaporate the water to leave a product of the resins. Here are the chemicals:

1. **Heat Stabilizers:** To enhance resistance to biodegradation in the formation process and throughout the lifespan of the PVC, heat stabilizers are used. Most commonly, lead based compounds (chemical compounds containing lead in various forms including salts and used in industries including in plastics and rubbers), organotin compounds (chemical compounds where tin is directly bonded during the heating process to one or more organic groups, used in multiple places such as PVC stabilizers). Lead based compounds are considered as somewhat toxic to plants in higher concentrations as they can negatively impact them. Once lead is founded in the soil, it is not readily washed away and persists for a lengthy period of time. Lead can cause problems physically and biochemically inside the plant when absorbed through the roots such as photosynthesis. Excess lead has properties which can cause stunted growth, chlorosis (the leaves of the plant turn yellowish), and can cause the root to turn black. Organotin compounds can contaminate the soil and the plants, posing environmental and health risks. Excess amounts of these compounds can be absorbed into the plant tissues causing effects biochemically, again related to photosynthesis, etc. These compounds can be toxic to plants, causing growth inhibition, leaf damage, etc.
2. **Lubricants:** To enhance flow characteristics of PVC resin during processing and to prevent it from sticking to machinery. These chemicals are often internal and external lubricants which include stearic acid (A chemical used as an internal lubricant to improve flowing processes of PVC. Acts to reduce friction between PVC particles during manufacturing, which improves its flow). Stearic Acid is naturally produced by plants and is considered to be non toxic to plants. There is no research which indicates that stearic acid is toxic to the soil or the plants as it is naturally present in the soil along with the production of it inside plants.
3. **Fillers:** Chemicals such as calcium carbonate are added to PVC plastic to enhance mechanical properties such as strength, reduce material cost, and act as a surface layer finish of the plastic. Calcium carbonate improves strength of PVC and hardness of PVC, making it more suitable for uses that require a lot of strength such as PVC pipes, etc. This filler is generally not considered toxic to the plants or the environment as it is used sometimes/occasionally in fertilizers. However, when other chemicals such as plasticizers (for flexibility) or phthalates are leeched, problems can arise regarding their toxicity, etc.

**PS (Foam):** Another widely used plastic, mainly in that of packaging of the products, etc. Also a thermoplastic polymer and formed through the polymerization process. Formed through a process known as free radical polymerization where polymer chains are produced from a chain reaction between the styrene monomer (main chemical used as the foundation of the polystyrene (PS) plastic) and free radicals (unstable particles and are highly reactive). With initiator chemicals introduced such as peroxides, the intense heat and pressure causes the peroxides to decompose into free radicals. With PS plastic being a hydrocarbon (chemical only containing hydrogen and carbon atoms), the free radicals under heat and pressure selectively attack the double bonds between the styrene monomers. This over time, creates longer chains of PS foam with only single bonds and the free radical polymerization process ends when two free radicals form a bond together. Here is a breakdown of the chemicals:

1. **Plasticizers:** Are used to improve the flexibility of the PS plastic. Common examples of plasticizers in PS foam plastic includes phthalates. Under certain environmental conditions such as prolonged exposure to UV radiation, PS foam tends to release these chemicals which may have detrimental effects on ecosystems as we mainly speak about soil and plant ecosystems. Phthalate plasticizers in PS foam can contaminate the soil mainly talking about nutrient concentrations etc. They may interact with the bacteria or biotic factors that play a role in the nitrification of soil ammonium into nitrogen (key nutrient for growth of plants). With the nitrogen levels decreased, this can lead to reduced growth rates of plants and reduced soil fertility. When plants absorb water or the chemical contaminated with phthalate plasticizer, this toxic chemical may have special properties that can interfere with their cell development, vigor, and root development.
2. **Brominated Flame Retardants:** PS microplastics may also contain brominated flame retardants (Brominated Flame Retardants (BRFs) are a group of man made chemicals that contain bromine that are added to reduce the likeliness of materials catching on fire. These are typically added to plastics, textiles, and electronics, but their issues mainly revolve around their health and environmental impacts. Brominated flame retardants are known to pose risks to both the soil and the plants. The specific chemicals used in brominated flame retardants are not disclosed or told. BRFs have been studied to be absorbed directly by the plant and accumulate inside of the plant’s tissue. These chemicals are known to have specific effects including toxicity causing leaf deformation, inhibition of photosynthesis, and reduced plant growth. Moreover, brominated flame retardants have also been studied to slightly increase the soil pH over time as well as affect soil organisms responsible for the synthesis of certain nutrients in the soil leading to nutrient defincies in the soil.

**Physical Presence:** Physical presence of microplastics in the soil can influence effects on the plants as well. This is because depending on its mechanical factors such as strength or flexibility, microplastics can influence the amount of space that the roots have to grow. They can inhibit this space causing the roots of the plant to work and grow around them. Especially in plants that are sensitive to environmental conditions such as radish microgreens, this can create a big problem to them.

\*It is important to note that certain effects can be influenced by certain environmental conditions which may speed up the leeching of the chemicals into the soil, etc. Furthermore, the specific effects also varies depending on the polymer (plastic) type, microplastic size (principles the mass and amount entered the soil or absorbed by the plant, etc.) Moreover, specific effects is also affected by plant type (plant resilience, resistance), and transportation effects (chemicals may be picked up along the way of plastic ecosystem entrance).\*

**Problem:**

How can the presence or composition (including chemicals) of different types of microplastics (PET, PVC, and PS) interact with the plants and the soil to hinder or affect its factors?

