

**Sriram Dokuparti**

**Experimental Project**

**Grade 8**

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| **Date and Time** | **Achievements and Notes** |
| **September 30, 2024** | **E-mailed Ms. Bretner about the science fair question.** **Question:** How can the chemical composition and structure of different types of plastics react with the soil & plants to hinder or affect its health?**Type of Project:** Experimental Project |
| **October 1, 2024****8:06 – 8:47 pm**  | Today, I will be conducting some background research on microplastics and their effects.* Plastics are a synthetic material made that can be molded into a soft material used for many purposes when turned into a solid. Toys, bottles, tools, can be made from plastic. It is convenient but harmful to the environment. Plastics are harmful to the environment because they do not biodegrade. It takes over 1, 000 years for plastics to break down so it is discarded. As the plastic production increases, the environment slowly builds up in these pollutants until it reaches a peak affecting a variety of lifeforms. These include sea life, wildlife, plants, and abiotic factors as well including soil.
* Plastic accumulates in the environment because it takes a long time for it to even start breaking down meaning that over the courses of decades of production, the plastic increases in population in the environment. As it reaches its peak, lifeforms like marine life and land life may accidentally consume it or get negatively impacted by it leading to several damages like oxidative damages in their body.
* When microplastics are accidentally consumed, they contain toxic chemicals such as phthalates, BPA, and heavy metals like antimony trioxide. When the animal bodies recognize these chemicals, they view it as foreign substances triggering a response from the immune system. This response is to release reactive oxygen species that are unstable molecules which can cause oxidative stress to the animals as there is an imbalance of free radicals and antioxidants in the body leading to the stress.
* These environmental damages can include chemical leeching of certain chemicals in the plastics that are dangerous to the environment over time such as antimony. This is a chemical metal that is used in the production of PET and can leech into liquids or the environment.
* The plastics including PET plastics often end up in natural animal ecosystems and affect life and later break up into smaller pieces of plastic known as microplastics.
* Microplastics also pollute ecosystems because as microplastics enter the food chain, they affect organisms at all levels. At first, small organisms such as plankton and insects consume the plastics first. Later, larger animals like birds and fish consume those organisms leading to the negative effects in them, and so on and so forth. This eventually then affects the whole ecosystem.
* These plastics break up into smaller pieces because of both physical breakings and chemical breakings. These physical breakings include when wind and water carry the plastics and over time, break the plastics into smaller and smaller pieces. During this, abrasion could occur where the bigger pieces rub against other surfaces causing the plastics to break into microplastics. Additionally, sunlight can also cause plastic to break down in the environment. Like other plastics, PET plastic is susceptible to UV radiation from the sun. Over time, as the plastic is exposed more to the sun, the chemical process of polymerization of the ethylene glycol and the terephthalic acid will start to weaken. This results in the plastic to break into smaller pieces and continue breaking as it continually exposed.
* In soil, it can cause problems like blocking ways for plants that grow in them to absorb nutrients and water properly. Additionally, the presence of microplastics in soil can sometimes make plants absorb the microplastics into the roots themselves by accident. This creates trouble and factors that make it more difficult or affect plants that grow in the soil in a negative way. Plastics can release chemicals into soil, damage the soil content, etc.

<https://oceanservice.noaa.gov/facts/microplastics.html> <https://iopscience.iop.org/article/10.1088/1755-1315/631/1/012006/pdf> <https://www.cancer.gov/publications/dictionaries/cancer-terms/def/oxidative-stress>  |
| **October 2, 2024****12:08 – 12:24 pm** | Today, I will be conducting some background research on the pollutants that might be present in the water and researching the composition of PET Plastic (The Plastic using in this experiment).* PET (Polyethylene Terephthalate) plastic is a strong synthetic fiber and is part of the family of polymers and polyester. PET is molded into beverage bottles after.
* PET is produced through the polymerization of ethylene glycol and terephthalic acid. Polymerization is a chemical process in which small molecules called monomers chemically bond together to form the complex structure of a polymer. This creates a strong and durable substance. Due to this substance’s durability and lightweight structure, it is commonly used for packaging and processing, shipments. This is also commonly seen in the environment due to its continuous production and creation.
* PET plastic is not easily biodegradable and as the production increases, the amount of plastic in the environment accumulates leading to damages in the environment such as to marine life and plants if the plastic mixes with the soil.
* PET plastic increases in danger when it comes to the part where microplastics from PET plastics (5mm pieces), can mix with the soil and affect the plant in many ways including water retention, absorption, nutrient imbalance, chemical leeching, etc.
* In plants, microplastics can directly stress the plant in several ways. This interaction can be commonly in the roots. As the microplastics mix with the soil, extremely small pieces can be absorbed into the root hairs, being absorbed into the plant itself and cause damage to the plant itself.
* Next, we can see the microplastic stress in the leaves as well. If there are really small pieces of microplastics, this can cause oxidative stress. This is because if the pieces are small enough, they can be absorbed into the plant. This causes the molecules of plastic to accumulate in the plant. This oxidative stress happens when there are not enough antioxidants in the body and there are too many particles. This results in less leaf growth and changes in photosynthesis.

<https://www.sciencedirect.com/topics/earth-and-planetary-sciences/water-pollutant> [https://bio.libretexts.org/Bookshelves/Ecology/Environmental\_Science\_(Ha\_and\_Schleiger)/06%3A\_Environmental\_Impacts/6.02%3A\_Pollution/6.2.01%3A\_Water\_Pollution/6.2.1.01%3A\_Water\_Pollutants\_and\_Their\_Sources](https://bio.libretexts.org/Bookshelves/Ecology/Environmental_Science_%28Ha_and_Schleiger%29/06%3A_Environmental_Impacts/6.02%3A_Pollution/6.2.01%3A_Water_Pollution/6.2.1.01%3A_Water_Pollutants_and_Their_Sources) <https://archive.nptel.ac.in/content/storage2/courses/105105048/M10L12.pdf>  |
| **October 30, 2024****7:53 - 8:10pm** | Today, I will be doing more background research.* Microplastics and harmful pollutants in water and soil are becoming a global problem due to the constant manufacturing and production of plastics which are being disposed of inefficient methods.