**Hypothesis:**

If the type of microplastic being tested with changes, then the effect of it on the plants and the soil will also drastically differ. This is because different microplastics were tailored to have different properties such as strength, durability etc. Along with this, the various chemical additives such as plasticizers for strength, brominated flame retardants for reduced flammability can cause specific affects such as stunted growth, reduced root development, etc. The effect can also differ because of the concentration differences from plastic to plastic. For example, PET has an increased amount of plasticizers than PVC since PET requires more durability and flexibility than PVC. Moreover, the chemicals that may be leeched into the soil over time may be absorbed by the plant which can additionally cause differences in plant and soil factors Furthermore, certain environmental conditions can also influence the leeching of these chemicals causing the main effects along with the plastic’s presence. Overall, I believe that the effect will be an outcome of negative.

**Materials:**

\**It must be noted that the materials were adjusted to fit the circumstances of the scientific literature studies.\**

1. **PET microplastics –** Can be obtained from PET products such as empty water bottles (Natural Spring Water), (Purlife), etc. This can also be obtained from PET products and containers.
2. **PVC microplastics –** Can be obtained from PVC products such as PVC pipes or PVC products. This is one of the manipulated variable to test.
3. **PS microplastics –** Can be obtained from PS foam products (Styrofoam), and will be used as another manipulated variable. Ensure at least 2 – 3 sheets of this material are obtained.
4. **Gloves –** Required for PPE (Personal Protective Equipment). Gloves are required due to the sharp edges of the plastic. This is just for safety in the cutting process.
5. **Biodegradable Containers –** Essential for the growth of the plants. Ensure that the pots are BIODEGRADABLE and for plant growth uses only because using non suited plant growth containers may cause differences in growth which is unrelated to the microplastic’s effects.
6. **Soil –** To serve as one of the responding variables in the experiment and used for the plants to grow. Would require a loamy, sandy soil for this project since it would be much easier to assess the microplastic’s effects on the soil for a couple of reasons. This is easier because loamy and sandy soil is mostly neutral and has less fluctuations in factors when compared to other types of plastics – it is the most stable. This makes the data much more accurate and better to work with. Next, the soil remains well aerated which assists in assessing how microplastics affect the microbial activity, influencing soil pH more clearly, and again, more stable with les fluctuations from environmental factors.
7. **Seeds:** Radish microgreen seeds. This serves as one of the responding variables in this experiment and this species of plant was chosen due to its fast growing nature and properties to act sensitively to environmental conditions.
8. **Measuring Tool:** Required to measure factors of the plant such as plant height, root development, etc.
9. **Measuring Scale:** Required to pre measure the concentration amount of microplastics that are going to be added to the soil in mass, etc.
10. **5 – in – 1 Soil Meter:** Required to measure the soil pH, nutrient levels, etc. This uses a sensor or device that measures the soil’s alkalinity or acidity to record pH.
11. **Scissor or Mixer:** Assists in the process of cutting up the microplastics into smaller pieces as they will be applied to the soil and the plants.
12. **Oven:** Assists in the process of heating up the microplastics to erase any form of microplastic distortion.
13. **PDA plates:** To test the cleanliness of the of the microplastics to observe any distortions or microbial colonies. (Microbial colony refers to a cluster or group of microorganisms, typically bacteria or fungi, that have grown from a single cell or a small group of cells on a solid medium, forming a clone).
14. **Water source:** For the watering of the plants to ensure that plant processes such as photosynthesis occur normally.

**Variables:**

**Manipulated Variable:** The manipulated variable in the project is the type of plastic that is being used, whether that is PET, PVC, or PS. This is the thing that is changing, the soil and plant test factors are staying constant.

**Responding Variable:** The responding variable in this experiment is the soil and the plant tests. In the soil, I am investigating for (Changes in soil pH), (Soil Moisture Content Changes), and (Changes in Soil Nutrient Concentration as an average of the three most essential nutrients: Nitrogen, Phosphorus, and Potassium). As for the plants, I am investigating for (Changes in plant height), (Changes in Root length/growth), (Leaf Color Changes), and (Leaf Presence in % because different trials may have different amounts of leaves).

**Controlled Variable:** There is a table below that explains the controlled variables.

|  |  |  |  |
| --- | --- | --- | --- |
| Controlled Variables:Variables that need to be controlled in the experiment for best results | Condition: What needs to be controlled | Why: Why does that condition need to be controlled? | How are you going to control it? |
| Soil | Different types and brands of soil may have slightly different properties and contents such as organic matter, etc. | Make sure there is enough soil so that each test has an equal amount of soil per container. |
| Light Exposure | Light is essential for processes such as photosynthesis to occur. Unequal lighting may cause growth differences unrelated to the plastic's effects. This results in two manipulated variables: Light exposure and type of plastic.  | Going to make sure the pots and factors are placed in a well-ventilated area with each receiving equal amounts of sunlight. |
| Soil Amount | Different amounts of soil allow for the plants to have more space to grow and develop other functions. The concentrations of the plastics may also differ the effects on the tests.  | Going to add the same amount of soil per pot ensuring as much accuracy as possible. |

**Methods:**

Primary microplastics were produced on purpose such as microbeads to use in other products involving cosmetics, etc. On the other hand, secondary microplastics are pieces of microplastics that are derived from larger fragments of plastics that break down either due to mechanical or chemical breakdown processes, as listed above.

In this project, secondary microplastics were used rather than primary and these plastics were cut up manually. This is through a scissor for cutting up the plastics and then were placed in moisture free containers. To minimize contamination, etc. Heating processes were used and tested for maximum accuracy.

Then, the 5 – in – 1 soil meter was used to measure changes in soil pH, nutrient levels, moisture content, etc. All other tests were conducted like this.

As for measuring the plant height, the height is going to be measured as the shoot growth. This means that this is the height from the top of the soil. This means that the 0 cm mark is going to be just making contact or touching the soil.