<https://www.frontiersin.org/journals/plant-science/articles/10.3389/fpls.2023.1226484/full>  |
| **October 31, 2024****2:43 – 2:58pm** | Today, I will be creating plans for important dates to accomplish.**November 5:** Finish the methods, materials, and variables for the project and get them approved. **November 10:** Finish the background research and all necessary information needed for the project.**November 25:** Collect all the materials required for the project.**November 27:** Begin the process of growing the plants and start with the different sources of water with the concentration of different microplastics. **December 10:** Finish collecting all the data from the plant growth and begin the analysis portion of the project. **December 30:** Finish the graphs and standard deviation and data and finish analyzing all the data. **January 10:** Finish explaining how the plant growth changes and changes with the different concentration of water. **January 25:** Finish the conclusion and all necessary info for all the projects.**January 30:** Polish the project altogether and print everything.**February 10:** Attach everything to the trifold and make it aesthetically appealing. **February 21:** Science Fair.I hope I follow this plan! |
| **December 5, 2024** | I am currently behind. I will try to finish by end of the winter break. Today, I will be finishing the background research for this project and do the methods for this project.* The chance of which a plant encounters contact with microplastics is dependent on the area in which the plant is thriving.
* In terrestrial ecosystems, plants are exposed to microplastic stress which can affect their growth and development.
* Microplastics can disturb a plant’s physical growth and development. Microplastics in the roots or soil can disrupt plant growth because it can block the development of roots or alter their structure, which can then limit the plant’s ability to absorb nutrients and water from the soil.
* Secondly, in reality, there are chemicals and substances in the microplastics or in the water that could affect the growth and development of plants. Also, when microplastics are in the soil, they can release harmful chemicals, such as heavy metals, or persistent organic pollutants such as dioxins.
* Thirdly, microplastics can cause nutrient imbalance. This is because the microplastics can interfere with the nutrient uptake of plants. When water containing microplastics is introduced to the soil, the plastics can block pores in the soil, reducing the availability of essential nutrients for plants which can lead to stunted growth and poor development of the plants themselves.
* Finally, microplastics can alter the way water is retained or distributed, making it either too dry or waterlogged, which stresses plants and affects their growth.

<https://www.frontiersin.org/journals/plant-science/articles/10.3389/fpls.2023.1226484/full>  |
| **December 15, 2024** | Today, I will be finishing the background research for this project by investigating and researching the effects of microplastics in the soil. I will be researching the correlation between the effects of microplastics in the soil on the plant.* There are many mays in which microplastics can affect plants. These several methods include growth stability, root development, reduce nutrient availability, water retention, Chemical Leeching, Soil porosity, and light toxicity to the plants.
* Firstly, large microplastics that may range from 5mm to 1 cm may physically block plant roots from freely growing. As the plants encounter these large pieces, the roots would likely grow around them which may affect the plant’s ability to anchor itself into the soil. This then leads to the inability or poor ability of root development.
* Secondly, this can affect the water retention of the plant. Water retention is the ability of soil to hold water and supply it to the plants including the nutrients as well. However, when microplastics are introduced into the soil at high concentrations, they can cause clumps in the soil and also cause physical barriers preventing the water from reaching the plants via the soil.
* Thirdly, over time, the chemicals in the PET plastic may start to leech into the soil affecting the soil’s health eventually causing negative effects to the plants. This chemical leeching leads to light toxicity over time to the plants.
* Microplastics have been shown to affect the rooting ability of plants by altering the soil density and water holding capacity of the plant.
* PET Plastic which is present in plastic bottled water, can negatively impact the soil bulk density. This is because if the microplastics are present in high concentrations such as 15%, it can reduce soil compaction, reducing pore space, making it harder or more difficult for the water and nutrients to reach the plant. In turn, this affects the growth rate of the plant and its health.
* Additionally, microplastics can affect the stability of the aggregates in the soil by interfering with the soil’s non-living factors such as sesquioxide.
* Soil aggregates refers to groups of soil particles that bind more strongly to each other than adjacent particles. Aggregate stability refers to the ability of soil aggregates to resist splitting or breaking apart when different forces such as erosion or wind erosion, water erosion, or the presence of unusual substances are there such as microplastics.
* In Summary, PET Plastic can affect plants in many ways both being through the introduction of water or past existence in soil. They can affect the plants in several methods including growth stability, water retention, root development, the ability to uptake water or nutrients, etc.