For the root length, this is going to be measured at the end of the project where I am going to up root the plant and then measure the average root length in cm. Note that this number is an average as every single root cannot be displayed in a graph as it would be extensive and clumsy.

As for the leaf presence, this is measured as a percentage as across three trials, the number of leaves may differ and might need to be recorded as percentage. The controlled is always going to be placed at 100% leaf presence and the number of leaves compared to the controlled in that trial is going to be recorded as a percentage.

As for leaf color, this would just be a general observation of the color of the leaves after microplastic exposure of the three types.

In the end, some observable results are going to be displayed. This is just something we may see if the experiment was actually conducted.

**Procedure:**

Preparation:

1. Achieve a minimum of 1.8 kg of loamy and sandy soil and store it. This will be used for one of the main test later. (Aim for a little extra soil just in case).
2. Get at least 25 PET plastic bottles or containers with dimensions of 20 cm height and a diameter of 6.5 cm. These are typically the 500 mL bottles that are common. Ensure that when cut up, a minimum of 800 mg of this type of plastics are produced. There are three trials in this experiment and a third of MP’s per pot in each trial.
3. Ensure that each piece of microplastic is 5mm or under in size to replicate environmental conditions.
4. Similarly, repeat this step for PVC pipes ensuring that each piece is cut up into sizes that are 5mm or under. Since PVC pipes are tough, try using a mixer or other mechanical device to convert the larger fragments into microplastics. Ensure at least 800 mg of microplastics are produced.
5. Repeat this as well for PS **foam** microplastics as rigid PS can exhibit varied effects than PS foam microplastics. Again, ensure that 800 mg of microplastics are produced from the PS foam sheets.
6. Heat up the oven to 101 degrees Celsius or 213.8 degrees Fahrenheit. Place the three microplastics into separate trays ensuring that they are not mixed into the oven for 35 minutes.
7. Using the PDA plates, after the 35 min, place the microplastics into the plates and incubate them for 1 week (7 days).
8. After the 7 days, observe for any bacterial growth or microbial colonies on the PDA plates. If present, reheat in the oven and if not, transfer the microplastics into separate containers. This step ensures the cleanliness of the microplastics so that other factors may not affect the microplastics. I specifically chose 35 min because extensive heating of the microplastics can cause it to be damaged. However, microbial colonies or contaminations can be mitigated.
9. After no signs of bacterial growth observed, separate each microplastic type into three divisions because there are three trials and put each division into a separate Ziplock or container.
10. Label each container appropriately according to this format: (PET Trial 1), or (PVC Trial 1), or (PS Trial 1), etc.
11. Repeat this for all the containers ensuring no repetitions of labels and have all the containers stored at room temperature (20 – 22 degrees Celsius).
12. Achieve a total of nine **biodegradable** containers with a depth or height of 3.15 in and a diameter of at least 3 inches. Nine is required because there is three polymer types and 3 trials per polymer.
13. Position these containers in front of a well ventilated area such as a big window to allow sunlight to reach the plants equally. Ensure that each plant gets the same amount of sunlight.
14. Similar to labelling the containers, label the pots as well. MAKE SURE THAT THE LABEL IS THE SAME AS THE ONE ON THE CONTAINERS TO AVOID CONFUSION. (Ex. PET Trial 1), (PVC Trial 3), etc.
15. Gather all the other materials not used so far such as the seeds.

Testing:

1. Using the loamy and sandy soil, leave it at room temperature for 3-4 hours. Make sure that the soil reaches room temperature before use to avoid any extra variables in this project. You may use a thermometer to measure the temperature.
2. Using the loamy and sandy soil, add in 200 g of soil into each pot. To measure 200 g, use the measuring scale that can measure at 1g increments.
3. Prior to adding the seeds, pre-measure the microplastics and add them to each pot. This would have to be added at a 0.4% concentration per soil amount in each pot. Again, to measure this specific amount, utilize the kitchen scale to do so.
4. Next, to add the seeds, evenly distribute 4 radish microgreen seeds evenly throughout the pot and cover seeds with the soil.
5. To ensure reliable data, add a specific amount of 125 mL of water per day for the plant’s growth and to ensure enough water. This step has to be followed as it can impact the measure of microplastic effects on moisture content.
6. Starting from day 1, measure the soil pH, nutrient concentrations, etc.
7. Ensure that the variables are measured each day at 6:00 PM and that the plants are watered at 7:00 PM. The measurements should be taken prior to the watering as sudden changes might be observed if measured after.
8. Using the measuring tool, measure the changes in plant height, root length, at the end, etc.
9. Take any notes and observations for changes each day as it will be useful in the analysis.

**Raw Data:**

|  |  |
| --- | --- |
| Soil Test:  | Plastics  |
| Trial 1  | PET plastic  | PVC plastic  | PS plastic  | Controlled  |
| Soil pH  | 7.2 pH  | 7.1 pH  | 7.3 pH  | 6.8 pH  |
| Soil moisture (%) | 22%  | 21%  | 24%  | 20%  |
| Soil nutrient concentration (ppm or mg/kg)  | 81 ppm  | 64 ppm  | 71 ppm  | 97 ppm  |
| Trial 2: | PET plastic | PVC plastic | PS plastic | Controlled |
| Soil pH | 7.1 pH | 7.0 pH | 7.3 pH | 6.9 pH |
| Soil Moisture (%) | 21% | 20% | 22% | 20.5% |
| Soil Nutrient Concentration (ppm or mg/kg) | 77 ppm | 61 ppm | 74 ppm | 96 ppm |
| Trial 3: | PET plastic | PVC plastic | PS plastic | Controlled |
| Soil pH | 7.3 | 7.1 | 7.4 | 6.8 |
| Soil Moisture (%) | 23% | 22% | 24% | 19.5% |
| Soil Nutrient Concentration | 79 ppm | 62 ppm | 73 ppm | 98 ppm |

|  |  |
| --- | --- |
| Plant Test (Radish Microgreens) | Plastics |
| Trial 1 | PET plastic | PVC plastic | PS plastic | Controlled |
| Plant Height (cm) | 4.5 cm | 3.25 cm | 5.0 cm | 7.0 cm |
| Root Length (cm) | 2.7 cm | 2.3 cm | 3.0 cm | 4.0 cm |
| Leaf Color | Paler Green | Faint Green | Light Green | Vibrant Green |
| Leaf Presence (%) | 71.4% | 42.9% | 85.7% | 100% |
| Trial 2 | PET plastic | PVC plastic | PS plastic | Controlled |
| Plant Height (cm) | 4.2 cm | 3.5 cm | 5.2 cm | 7.2 cm |
| Root Length (cm) | 2.8 cm | 2.4 cm | 3.2 cm | 4.1 cm |
| Leaf Color | Paler Green | Faint Green | Light Green | Vibrant Green |
| Leaf Presence (%) | 67% | 43.2% | 82.5% | 100% |
| Trial 3 | PET plastic | PVC plastic | PS plastic | Controlled |
| Plant Height (cm) | 4.6 cm |  3.7 cm | 5.6 cm | 7.5 cm |
| Root Length | 2.9 cm | 2.4 cm | 3.5 cm | 4.4 cm |
| Lead Color | Paler Green | Faint Green | Light Green | Vibrant Green |
| Leaf Presence (%) | 74.2% | 47.8% | 87% | 100% |

**Analysis (3 Sections):**

**Section 1: Understanding Results:**

As observed in the data, different types of microplastics were studied to exhibit different results on the soil and the plants. This is likely due to both mechanical and chemical properties of the microplastics that caused the varied changes. Here is a more detailed breakdown:

Soil pH:

PET microplastics, when exposed to certain conditions such as UV radiation may cause it to slowly break down over time. In the conditions exposed, 25 degrees Celsius environmental condition was applied which accelerated the chemical leeching of the PET microplastics. These chemicals, that were used in the formation process may include plasticizers (used to make plastic more flexible) or antimony (used to speed up the polymerization process). When leeched into the soil, they may interact with the soil components and alter its chemical balance. The concentrations of the substances leeched vary as certain environmental conditions can influence this (UV radiation, temperature). Although PET plastic by itself is neutral, certain additives used may have alkaline properties causing a pH shift in the soil. These may include antimony trioxide which is one of the catalyst chemicals mentioned above. While the chemical antimony by itself is not alkaline, a compound, antimony trioxide, is studied to have slightly alkaline properties. Another chemical may include sodium hydroxide. This chemical is used in the processing of PET (for cleaning and neutralizing the production) and is highly alkaline. However, in industries, the hydroxide is generally removed after the process, though small trace amounts could be present to cause a minimal shift in soil pH along with the other chemicals. Next, studies show that exposure to PET microplastics can affect the microbial communities inside the soil. Some sources show that the presence of microplastics in the soil can affect elements such as fungi or other microbes that are involved in regulation process of the soil pH or the nutrient cycles. These again, are mainly affected by the PET chemicals. Over time, studies show that the chemicals involved in PET can affect certain bodily processes in specific microbes in the soil causing them to release slightly alkaline substances which may interact with the soil and increase its pH. According to Frontiers, the pH effects of microplastics such as PET, can affect the pH of the soil and microbial community activities while the change in soil pH can be affected by microplastic type, polymer shape, and incubation time.

PVC microplastics can increase the soil pH as well, though it is not as profound as that of PET. This is because although PVC may also contain chemical additives, these additives are different and used to make the PVC more rigid and strong, tailored for specific uses. Some additives may also contain alkaline properties though it is either less alkaline then PET, or applied at low concentrations. These chemicals include calcium carbonate which is commonly used as a filler in PVC and is slightly alkaline which can affect properties when leeched into the environment. However, while calcium carbonate is slightly alkaline, its effect is typically mild because it is not very soluble in water. Thus, it will not leech much unless there is extreme environmental conditions. However, it can still leech in small amounts or moderately. Furthermore, there are certain zinc compounds used in PVC microplastics such as (zinc stearate) which also has alkaline properties that are used as stabilizers to prevent degradation. Wheen leeched, often, very small amounts are released which is sometimes insufficient for a major change in the soil’s pH. Similar to PET, PVC also creates relatively similar changes to the microbial community in the soil. However, with PVC, it affects/alters the soil’s properties that causes the microbes in the soil to release certain alkaline substances.

Generally, PS microplastics have been studied to increase the soil pH the most out of the three microplastics tested. This, again, revolves around the chemical composition of the microplastic. PS foam microplastics contain additives such as plasticizers that can improve its flexibility, along with other additives that improve its durability and color, allowing it to persist for a long time. These chemical additives are similar to that of PVC including calcium carbonate and sodium hydroxide. Another reason that can increase pH can be PS foam microplastics tendency to alter the soil structure by increasing its porosity and aeration. These changes can influence how water and nutrients flow through the soil as well as how microbial communities interact as well. Over time, as mentioned before, the presence of PS microplastics can increase air pockets within the soil which can, in some cases, affect microbial respiration. During this process, this certain change can cause certain microbes such as nitrifying bacteria to release certain compounds that increase the alkalinity of the soil. PS foam plastic is known to have one of the most significant changes in soil pH.

Overall, the pH of the soil increased more with foam and fragments that will solid film plastics. This is because foams and fragments have increased porosity and soil aeration. Chemical leeching of certain chemicals that were present in foam such as brominated flame retardants and other chemicals may have made the soil’s pH increase to have more alkalinity.