<https://pubmed.ncbi.nlm.nih.gov/34742990/#:~:text=Microplastics%20have%20been%20shown%20to,chlorophyll%20a%2Fchlorophyll%20b%20ratios>. <https://thesoilking.com/blogs/news/5-water-retention-methods-for-organic-growers#:~:text=Water%20retention%20is%20the%20ability,dry%2C%20hot%2C%20sunny%20environments>. <https://soilhealthnexus.org/resources/soil-properties/soil-physical-properties/aggregate-stability-and-aggregation/#:~:text=Soil%20aggregates%20are%20groups%20of,or%20wind%20erosion%20are%20applied>.  |
| **December 16, 2024** | Today, I will be adding some more background research to the project to add the final touches to it.* Microplastics are small plastics that usually range 5mm or under in size and form to come in various shapes.
* They are highly problematic and a growing issue due to the fact that they are so small resulting in their easy integration into both marine and terrestrial life easily entering ecosystems and even plants.
* These plastics entering ecosystems is developing a growing global problem. In just 2023, over 413.8 million metric tons of plastics were produced. This massive amount poses several risks of the global ecosystems. Microplastics are categorized into types: Primary microplastics and secondary microplastics.
* **Primary Microplastics:** Primary microplastics are directly manufactured into small sizes. These plastics are generally small and usually found in products such as cosmetics and personal care products. These products include exfoliating beads, face washes, and scrubs. These products contain these tiny plastic particles known as microplastics. Another example of primary microplastics can be industrial pellets. Plastic manufactures use these small pellets also known as nurdles as raw materials for creating larger plastic products through a process called polymerization and other processes. These pellets are often spilled into the environment during transportation or during handling.
* **Secondary Microplastics:** Secondary microplastics are formed when larger pieces of plastics break up into smaller pieces of plastic. Plastics like bottles, bags, fishing nets, and other plastic items degrade into smaller pieces or microplastics over time due to several reasons. Prior to explaining the factors, it is necessary to understand three main types of microplastics and their composition. (PET, PVC, PS)
* **PET plastic:** PET plastic is a form of plastic among the many types. In its longer form, Polyethylene Terephthalate is a type of thermoplastic polymer meaning polymers that are softened through heating processes before being processed and then left to cool and harden. Once cooled, they show no changes in chemical properties meaning that they can be re-melted and reused several times.
* This thermoplastic polymer is commonly used in packaging and textiles. It is known for its strength, durability, and resistance making it a wide choice in plastic production industries.
* PET plastic is most used for products such as water bottles, soft drink containers, and food packaging. Additionally, this polymer is used for making products such as polyester and fabrics.
* How is PET plastic made?
* PET plastic is made through a process called polymerization. This process includes the polymerization of two key chemicals called terephthalic acid and ethylene glycol.
* Terephthalic acid is derived from petroleum or natural gas. Terephthalic acid is responsible for the main rigid structure of PET plastic.
* Ethylene glycol is a distinct chemical that is used in the polymerization. However, this chemical is also found and derived within natural gas or petroleum. When these two chemicals are obtained, the key production is formed through a reaction of polyester polymerization.
* Monomers are atoms or small molecules that bond together to form more complex structures such as polymers.
* The monomers of the two chemicals (terephthalic acid and ethylene glycol) are chemically reacted under high heat and pressure under a reactor. The intense heat forces the atoms and molecules inside the chemicals to join together and bind together.
* This heat and pressure creates ester bonds, which link the monomers together to create long chains of Polyethylene Terephthalate, also known as PET.
* As a byproduct, this reaction produces water as the monomers bind together which is removed to further continue the plastic making process.
* These long chains of plastics are made through two main stages.
* The first stage is known as polycondensation which is the first step into heating the terephthalic acid and ethylene glycol to form a pre-polymer. This pre-polymer are short chains of PET.
* The second stage involves re-heating the short chains again under the reactor to form an even stronger and longer chain giving the PET plastic its durability and strength as a whole.
* Next, after these two stages, the result is in liquid form. A machine known as an extruder is used to shape the molten PET into long continuous forms.
* The molten PET then enters a die (specialized mold) which shapes it into a long strand or sheet. The PET is then cooled so it cools into smaller solid pieces known as pellets which allow it to encounter easy transportation.
* Pellets are the standard form in which PET is transported so that it can be melted again into different products for purpose and to strengthen the structure further. These pellets are around the size of grains of rice.
* **PVC Plastic:** Among the other types of plastic, PVC plastic is another. PVC plastic in its longer form stands for polyvinyl chloride. PVC plastic can be found in products such as pipes and flooring to medical devices.
* PVC plastic is known for its durability, chemical resistance, and versatility. To make this plastic, it first begins within a gas known as vinyl chloride.
* This gas is produced from a chemical reaction between ethylene and chlorine.
* The chemical reaction between these two chemicals forms a substance known as vinyl chloride monomer. This is a simple molecule which is the base for creating the product: PVC plastic.
* This background step is crucial because we have to create the plastic from this base. Next, there is the polymerization process. In the polymerization process, the vinyl chloride monomer is heated at high temperatures usually ranging between 60 degrees Celsius to 200 degrees Celsius. The monomers is heated at these temperatures and exposed to chemicals that we call initiators. These chemicals are often peroxides. The combination of these two things help boost the polymerization process to make the monomer particles bond with one another creating long chains: PVC as a solid plastic.
* The polymerization to create PVC plastic us done in two methods: suspension polymerization & emulsion polymerization.
* **Suspension Polymerization:** First, the vinyl chloride monomer is dissolved in water along with a special agent which is polyvinyl alcohol which helps keep the monomers separated. After this step, heat and pressure are applied to force the particles to bind together and form the PVC plastic.
* Water is used in the process to help control the temperature and prevent the plastic from getting too hot and disrupt the chain process.
* After the polymerization of the monomers, the resins that are produced from the reaction are dried, washed, and then sent to encounter more processes.
* **Emulsion Polymerization:** In this process, the vinyl monomer is mixed with water and a special emulsifying agent (soap) is used to help the monomers dissolve into tiny droplets. Then, polymerization initiators (chemicals) are also added.
* Heat is then applied, and the chemicals and agents that were applied help the droplets bond together forming fine PVC plastic particles.
* As time passes, these chains grow larger and larger along with accumulating strength. Then, after the process, the chains are separated from the water.
* After polymerization, the PVC is in a form of white powder or paste. These fine particles of PVC are known as resin.
* The resin is then processed and refined to make the final plastic products. The PVC resin is then mixed with additives such as:
* Plasticizers: To make it more flexible
* Stabilizers: To make it less easy for it to degrade
* Lubricants: To make the resin easier to mold
* Fillers: Enchance properties such as strength
* These additives are mixed with the PVC resin in an industrial machine called an extruder which results and leaves a compound that is ready for shaping.
* In the shaping process, the PVC compound that is created is forced through a mold to create long shapes like pipes and sheets. To force the PVC through the mold, it is melted and then forced encountering the cooling process later.
* Another molding process is injection molding. Injection molding involves heating up the plastic into a liquid and then injecting it into a mold. Then, the injected plastic is then cooled. Finally, the last form of molding is known as blow molding. After the cooling and molding, the plastic is ready to be shipped to its destinations to be used for its desired purposes. **PS Plastic:** PS plastic is also another used plastic with its own functions and uses. PS plastic in its longer form, stands for Polystyrene plastic. This plastic however, is a synthetic polymer made from the monomer “styrene.” This type of plastic is found in both solid and foam forms. Although it is used commonly for it’s versatility, it is also second thoughted because of its environmental impact due to the fact that it does not easily biodegrade. This type of plastic is made from a monomer called styrene (C8H8) and is a liquid hydrocarbon that is derived from petroleum or natural gasses.
* A hydrocarbon is a organic compound that consists ONLY of hydrogen and carbon atoms.
* Hydrocarbons are classified into mainly four different types based on their bonds between the carbon atoms!
* Alkanes: These have only single bonds between carbon atoms and are also known as saturated hydrocarbons. An example can be methane. (CH4). (One carbon atom per four hydrogen atoms).
* Alkenes: These contain at least one double bond between carbon atoms and are unsaturated hydrocarbons. An example can be ethene. (C2H4) (Two carbon atoms per four hydrogen atoms).
* Alkynes: These contain at least one triple bond between carbon atoms and are also unsaturated hydrocarbons. An example can be ethyne (C2H2). (Two carbon atoms per two hydrogen atoms).
* Aromatic Hydrocarbons: These have a unique ring structure with alternating single and double bonds. An example can be (C6H6) or benzene.
* Polystyrene (PS) is a hydrocarbon polymer and is made from the monomer styrene. This is a aromatic hydrocarbon. The chemical formula for this monomer is C8H8 and it consists of the benzene ring and is attached to a vinyl group.
* Double bonds occur because of electron sharing. Each carbon atom has four electrons in its outer shell and requires eight to be stable. By sharing two pairs of electrons, the carbon atoms form double bonds and this causes them to become more rigid and stronger along with the decrease in their flexibility. Additionally, this double bond means that it becomes much more reactive than a single bond because of the shared electrons.
* Triple bonds occur because of similar reasons to double bonds. However, triple bonds are formed when three pairs of electrons are shared rather than two pairs of electrons. These three pairs of electrons causes similar affects to those on double bonds however triple bonds make the carbon atoms much stronger, rigid, and reactive.
* In a ring structure like benzene, the carbon atoms are connected in a loop or ring. An example can be benzene which has six carbon atoms. This causes a hexagon like structure and the ring like structure makes the ring stable. This is because electrons are shared around the entire ring rather than just between two carbon atoms. In the styrene monomer, there are 8 carbon atoms per styrene unit).
* Back to the PS plastic, polystyrene is formed by polymerizing the styrene molecules. The polymerization process begins with the introduction of an initiator (typically a peroxide) into the process. This initiator decomposes in the process due to the heat and produces free radicals.
* Free radicals are highly reactive particles that contain unpaired electrons. Paired electrons can be found within bonds between carbon atoms.
* These free radicals that are formed from the initiator attacks the styrene molecule. When the styrene molecule is attacked, the single or double bond that is formed breaks, creating unpaired electrons. With the unpaired electrons, this forms a new free radical that tends or has properties to attack another styrene molecule. After these continuous attacks, this forms a dimer when two monomer particles (styrene monomer) bond together. This continues and forms a chain. Over time, longer polymer chains occur with thousands of styrene monomers linking together to form the polystyrene plastic! (PS).
* Some types of polymerization can be ones that we discussed with the suspension polymerization: suspending the monomer in water and emulsion polymerization: droplets.
* Polystyrene also has a property making it a thermoplastic polymer meaning it softens upon heating and it can be reprocessed.
* The primary raw material to make PS plastic is styrene and this material is derived from petroleum or natural gas.
* For more detail, styrene is produced from the dehydrogenation of ethylbenzene or from the alkylation of benzene with ethylene. Benzene HAD the ring like structure of the carbon bonds.
* Specifically, when it is placed in the polymerization reactor, it is placed with benzoyl peroxide.
* After polymerization, the polystyrene is usually in the form of a viscous liquid or solid beads dependent on the method used (Emulsion or Suspension).
* If foamed polystyrene or Styrofoam is required, then elements like Carbon dioxide or pentane are introduced which have properties that cause the P.S plastic to foam. This addition makes the P.S plastic expand into a rigid, lightweight structure.
* After this, the plastic is then passed through an extruder where the solid plastic is then melted and then shaped into various shapes to satisfy its purpose such as films, plates, and molded objects such as cups or packaging. The foam sheets are also used for insulation or packaging comfort.
* As mentioned prior, this plastic may also be added with additives that enhance the chemical properties such as colorants, or stabilizers, or other substances for strength or durability.
* Along with this plastic, besides it’s versatility, it poses a significant environmental concern.
* P.S plastic, especially in its foam form, is known for its low biodegradability and high environmental impact. It often breaks into microplastics which are harmful to aquatic and terrestrial ecosystems. Due to its rigid structure, P.S is challenging to recycle and often ends up in landfills or as pollution in oceans.
* Plastics like PET, PVC, and PS plastic are produced from chemicals that are used in everyday products. Examples can be bottles, packaging, electronics, etc.
* These products enter the environment after being discarded or improperly managed.
* Microplastics can be produced to break down into smaller pieces due to both physical breakdowns and chemical breakdowns. These include:
* Physical Breakdown: Plastics are exposed to natural forces like wind, water currents, and wave action which can cause physical stress to the plastics slowly breaking them into smaller pieces. This repeated stress weakens the material’s structure leading to cracks and breaks in it. Additionally, abrasion could occur when the plastics rub against rough surfaces like sand and other debris further breaking them down into smaller fragments.
* Chemical Breakdown: Exposure to UV radiation from sunlight triggers photo-oxidation which is a process that weakens the strong chemical bonds between the chemical bonds in the plastic. In plastics like PET, the ester bonds that are formed between the ethylene glycol and terephthalic acid begin to degrade under the prolonged sunlight exposure.
* As these polymer chains break, the plastic looses its strength, becomes brittle, and eventually breaks into microplastics also influenced by forces like wind and weather.
* Similar to PET plastic, PVC plastic also undergoes chemical degradation primarily due to UV radiation, heat exposure, and oxidation over time. This breakdown weakens its molecular structure, leading to break downs into microplastics:
1. Chlorine Instability: PVC contains chlorine atoms in its polymer making it highly sensitive to UV radiation from sunlight. When exposed to long periods of time of UV rays, the carbon chlorine bonds in the PVC plastic chain begin to break. This process releases hydrochloric acid as a byproduct from the chain bond breaks which further accelerates the degradation rate as a second chemical reaction. This is known as dehydrochlorination. This process also helps break down the long chains into smaller ones changing from larger plastic fragments or products to smaller fragments or pieces. Additionally from breaking to smaller chains, the polymer chains may weaken, causing PVC to loose flexibility and become brittle little pieces.
2. Thermal Degradation: SOLID PVC after its formation begins to degrade at high temperatures even without UV radiation. This also causes the carbon chlorine bonds to break, causing further releases of the hydrochloric acid. This hydrochloric acid further speeds up the process of degradation of the plastics.
* These effects are similar for the PS plastic as UV radiation, heat and exposure, and oxidative damage breaks down the plastics.
* One of the most common types of microplastics found in the environment is from plastic fragmentation (Bottles, Packaging, etc).
* The enter the environment as mentioned before through mechanical and chemical breakdown processes including U.V radiation, etc.
* Due to wind and water transport, these plastics can end up in oceans and soil. These plastics can be persistent and harm the environment for years or even centuries.
* Another common type of plastic finding itself in ecosystems can be synthetic microfibers which usually come from clothing as the clothing industry booms.
* Their sources are polyester, nylon, and acrylic fibers from clothing and textiles.
* Washing synthetic clothing releases approximately 700 000 fibers per wash into the wastewater making it prone and easy to enter the environment when the wastewater is discarded.
* These microfibers are easily ingested by fish and plankton affecting their bodies greatly.
* These microfibers usually make up approximately 35% of microplastics in ocean ecosystems.
* Plastics such as PET, PVC, and PS are common sources of microplastic pollution in the environment are even more problematic when they enter the environment.
* PET plastic enters the environment through poor handling of bottles, or other objects made up of this plastic. This can lead to contamination over time.
* Through the chemical and physical breakdowns that were discussed, PET plastic’s degradation in the environment can create volatile organic compounds.
* Volatile organic compounds are a group of compounds that can vaporize into the air. These chemicals are present in many products used today such as paint, varnish, wax, and various cleaning and cosmetic products. Exposure to these vapors can cause a variety of health concerns.
* Volatile organic compounds are given the name volatile because they can easily vaporize at room temperature and organic because they contain carbon compounds.
* VOC’s are characterized by their ability to quickly vaporize at low temperatures. They evaporate at low temperatures because of several reasons including their molecular structure, such as hydrogen bonds. These bonds in the VOC’s are weak and not as strong as the hydrogen bonds in water. Because of these weak bonds, VOC’s require less energy to escape from their current state such as liquid to gas thus, allowing it to vaporize quickly.
* Another type of plastic that may enter ecosystems is PVC plastic. When PVC plastic enters the ecosystem and is discarded as waste, it can leach into the soil, especially when it is exposed to UV radiation from sunlight or experiences physical stress such as abrasion. PVC plastic by itself does not contain chemicals but the chemicals that are added to it such as the additives that enhance its flexibility or color can severely impact the soil. (More detail will be added later for depth)
* Another method that PVC may enter the atmosphere is during manufacturing. During manufacturing, small PVC particles can be released into the air, escaping the factory, and contaminating the atmosphere through animals that may inhale it or contaminating the air in general. PVC plastic is harmful to the environment. For similar chemical leeching reasons as PET, PVC plastic contains additives such as phthalates, lead, and bisphenol A. (More detail will be added later)
* PS plastic poses several health concerns. This is because the plastic could be ingested by wildlife like fish, turtles, birds, etc. These animals often mistake small PET particles as food and consume it. This causes them to encounter problems such as malnutrition, blockages, or even death. PS plastic is also prone to releasing harmful chemicals and toxins. These chemicals are different to those found in PVC plastic and PET plastic. In PS plastic, chemical leeched include styrene (Foundation of PS plastic) and benzene. During its formation, PS plastic forms long strong chains between the styrene carbons and hydrogen atoms. This strength makes it tough as it should be for its purposes. However, this strength also becomes problematic when PS plastic is accidentally released into the environment. This strength means low biodegradability causing it to persist for several centuries or years LONGER than PET or PVC.
* PS plastic can enter the ecosystem through littering or as industrial waste. Foam cups and products may be littered and be discarded in an efficient and harmful way causing their presence in natural ecosystems.
* Another method in which PS plastic can enter the ecosystem is through industrial waste. The polymerization process in which PS plastic is made or other processes can release PS plastic particles into the air and harm ecosystems as well. This is called industrial waste or industrial contamination. Similar to PVC plastic and PET plastic, PS plastic can cause damage to marine life when it accumulates in the water harming the fish population after they consume the strong plastic or other marine organisms and biotic factors.
* Here is where detail on the chemicals involved in the plastic making processes is included.