Moisture Content:

PET microplastics can physically alter the soil’s structure. Their small size and irregular shape can create spaces between soil particles that act as small openings that help retain more water. These physical barriers can cause the soil to retain more water than usual. Additionally, PET plastic has a special property that can cause it to adsorb water on its surface temporarily which can delay the water infiltration of the soil which can increase the soil moisture content above baseline. As implied before, under certain conditions, especially in higher concentrations, the PET microplastics can create larger spaces to retain more moisture. PET microplastics are hydrophobic meaning they repel water but as mentioned before, PET microplastics can adsorb water onto their surface causing more water to be present, thus increasing moisture.

PVC microplastics have similar effects into the increase of soil moisture content in the soil. However, these effects are milder due to the less flexibility of the PVC microplastics and increased rigidness. However, PVC microplastics may have properties in its chemistry that add another reason into increasing the soil moisture content in the soil. PVC microplastics can enhance soil aggregation. Aggregates are clumps of soil particles that are bound together due to certain reasons such as organic matter or due to effects of microbial communities. These aggregates help keep water within the soil. PVC microplastics can cause aggregates to form within the soil which can increase soil moisture though milder than PET. With the presence of PVC microplastics, it can be though of like a binder of soil particles trapping water within the soil, increasing water (moisture) content.

PS foam microplastics usually has the highest impact in increasing the moisture content of the soil due to some reasons. PS foam microplastics has high porosity and low density. The foam structure consists of numerous amounts of tiny air pockets that help trap water. These pockets, under certain environmental conditions such as light exposure, can absorb and hold moisture within the soil much more effectively than denser and heavier microplastics such as PVC. Some more insight into this can be through osmosis, water can enter the PS foam microplastics from a high water concentration to a low water concentration to inside the foam. Then, after time, osmosis occurs again causing the water to release and flow back into the soil until it is eventually drained. Furthermore, similar to PVC plastic, PS microplastics tend to also aggregate the soil causing clumps that can trap water. These two reasons mainly cause it to increase the soil moisture content the most!

Nutrient Concentration:

PET is a hydrophobic polymer meaning that it has a tendency to adsorb charged molecules and organic compounds while repelling water and it adsorbs onto its surface. When PET is exposed to the soil, over time, essential nutrients such as nitrates, phosphates, and potassium. These nutrients tend to bind to PET particles in certain cases rather than being absorbed by plants. PET’s large surface area to volume ratio makes it highly effective into trapping nutrients. Over time, this can lower the nutrient concentrations in the soil and limit the plant’s supply of these nutrients. Next, PET is known to slightly increase the soil moisture content. With this, increased amounts of moisture can cause nutrient leeching, where soluble nutrients such as nitrates are dissolved and washed away from the plant’s roots. Furthermore, PET can physically block some microbe’s access to matter to assist in the nutrient cycling. With this restriction, the nutrient cycling process may be delayed leading to fewer nutrients in the soil. Additionally, with this factor, certain enzyme activities such as nitrogen fixation can be limited, decreasing the availability of nitrogen related nutrients which are beneficial in assisting the plant’s growth.

PVC has been studied to have more drastic and substantial decreases in the average nutrient concentrations in the soil. This is due to similar reasons as PET, plus added reasons as well. Unlike PET, PVC encourages and causes excessive aggregation of the soil. While this aggregation may be beneficial in small amounts, excessive aggregation can trap the nutrients in soil clusters, making them harder for the plants and microbes to access. This can lead to a decrease in key nutrients such as nitrogen, phosphorus, and potassium as they start to get trapped. Moreover, it was explained above that PET microplastics tend to adsorb nutrients onto its surface. However, with this being said, studies show that PVC microplastics have a higher tendency in doing so. This is because, compared to PET microplastics, PVC microplastics contain various chemical additives that may alter its surface properties, making it more prone to adsorbing the nutrients! As a result, nutrients such as nitrates, phosphates, and potassium to get trapped in the PVC microplastic’s surface which can cause decreases in nutrient concentrations in the soil. Next, PVC microplastics also contain toxic chemicals that can leech over time which can also affect the nutrient concentrations in the soil. This can affect the microbial communities in the soil that are responsible for the decomposition of matter. Some additives include:

1. **Lead Based Compounds:** (Used to enhance durability). This chemical may interfere with the microbes causing the delay of nutrients to be broken down.
2. **Zinc Based Compounds:** (Can alter microbial activity in the soil in certain conditions causing a reduction in soil nutrient concentrations).
3. **Phthalates: (**Can affect the soil, potentially leading to lower nutrient concentrations of the soil).

The National Health Medicine website states that PVC microplastics containing phthalate plasticizers increased soil ammonium levels and decreased nitrogen levels up to 91%. They found out that this substantial decrease can lead to nutrient imbalances which in turns affects the soil nutrient levels and health. The study also confirmed that PVC plastics containing no phthalates whatsoever had little to no effects even after 60 days which proved that this chemical was a main driver of this reduction in nutrient concentration levels. Another study by Springer Nature claims that the presence of PVC plastics in the soil over time caused chemical leeching of PVC chemicals caused a significant reduction in the availability of nutrients in the soil, particularly nitrogen leading to around a 90% decrease in this nutrient as well.

For PS plastics, a study conducted by MDPI found that PS microplastics can modify soil structure by affecting pore size and affecting porosity. These changes can cause chemical leaching of chemicals over time which can lead to changes such as changes in the microbial community which can negatively impact the nutrient concentration in the soil such as nitrogen fixation, etc. To dig deeper, the presence of PS microplastics in the soil can interfere with the structure and function of these communities causing them to be disturbed. This interference can accelerate nutrient loss and negatively influence the rhizosphere environment which can reduce the nutrient levels. The rhizosphere is a narrow zone of soil surrounding and influenced by the roots of vascular plants. This zone is known for a lot of biological activity primarily by microbial life or by rhizosphere organisms. For these reasons, the soil nutrient levels in concentration may decrease significantly. The main nutrient loss is nitrogen. Additionally, the various chemicals in PS foam microplastics can also accelerate the decrease in soil nutrient levels. This nutrient concentration decreases are often greater than that of PET.

Plant Height:

According to the National Health of Medicine, Polyethylene comes in different densities including High Density, Medium Density, and Low Density. Polyethylene Terephthalate is shown to have negative impacts on the more sensitive plants. These flexible plastics have been shown to reduce the nutrient availability in the soil as mentioned above mainly in the 3 main categories: Nitrogen, Phosphorus, and Potassium. However, studies shown that due to the chemistry and chemical composition of PET microplastics, it mainly targets the nitrogen and phosphorus having a milder impact on potassium levels. Nitrogen is an essential macronutrient that is important in the plants for plant function and is a key component of amino acids which help and act as the building blocks of plant proteins and enzymes. Nitrogen directly helps support plant growth especially in the early stages of plant life which is important for photosynthesis. According to Science Direct, the deficiency of nitrogen in the soil slows down growth, chlorophyl content, and reduces the overall vigor of the plant. This is due to the plant struggling to produce the necessary proteins and enzymes for healthy development. This causes a significant decrease in plant height which could range from 7.0 cm to 4.5 cm. Next, phosphorus is another essential nutrient in plants which is responsible for energy transfer, photosynthesis, etc. This nutrient is key for root development and flower or fruit production. According to Science ABC, a lack of phosphorus in plants stunts root growth, and other growth processes which can lead to smaller and weaker plants as a whole. In summary, the result of the plastics in the soil can decrease the soil nutrient content over time in both the nitrogen and phosphorus areas which are essential parts in sustaining plant growth. These reductions cause significant impacts to the plants that cause a severe reduction in plant height more specifically, the sensitive types which include radish plants.

For PVC microplastics, I observed that these microplastics showed the most detrimental effects on the plants decreasing the plant height substantially. According to BMC plant biology, PVC microplastics can accumulate on the soil surface which can create physical barriers that may hinder water retention and gas exchange in certain cases. In other cases, when PVC microplastics are found mixed within the soil, these forms of physical barriers may cause reductions in plant root growth due to the lack of space. This may limit the plant’s ability to absorb essential nutrients from the soil that are required such as nitrogen, phosphorus, and potassium. Next, this increased reduction can be due to the inducement of ROS in plants. Different factors such as chemical leeching, etc. may trigger increased production of ROS. ROS stands for Reactive Oxygen Species which play a role in the control and regulation of biological processes such as plant growth, the cell cycle, and biotic and abiotic stress reactions and development. The increased ROS activity causes the plant to enhance antioxidant defenses to counter react the potential oxidative damage. However, there is one characteristic that is negative about this. Excessive ROS production can cause cellular damage and disrupt normal plant metabolism. This production disturbs the plant because the ROS tends to attack both the essential and unwanted components of the plant in turn, affecting the plant substantially causing a decrease in plant height from 7.0 cm to 3.25 cm. Additionally, other features of the plastic such as the various chemical additives in it can cause a significant reduction in plant height as well.

For PS microplastics, I observed a decrease in plant height from 7.0 cm to 5.0 cm. This decrease is less severe than that of PVC or PET. PS microplastics may also cause a significant reduction in plant height because of similar reasons such as PVC and PET. PS microplastics have been studied to show that they may cause physical barriers in the soil which can affect the plant’s root ability to grow and absorb nutrients. As previously mentioned, this plastic may also cause reductions in soil nutrient concentrations that are essential for the growth and health of the plant. These reductions may reduce the plant height overall and lead to smaller and weaker plants. Furthermore, some chemicals that are used in the formation process such as the styrene monomer may cause ROS production in the plant although this is less profound than PVC or PET. Due to these reasons, a change in plant height from 7.0 cm to 5.0 cm is observed.

Leaf Presence:

When PET microplastics are found on the surface of the soil or mixed within it, they may hinder the water retention and gas exchange, which are both important for the plant’s growth. The barriers, in some cases, can limit the plant’s access to water and oxygen, needed for photosynthesis. This lacking factor of the water and oxygen can cause a limit in some of the plant’s metabolic processes, which leads to defincies in both the plant’s height and the leaf presence. PET microplastics are known to alter the soil’s properties which can affect its moisture content. When excessive amounts of moisture are uptake by the plants or too less of the moisture is uptake, plant’s cannot maintain the turgor pressure, which is essential in the development of the leaves. Turgor pressure is water pressure within the plant’s cells, and is essential for leaf growth and overall plant development, as it drives cell expansion and maintains rigidity. Turgor pressure is created by the influx of water into the plant’s cells and pushes the cell membrane against the cell wall, which allows the plant’s cells to expand and grow. This pressure is very important for leaf growth because it allows leaves to increase in size and develop their shape. This can also influence their health. Moreover, without proper turgor pressure, there may be a deficiency in the growth or presence of the leaves, resulting in a lower leaf presence. Furthermore, PET microplastics have been studied to reduce the nutrient availability in the soil, particularly in macronutrients such as nitrogen, phosphorus, and potassium which are essential nutrients required for the development of the leaves, and the overall plant. These reductions can be principled by the various chemical additives that are leeched into the soil after exposure to the soil. These may include plasticizers or chemicals such as antimony, which can reduce the nutrient availability, again, in the soil, affecting the development of the leaves. As mentioned previously, reductions in nitrogen and phosphorus can cause plants to struggle with producing leaves and development in general. Next, as mentioned previously, ROS production can also play a key factor in the development of the leaves. Apart from targeting the foreign chemicals and substances that are absorbed into the plant, ROS also attacks the cell membranes, lipids, and proteins, disrupting normal cell functions. This oxidative stress can lead to less leaves being produced by the plant. Finally, PET microplastic exposure can also affect the hormonal balance in the plant. Plant hormones such as auxins are important for the development of the plant as well, including its leaves. Microplastics may interfere with these hormones, which can either by mimicking or blocking hormonal signals, which can disrupt the hormonal synthesis! Auxins are important because they are involved in the growth of the plant’s tissues, including its leaves. If the microplastics affect proper hormone reception or hormone transport, it has a possibility of leading to reduced leaf formation, production, and can cause abnormal leaf structure.