**PET Plastic:*** In the PET plastic making process, chemicals such as ethylene glycol and terephthalic acid.
* Ethylene glycol is an organic compound that has two main purposes including acting as a raw material when manufacturing polyester products and for antifreeze formulations.
* Each particle of ethylene glycol is made of carbon, hydrogen, and oxygen. The chemical formula for ethylene glycol is (C2H6O2). This means that each particle in the substance has 2 carbon atoms, 6 hydrogen atoms, and 2 oxygen atoms.
* Every chemical or substance includes both physical characteristics and chemical characteristics.
* Physical characteristics of ethylene glycol includes it appearance which is colorless, and clear. It is mostly odorless and has a slightly sweet smell. It has a sweet taste but if ingested, is toxic to the human body. It has a boiling point of 197.3 degrees Celsius. It has a melting point of (-12.9 degrees Celsius). Additionally, this chemical is completely soluble in water.
* Chemical characteristics of ethylene glycol includes it’s alcohol group. The chemical is a hydroxyl meaning that it has connections or formations consisting of one atom of hydrogen. This formation makes it a type of alcohol called a “diol.”
* The ethylene glycol is also flammable burning with a faint blue flame producing carbon dioxide and water. This substance also has a low vitality meaning that it does evaporate easily at common temperatures or does not evaporate at room temperature. Another characteristic of ethylene glycol is that it is toxic to humans and animals causing kidney damage and nervous system damage.
* Ethylene glycol is colorless due to the fact that it does absorb visible light. This is because the atoms in the ethylene glycol including oxygen, hydrogen, and carbon, do not form double bonds or complex structures which does not give it the ability to absorb visible light in a way that we can see it. Instead, this structure that is formed by the connection in ethylene glycol forms a structure in which ultraviolet (UV) rays are absorbed.
* Terephthalic acid is another chemical that is involved in the polymerization of PET plastic. This chemical of terephthalic acid is (C8H6O4). This means that this acid has eight carbon atoms, six hydrogen atoms, and four oxygen atoms per molecule.
* Some fun facts about terephthalic acid is that in its chemical composition, it forms two carboxyl groups.
* A carboxyl group is a group in which there is one carbon atom, two oxygen atoms, and one hydrogen atom.
* Some key characteristics about terephthalic acid is that it is odorless and has a poor solubility in water unlike that of the ethylene glycol
* Next, due to the fact it forms carboxyl groups, this means that the terephthalic acid acts as a weak acid
* This acid reacts with some chemicals such as ethylene glycol to form ester bonds to form long chains in which how PET plastic is made or formed.
* Some uses for terephthalic acid is that it is used in the production of PET plastic and has other uses in industries as resins.