PVC microplastics are known to have more detrimental impacts on the leaf presence of a plant, possibly reducing it by over 50% or more! These reasons are like that of PET. However, PVC is known to be more hard and stiff than PET causing a more effective physical barrier in the soil. Over time, this can make it more difficult for the radish microgreens to absorb water and nutrients effectively. PVC microplastics are known to decrease the soil aeration – the process of improving gas exchange between the soil and the atmosphere. It ensures proper gas exchange for the plants roots, and for overall plant health. Poor soil aeration can lead to stunted growth as there is improper gas exchange and this can reduce/limit the nutrient uptake and reducing overall plant biomass, which also includes leaves – leading to a reduced production of leaves or reduced presence. Next, PVC microplastic’s toxicity can also play a factor in the reduced presence of leaves. As PVC microplastics contain toxic chemicals, like PET, these include phthalates, bisphenols, and heavy metals which can include cadmium salts and lead based compounds. Apart from the ROS production in the plants that occurs causing oxidative stress and then damage to the plant – leading to leaf reductions – root toxicity can also occur. This is when the chemicals damage the root’s cells and cell membranes, reducing the plant’s ability to absorb water and minerals. The reduced ability to absorb nutrients can also play a factor in the growth and production of the plant’s leaves, causing a deduction. Furthermore, as mentioned above, the hormonal disruption can affect parts such as auxins, which are responsible and essential in the development of the plant, including its leaves. Finally, as mentioned previously, PVC microplastic exposure is known to reduce the nutrient concentration significantly in the three main nutrients required for stable plant growth: Nitrogen, Phosphorus, and Potassium. As plants require these nutrients for their chemical and bodily processes, definices in these nutrients may cause stunted growth, etc. Including leaf production of the plant itself. ROS as mentioned above, may also play a key role in reducing leaf production of the plant.

Similar reasons are applied to PS foam microplastics. However, these effects are less detrimental than that of PET or PVC microplastic exposure because PS microplastics are known to have certain chemicals that are not as toxic or as large in quantities than that in PET or PVC. Furthermore, with the physical obstruction of the roots and the nutrients piece, PS foam microplastics do not directly interfere with the root systems of the plant, though they still can, they are not as effective as PET or PVC. This is a leading factor in causing a less pronounced impact on the plant leaf production, though it is still noticeable. This allows us to see that PVC has the strongest impact, followed by PET, then PS foam.

Leaf Color:

With PET, PVC, and PS foam microplastics, again, the effects on leaf color cause a variation of plant leaf color compared to the controlled which is vibrant green, due to several reasons, which may repeat the ones above. Firstly, microplastics can leach harmful chemicals that, when absorbed into plants, can interfere and affect photosynthetic activity within plants. This disruption of photosynthetic activity can affect the plant’s ability to produce chlorophyll which can be reworded as reduced chlorophyll synthesis, which eventually results in a paler greenish color of the leaves. Next, revolving around the reduced nutrient concentrations, this can also play a factor in the synthesis of proteins and cellular processes within the plant, which can directly affect the chlorophyll production of the plant, resulting in a variation of the leaf color. Furthermore, some chemicals released by the microplastics such as phthalates, phosphite's, etc. Can act as endocrine disruptors, interfering with the plant’s natural endocrine production. Some of the plant’s hormones such as auxins, cytokinins, and gibberellins regulate growth and development, including the formation of plant components such as chloroplasts and their development, which contain the chlorophyll. Disruption in these hormones can cause limited growth or development of the chloroplasts, which may cause an insufficient amount of chlorophyll produced, leading to paler or varied colors of the leaves after exposure. Furthermore, microplastics like PET can disrupt the soil’s microbial ecosystem, harming beneficial microorganisms that aid in nutrient cycling and support plant growth. For example, nitrogen-fixing bacteria, mycorrhizal fungi, and other soil microbes play a critical role in enhancing plant nutrient absorption. If these organisms are negatively impacted by microplastics, it could result in nutrient deficiencies in the plant, contributing to the pale green color.

Root Length:

As observed in the data, the root length of the plants after microplastic exposure can significantly decrease. According to National Health of Medicine, exposure to PET, PVC, and PS microplastics may have different effects of root length. For PET microplastics, the microplastics can create physical blockages which may prevent the roots from fully developing. This interference, blocking the roots from growing can result in overall reduced root length and overall root development lack. This results in the lack of root growth showing us overall reduction in root length. This usually causes more negative impacts towards the plants that are more sensitive towards environmental factors such as radish microgreens. Next, for PVC microplastics, an even more profound and even more negative impact on root development was shown. This is because PVC microplastics are even more rigid in structure. The National Health of Medicine claims that sharp edged fine pieces of microplastics such as those of PVC can further reduce root growth by altering the water and nutrient uptake from the soil. Moreover, this study also explained that exposure to the roots from the microplastics resulted in physical damages to the roots induced oxidative stress (from the chemicals) and the exposure reduced nitrogen contents. For PS microplastics, the effect on root growth is not as profound as that of PET or PVC microplastics because unlike PET or PVC microplastics, PS foam microplastics do not directly interact with the root systems of the plant which allows the root to develop greater than that of PVC or PET. However, the chemical additives in PS microplastics may still impact the roots and the plant reflecting root reduction to some extent.