PVC Plastic:* In the production of PVC plastic, mainly one chemical is used to produce it. The chemical is known as vinyl chloride monomer.
* This monomer is the base for the creation of PVC plastic. The polymerization process is centered around this chemical of the process.
* Some characteristics of this chemical is that the monomer is that it forms a double bond between two of its carbon atoms. It chemical formula is (C2H3CI).
* The elements involved in each particle of the monomer are carbon, hydrogen, and chlorine. It has two carbon atoms, three hydrogen atoms, and one chlorine atom.
* The monomer has a mildly sweet smell, has a boiling point of approximately (-13 degrees Celsius), and is slightly soluble in water however is more soluble in organic solvents.
* Some chemical properties of the monomer is that it is highly reactive and easy to polymerize due to its reactiveness. This reactiveness is present because of the double bond of the carbon.
* Under heat and pressure, it has properties which enable and make it form long chains which form a substance known as PVC or polyvinyl chloride.

<https://www.vaisala.com/en/chemical-industry-solutions/chemicals-allied-products/polyethylene-terephthalate-pet-production-process#:~:text=PET%20is%20produced%20in%20the,are%20later%20recovered%20and%20recycled>. <https://omnexus.specialchem.com/selection-guide/polyvinyl-chloride-pvc-plastic#:~:text=Polyvinyl%20Chloride%20(PVC%20or%20Vinyl,So%2C%20what%20is%20PVC%3F> <https://www.chemicalsafetyfacts.org/chemicals/polystyrene/>  |
| **December 18, 2024** | Today, I will be formulating the hypothesis for my experiment.If the type of plastic that is being used changes, then the effects of it on the soil would also drastically change. This is because different plastics have different chemical compositions and different chemicals that are used in the production process. These can include chemicals such as ethylene glycol and terephthalic acid in PET plastic, vinyl chloride monomer in PVC plastic, and the styrene monomer in PS plastic. These chemicals have different properties such as different smell, elements in their compounds, and chemicals that are added to strengthen certain properties such as strength, etc. When the plastic mixes with the soil or affects the plants, these different properties can cause the plastics to negatively affect the plants differently. Furthermore, with the different chemical compositions, different factors such as UV radiation may cause the plastics to release different chemicals at different concentrations which additionally adding to negative effects. These may include changes in soil pH levels, etc.  |
| **December 18, 2024** | Today, I will be doing the variables for the experiment (manipulated variable, responding variable, and controlled variables)**Manipulated Variable:** The manipulated variable of this experiment is the different type of plastic that is being used. These plastics are PET (Polyethylene Terephthalate), PVC (Polyvinyl Chloride),and PS (Polystyrene).**Responding Variable:** The responding variable in this experiment is to collect the data of the changes that were made by the plastic to the soil and the plants. The data being collected includes:**Soil:** Soil pH (How the presence of microplastics in the soil affects soil pH at a given concentration). Soil Moisture (How the presence of microplastics in the soil affects water retention further affecting the soil). I will also be measuring the presence of toxic chemicals in the soil as well.**Plants:** Plant Height (from the bottom of the pot to the tip of the tallest peak). Leaf Count (Number of leaves present). Stem Diameter (How long the diameter of the stem is. \*Measure the diameter in cm.\*) Leaf Color (Color of the leaves of the plant. Calculation: Green Leaves – Rotten Leaves). Root length (Measure the length of the roots at the end). **Controlled Variables:**