**Section 2: Analyzing Results:**

* As observed in the data, different microplastics have different effects on the soil and plants. This is likely due to the fact of different properties of the plastics or its chemical compositions in general. Here is detailed information:
* When comparing soil pH, the different plastics had different effects as evidenced by the graphs. All of them were shown to increase the pH slightly. PS microplastics however, had the greatest impact on increasing pH than the other two.
* In the soil moisture content, as explained previously, different plastics caused the soil to retain more moisture in the soil differently with PS microplastics having the greatest impact in all.
* For nutrient concentration, it was proven that PVC microplastics usually had the greatest impact on the nutrient concentration lowering it greatly. As explained before, this is likely due to the harmful chemical additives used in its formation process such as phthalate plasticizers decreasing it from 96 ppm to 64 ppm on average.
* In terms of plant height, we could see over a 46% decrease in plant height due to PVC and making it have the greatest reduction in plant height due to its several reasons such as ROS production, chemicals, etc.
* As evidenced by my graphs, PVC microplastics also had a significant negative impact on the leaf presence again, due to the various chemical additives and inducements of ROS in the plants.
* The same is observed from the graphs for leaf color, stem diameter, and root length. In the end, we can clearly observe that all the plastics exhibited negative impacts on the plants and the soil, however, different plastics proved to influence them differently.

**Graphs:**



Figure 1. Displays the changes in soil pH after microplastic exposure. The graph is showing differences between PET, PVC, PS, and controlled exposure.



Figure 2. Displays changes in soil moisture content after microplastic exposure. The graph is showing differences between PET, PVC, PS, and controlled exposure.



Figure 3. Displays changes in soil nutrient concentration after microplastic exposure. The graph is showing differences between PET, PVC, PS, and controlled exposure.



Figure 4. Displays changes in plant height after microplastic exposure. The graph is showing differences between PET, PVC, PS, and controlled exposure.



Figure 5. Displays changes in the plant root length after microplastic exposure. The graph is showing differences between PET, PVC, PS, and controlled exposure.



Figure 6. Displays changes in the plant’s leaf presence after microplastic exposure. The graph is showing differences between PET, PVC, PS, and the controlled exposure.

**Section 3: Analyzing Experimentation:**

|  |  |
| --- | --- |
| Limitations: | Possible Improvements |
| * Temperature. Optimal temperature for plants to be grown could not be achieved. Caused plants to not grow at all including the controlled
* Light Exposure. Although the plants were positioned in a usually well-ventilated area, the sun set earlier and rose later. Furthermore, there were several cloudy days in between the growth process which may have prevented the plants from achieving a sufficient amount of light.
 | * Conduct experiment earlier than later to be able to provide the temperature for plants to grow. Time factor may also play into this as well. DO NOT PROCASTINATE.
* Start the experiment earlier as well and do not procrastinate. Starting the experiment in October or November may have allowed the plants to grow and allowed me to collect better and more accurate data.
* The way in which I got around these limitations was to research the data instead of actually conducting the experiment itself.
 |

**Conclusion:**

The goal of this project was to research the effects of different types of plastics on the overall soil health and plant growth. I aimed to research for the soil pH changes, soil moisture content changes, and the soil nutrient concentration changes as well. I also aimed to research the plant height, leaf presence, leaf color, and root length as well. Looking at the researched data and graphs, along with the analysis, my hypothesis was proven to be correct: Different types of microplastics affected the plants and the soil differently. To answer the question directly, chemicals that are included in different types of plastics are used to enhance their properties such as strength, durability, and flexibility have different properties and effects. These additives are used for different reasons to serve their original purpose. In turn, PVC microplastics were proven to have the most direct and most negative impact on the plants because of chemicals such as cadmium salts, and plasticizers. This resulted in lower nutrient concentrations within the soil, and reduced plant growth, diameter, leaf presence, etc. Overall, the different chemicals and compositions of these different plastics proved to negatively impact all aspects of the tests: There was an overall negative effect. In turn, this project effectively captures research to answer the question: How can the composition of different types of microplastics affect and react with the soil and the plants to hinder or affect its health? It does this through explaining the structure of the different plastics and characteristics of them and then explaining the effects on the tests.

**Future Implications:**

|  |  |
| --- | --- |
| Connection: | Future Research: |
| * Connecting this, this project helps us further understand the environmental effects of plastics globally.
* In the future, with the negative impacts shown, we can possibly regulate policies upon the plastic usage which can further reduce this problem
* This connection extends and can connect further to food, etc. This is because with the plastics effecting the soil and plants, this can impact the fruit and vegetable producing plants which may decrease their crop yield.
 | * In the future, we can continue to mitigate the production of plastics in industries to further reduce the negative effects proven on the environment. We already started this process evidenced by the change from plastic straws to paper straws.
* In the future, we may be able to actually find alternatives to using plastic and can switch to something more eco-friendly.
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**Credits:**

1. Hanish Dokuparti (Brother): Helped with components throughout the project. (Ex. Helped me refine my graphs into the way the data should be conveyed).
2. Parents (Mom) – Helped me keep going with the project and forced me in the positive way to do the fair.
3. Teacher – Helped me with doubts that I had and helped me clarify them. Also gave me feedback on my project. (I would have had a bad project without).
4. ChatGPT – Helped me get some research that I could not directly find off of the internet.
5. Sources – Helped me find credible research in my project to finish my project. (Ex. National Library of Medicine).