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| --- | --- | --- |
| **Controlled Variable** | **Why it needs to be controlled** | **How it is going to be controlled** |
| Soil | Different types of soils or soils from different companies have different contents and concentrations varying in substances such as organic matter, minerals, etc.  | To control this, the same type of soil is going to be used among all the concentrations and trials. |
| Light Exposure | Light is essential for photosynthesis. Unequal lighting may cause differences in plant growth that can be unrelated to the microplastic’s effect. Without the light exposure being equal among all plants, there would be inconsistent results because then two manipulated variables would be present: light exposure and type of plastic introduced.  | This controlled variable is going to be controlled through all the pots achieving equal amount of sunlight through all the pots in the same area near a huge glass window allowing the light to reach all the pots to an equivalent amount.  |
| Soil Amount | The soil amount must be controlled because more soil means more dilution of the microplastics in the soil. Keeping the soil the same would ensure consistent results because the amount of soil also means the amount of space the plant must grow along with space for root growth.  | To control this, I will using the same amount of soil through a pre-measured amount through the mass of the soil. This can be measured through a kitchen scale or using the density of the soil. Mass = Density x Volume. |
| Plant Species | Different plants have different resilience and immunity to several environmental factors such as microplastics due to their adaptations. Controlling the plant species would allow consistent results because different plants react to these factors separately. Another reason the plant species should be controlled is because different plants have different structures and growth speeds, rates, etc. For example, some plants have tap roots while some have fibrous roots. | This aspect of the controlled variables is going to be controlled by ensuring the plant species are the same without any variation between the species. Furthermore, I am also going to be controlling this by adding the same amount of seeds per pot. The seed that is going to be used is going to be radish microgreens due to their speedy growth rate, etc.  |

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| December 22, 2024  | Today, I will be researching the materials and formulating the methods for my experiment.**Materials:**1) PET Microplastic - (Can be obtained from plastic bottles. To achieve microplastics 5mm or under, cut up into smaller pieces)2) PVC Microplastic - (Can be obtained from PVC pipes. Try cutting this plastic with stronger scissors due to its resistance)3) PS Plastic - (Can be obtained from PV foam. This foam should be handled carefully as it can easily break and is exceptionally light)4) Gloves & Mask - (The plastics may be dangerous and may cut your fingers due to its sharp edges)5) Biodegradable Pots & Containers - (Require 24 pots. 3 x 4 x2 = 24 pots. 2 trials each Plastic and concentration)6) Soil - (300 g of soil per pot. 300 x 24 = 7.2 kg of soil)7) Plants - (Require 48 seeds. Planning on using radish microgreens)8) Water - (100 mL of water per watering per plant in a pre-measured can)9) Measuring Tool - (To measure the plant growth per 24 hours. Measuring plant height, leave growth, leave quantity, root development at the end)10) Measuring scale - (To add precise measurements of plastic per pot at a given concentration per soil amount)11) Heater - (To regulate the heat temperature if it gets chilly)12) 5 –in – 1 Soil Meter - (To measure nutrient content in soil, pH of soil as well)**Method/Procedure (Experimental Design):**Preparation:1. Achieve 8 containers that are composed of Polyethylene Terephthalate plastic or PET plastic that are dry with little to no moisture inside.
2. Using a sharp scissor or knife, cut the container or bottle into small pieces that vary in size around 0.3 cm – 1 cm while trying to aim for around 0.5 cm. The goal is to simulate real life conditions.
3. Obtain 1 – 2 PVC pipes. Make sure that the pipe is large enough to hold a minimum of 24 g of plastic inside.
4. Use a powerful saw or some supplies, cut the PVC pipes into small pieces. (It is ok if the initial cutting is larger than 1cm. Later cut it up into smaller and more experimental size pieces.)
5. Get a few polystyrene sheets to cut up to use the third plastic in the experiment. Make sure that these sheets are enough to get at least 24 g of microplastics.
6. Use a utility knife or scissor to cut the polystyrene foam into several pieces that are approximately 0.5 cm in length. This is the ideal length for microplastics.
7. Pour each microplastic type into a sperate Ziplock. For PET plastic, divide the total amount of g (24) in 3 and pour each third into a separate Ziplock. Name one Ziplock “PET Trial A”, another “PET Trial B” and another “PET Trial C.”
8. Repeat these steps with the other plastics naming PVC as “PVC Trial A” “PVC Trial B”, “PVC Trial C.” Repeat this as well for PS naming “PS Trial A”, “PS Trial B,” and “PS Trial C.” This shows the three trials that are being done in this project.
9. There would need to be use of nine pots in this experiment. This is because there are 3 trials and three types of plastics that are being compared in this experiment. (3 trials x 3 types of plastic = 9 total pots).
10. Position the pots in front of a mirror that allows light to travel through for sunlight.
11. Divide these plants into separate rows with labels on each pot indicating which plastic that it and its trial on it. (Ex. “PET, Trial 1, 10% concentration). Make sure that each row has 3 plants since there are 3 types of plastic per trial
12. Plant 300 g of soil per pot. To measure precisely this amount, either use the formula for calculating the mass: Density x Volume. Another promising method as to finding the mass may be to use a kitchen scale to measure.
13. Achieve Radish Microgreens with the option of growing them in soil.

**Testing:**1. First, leave the soil at room temperature for 2-4 hours to ensure that the soil fully reaches room temperature without temperature fluctuations which may affect the plants.
2. Using the radish microgreen seeds, scatter 8 seeds all throughout the pot evenly ensuring an appropriate amount of space between each seed in the pot.
3. Using the **appropriate** plastic, measure the appropriate amount of plastic using the given concentration divided by number of waterings. This means that the given concentration is the amount of g per soil amount. (Ex. 5% concentration means 0.05 x 300 = 15 g total microplastics across all days. To get the amount of plastic per day, divide by 10).
4. Make sure that all plants get an equal amount of microplastics collectively for accurate results.
5. Using the formula listed above, add 50% of the concentration by mixing the plastics with water and the other half by pre-mixing it with the soil.
6. Each day, test the pH of the soil using the soil pH meter, soil moisture, and measure the presence of the toxic chemicals in the soil through the nutrient monitor function in the meter as well
7. Repeat this for the plants. For the plants, measure for plant height, leaf count, stem diameter, leaf color, germination rate, germination time, and root length (cm at the end).
8. Take observations and collect data of the growth daily for later uses to create graphs, etc.

This is a picture of the calculations and how the trials should look like per plastic type:  |
| **January 5, 2025** | Today, I will be creating a table as to how my collected data should be looking like:\*The data is going to be recorded based upon recent studies due to limitations in the growing process such as temperature and sunlight.\**The following table shows information that is studied at the end of the 10 days. The following three tables display information about the effects of the plastics in ten days. It shows three trials.*

|  |  |
| --- | --- |
| 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 (% per 300 g) | 22% | 21% | 24% | 20% |
| Soil nutrient concentration (ppm or mg/kg) | 81 ppm | 64 ppm | 71 ppm | 97 ppm |

|  |  |
| --- | --- |
| Soil Test | Plastics |
| 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 (% per 300 g) | 21% | 20% | 22% | 20.5% |
| Soil nutrient concentration (ppm or mg/kg) | 77 ppm | 61 ppm | 74 ppm | 96 ppm |

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| Soil Test: | Plastics |
| Trial 3 | PET plastic | PVC plastic | PS plastic | Controlled |
| Soil pH | 7.3 pH | 7.1 pH | 7.2 pH | 6.8 pH |
| Soil moisture (% per 300 g) | 23% | 22% | 24% | 19.5% |
| Soil nutrient concentration (ppm or mg/kg) | 79 ppm | 62 ppm | 73 ppm | 98 ppm |

<https://www.researchgate.net/publication/361963214_Individual_and_combined_effects_of_microplastics_and_oxytetracycline_on_cherry_radish><https://pmc.ncbi.nlm.nih.gov/articles/PMC10966681/?utm_source=chatgpt.com> <https://www.frontiersin.org/journals/environmental-science/articles/10.3389/fenvs.2021.675803/full> <https://journals.sagepub.com/doi/10.1177/0734242X241299110> <https://spj.science.org/doi/10.1080/20964129.2022.2133638> <https://academic.oup.com/pnasnexus/article/3/10/pgae433/7828925?login=false> *The following three tables display information about the effects of plastics on plants and it properties.*

|  |  |
| --- | --- |
| Plant Test: | Plastics |
| Trial 1 | PET | PVC | PS | Controlled |
| Plant Height (cm) | 4.5 cm | 3.25 cm | 5.0 cm | 7.0 cm |
| Leaf Count (Total Leaves) | 5 leaves | 3 leaves | 6 leaves | 7 leaves |
| Stem Diameter (mm) | 1.7 mm | 1.2 mm | 2.2 mm | 2.5 mm |
| Leaf Color | Paler Green | Faint Green | Light Green | Vibrant Green |
| Root Length (cm) | 2.7 cm | 2.3 cm | 3 cm | 4 cm |

|  |  |
| --- | --- |
| Plant Test: | Plastics |
| Trial 2 | PET | PVC | PS | Controlled |
| Plant Height (cm) | 4.2 cm | 3.5 cm | 5.2 cm | 7.2 cm |
| Leaf Count (Total Leaves) | 4 leaves | 2 leaves | 5 leaves | 8 leaves |
| Stem Diameter (mm) | 1.6 mm | 1.1 mm | 2.3 mm | 2.6 mm |
| Leaf Color | Paler Green | Faint Green | Light Green | Vibrant Green |
| Root Length (cm) | 2.8 cm | 2.4 cm | 3.2 cm | 4.1 cm |

|  |  |
| --- | --- |
| Plant Test: | Plastics |
| Trial 3 | PET | PVC | PS | Controlled |
| Plant Height (cm) | 4.6 cm | 3.7 cm | 5.6 cm | 7.5 cm |
| Leaf Count (Total Leaves) | 6 leaves | 4 leaves | 5 leaves | 9 leaves |
| Stem Diameter (mm) | 1.5 mm | 1.0 mm | 2.2 mm | 2.5 mm |
| Leaf Color | Paler Green | Faint Green | Light Green | Vibrant Green |
| Root Length (cm) | 2.9 cm | 2.4 cm | 3.5 cm | 4.4 cm |

[*https://pubmed.ncbi.nlm.nih.gov/33299822/*](https://pubmed.ncbi.nlm.nih.gov/33299822/)[*https://nph.onlinelibrary.wiley.com/doi/10.1111/nph.15794?utm\_*](https://nph.onlinelibrary.wiley.com/doi/10.1111/nph.15794?utm_)[*https://pubmed.ncbi.nlm.nih.gov/34742990/*](https://pubmed.ncbi.nlm.nih.gov/34742990/)[*https://pubs.acs.org/doi/10.1021/acs.est.9b01339?utm\_source=chatgpt.com*](https://pubs.acs.org/doi/10.1021/acs.est.9b01339?utm_source=chatgpt.com)[*https://www.pnnl.gov/news-media/root-microplastics-plants?utm\_*](https://www.pnnl.gov/news-media/root-microplastics-plants?utm_)Observations:

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| *Observations of the plastics* | PET Plastic | Translucent structure with high flexibility and strength. Lightweight and durable. Smooth with sharp edges, fine. |
| PVC Plastic | Translucent, white color. Rigid and heavier than PET. Low flexibility with sharp edges. |
| PS Plastic | Bulbous, foam similar structure. Rough texture, squishy, lightweight, medium flexibility. |

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| *Observations of Effects of plastics on soil (PET Microplastics, 8%)* | Measure: | Observations: |
| Soil pH | Slight increase in pH, more basic. Mostly neutral structure. Subtle color change to lighter color. Light visibility of harder surface. |
| Soil Moisture | Slight increase in soil moisture. Visible crowded water on surface. Over saturation of water causing mushy wet texture of soil. Limited drainage of water. |
| Nutrient Concentration | Slightly more compact appearance, light dry spots in some areas. More compaction compared to controlled. Low microplastic biodegradability.  |

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| *Observations of Effects of plastics on soil (PVC Microplastics, 8%)* | Measure: | Observations: |
| Soil pH | Milder increase in soil pH compared to PET. More neutral structure, no noticeable changes in soil color. Light, soft surface.  |
| Soil Moisture | More neutral side increase in soil moisture. Light mushy texture of soil. Plastic had capacity into minimal surface water retention through droplets & moisture. Limited water drainage. |
| Nutrient Concentration | Some spots of soil felt extremely dry compared to other parts. Some parts of soil felt extremely compact. Reduced nutrient concentration the most compared to other plastics. Additional blotchy visibility. |

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| *Observations of Effects of plastics on soil (PS Microplastics, 8%)* | Measure: | Observations: |
| Soil pH | Noticeable increase in soil pH. Slightly lighter color than controlled and other plastics. Surface felt dry, powdery, rough.  |
| Soil Moisture | Little to no absorption of water. Extremely limited water drainage. Visible water droplets on surface. Soil looks compact and clumpy. |
| Nutrient Concentration | Some spots of soil felt extremely dry compared to other parts. Some parts of soil felt extremely compact. Reduced nutrient concentration is not as drastic compared to PVC plastic. Less frequency of blotches and dried areas than compared to PVC. |

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| *Observations of Effects of plastics on soil (PET)* | Measure: | Observations: |
| Plant Height | Significant reduction in plant height compared to the controlled. Plant looks to have experienced stunted growth, weakness, did not reach full potential. Growth seems minimal. |
| Leaf Count | Fewer leaves were present compared to controlled. Growth could have been delayed to some extent, or restricted. Plant was not able to develop many leaves likely due to stress. Leaves looked curled and weak. |
| Stem Diameter | Stem was weak, thin. Stem looks fragile with little thickness. Stem leaned a little with limited structural support. Stem was soft and not firm. |
| Leaf Color | Leaf color was slightly paler than the controlled. Leaves looked curled and this leaf color shows signs of nutrient deficiencies. |
| Root Length | Root length was significantly shorter than that of controlled. Roots seemed underdeveloped without reaching full potential. Roots felt compact. |

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| *Observations of Effects of plastics on soil (PVC, 8%)* | Measure: | Observations: |
| Plant Height | Significant reduction in plant height, stronger than PET. Plant height shows clear and significant stunted growth effects. Clear signs of MP stress are shown here.  |
| Leaf Count | Fewer leaves present, with weaker structures than that of PET stress. Leaves appear underdeveloped, small, and fragile. |
| Stem Diameter | Stem is thinner and weaker. Stem is fragile with poor structural support: leaning, bending. Shows difficulty into standing upright. |
| Leaf Color | Leaf color appeared to be faint green. Plant experienced poor Chlorophyl production. Plant leaves in poor condition. |
| Root Length | Extremely short roots were present with very fragile textures. Roots were extremely close together and more undeveloped than PET.  |

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| *Observations of Effects of plastics on soil (PS)* | Measure: | Observations: |
| Plant Height | Less significant of a reduction than PET or PVC. Plant grew significantly though away from normal potential. Noticeable signs of underdevelopment could be seen. |
| Leaf Count | Minor effect of MP stress on leaf count was present. Leave reduction was minimal. Leaves were slightly fragile with minor curling.  |
| Stem Diameter | Stem was mostly strong with minor fragility present. Stem was mostly thick but lower than the controlled. Semi- strong, semi sturdy. |
| Leaf Color | Leaf color was light green compared to vibrant green of controlled. Minimal devoid of Chlorophyl production was present. |
| Root Length | Roots looked less developed than controlled. Roots were somewhat close together but not weak. Minimal fragility could be observed.  |

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| **February 9, 2025** | *Today, I will be creating the graphs that I will need for the project.**\*Graphs will be added on February 14, 2025* |
| **February 11, 2025** | *Today, I will be doing some of my analysis that will stretch over the course to tomorrow as well as I will be attempting to finish the project by the evening/night of Thursday February 13, 2025*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:Why does pH of soil increase after exposure to PET microplastics?:PET microplastics, when exposed to various environmental conditions over time such as UV light or exposure can slowly degrade over time. During degradation, this plastic may release chemical additives that are added during its formation process such as plasticizers (substance to make a material more soft and flexible). These substances, once released into the soil over time, may interact with soil components and alter its chemical balance. The concentration of these substances vary dependent on environmental conditions. In certain cases, although the plastic itself may be neutral, they may have alkaline or basic properties coming from the chemicals used in the formation process. Although mostly neutral, these chemicals can still increase the pH lightly over time such as about (0.2 -0.4). In cases like over the course of ten days, the increase of approximately the amount listed above is expected. Furthermore, in environmental conditions, some studies show that the presence of PET microplastics in the soil can affect microbial communities in the soil. Some sources show that the presence of microplastics in the soil can affect elements such as fungi and other microbes that are included in the soil through the chemicals in PET. These communities can be involved in the regulation of the pH of the soil. Over some time exposure, the microbes may release certain substances that can increase the alkalinity of the soil which makes a higher pH! According to frontiers, the pH of microplastics including PET, can affect soil pH and microbial community activities while the change in pH can be dependent on microplastic shape, polymer type, and incubation time. PVC microplastics can also increase the pH of the soil over time. However, this increase is not as profound as PET microplastics. As explained before, this microplastic also contains chemical additives. PVC however, contains additives that make it stronger and more rigid. Some additives may contain alkaline properties similar to PET microplastics but these plastics usually have a milder effect than that of PET. However, this exposure does still increase the pH of the soil. Secondly, PVC microplastics also have a relative similar change to the microbial communities in the soil. However, PVC microplastics, rather than directly effecting the communities alters its structure which causes them to release slightly alkaline substances that in-turn increases the soil pH mildly.PS microplastics also increase the soil pH significantly. However, especially PS foam, usually creates a larger increase in pH due to its chemical composition. PS foam microplastics contain chemical additives similar to PVC and PET that help improve its durability, flexibility and color. Apart from the plasticizers, flame retardants including brominated flame retardants. This is a mixture of man made chemicals that are added in a variety of products including for industrial use which make them less flammable. Some of these chemicals may include properties or elements that make it more alkaline or basic, which can leech into the soil over time to increase the soil pH! 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. Why does the soil moisture content increase?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!Why do microplastics reduce Soil Nutrient Concentration?As mentioned before, PET microplastics can interfere with microbial activity within the soil such as breaking down organic matter to release nutrients into the soil. Some ways in which PET microplastics can interfere with microbial activity can be through its composition of substances such as plasticizers. These chemicals can hinder the microbes in the soil and as these microbes are affected, the breakdown of organic matter can be slowed down which can lead to less nutrient availability in the soil itself. Additionally, through the leeching of these certain chemicals can affect the soil in a way where there is less nutrient availability such as plasticizers affecting the soil in a negative way which can impact the three main nutrients required in the soil: Nitrogen (N), Phosphorus (P), and Potassium (K). For PVC plastics, they usually have a much more profound nutrient decrease in the soil due to the same reasons as PET. However, their decrease is much more strong because apart from the plasticizers used in their formation process, PVC plastics have many more chemicals that are used such as phthalate plasticizers which impacted the soil health. 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.<https://pubmed.ncbi.nlm.nih.gov/34865900/> <https://link.springer.com/article/10.1007/s11783-025-1926-6?utm_source=chatgpt.com> 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. 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.<https://www.mdpi.com/2223-7747/14/2/256?utm_> <https://www.frontiersin.org/journals/environmental-science/articles/10.3389/fenvs.2021.675803/full?utm_> Why does the presence of microplastics effect plant height significantly?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.<https://pmc.ncbi.nlm.nih.gov/articles/PMC10452891/?utm_> <https://www.sciencedirect.com/science/article/pii/S235239641930045X?utm_> Scienceabc.com 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. <https://bmcplantbiol.biomedcentral.com/articles/10.1186/s12870-024-05661-w?utm_> 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.Why does the presence of microplastics cause changes in leaf presence?As mentioned previously, PET, PVC, and PS microplastics cause a reduction in soil nutrient concentration. As nitrogen, phosphorus, and potassium levels decrease in the soil, it can cause the lack of plant growth and leaf production. Furthermore, as I mentioned previously, chemical additives in the soil and the absorption of these chemicals can also cause reduced plant height and leaf presence. The quantitative data I researched shows that usually, PS microplastics have the less detrimental and negative effects on plant leaf presence than PET or PVC. All of these microplastics have different effects on the leaf presence of the plant due to their distinct properties such as rigidness, flexibility, etc. These negative effects can also be characterized by their different compositions and chemicals in their formation process.Why does the Stem Diameter of the plant decrease?The reasons for reduction in stem diameter are like the reasons of reductions in leaf presence. This mainly due to the decreased availability of nutrients such as nitrogen, phosphorus, and potassium. These defincies can cause a reduction of overall plant growth, leading to thinner stems. For example, a study conducted by MDPI found that in environments with medium to high concentrations of PS microplastics, several growth and plant factors such as germination rate, stem length, and root length were severely impacted. PVC microplastics usually had the most detrimental impact on STEM diameter due to the presence of various chemical additives such as plasticizers and stabilizers which could affect the plants ability to grow and produce healthy and strong stems. Finally, another reason could be due to the fact of the ROS. As mentioned before, this immune response may impact the plant’s health overall and cause reductions in stem diameter as a result. <https://www.mdpi.com/2073-4395/14/5/923?utm_> Why does the leaf color of the plant change?In PET microplastics, the exposure of this plastic can cause the leaf color of the plant to turn paler green. This is because of similar reasons previously plus one added reason. As I previously mentioned, the effect of the microplastics on the plant such as if it is absorbed or its leached chemicals such as plasticizers are absorbed, this can cause impact on the plant through the oxidative immune reaction that is induced by the plastic. Additionally, it is not explicitly mentioned online, but studies show that other chemicals that are used in the PET plastic apart from plasticizers which are harmful to the plant. Studies show that continuous exposure to PET microplastics to disturb chloroplast distribution and inhibit photosynthetic activity. This disturbance due to the PET microplastics reduces the plant’s ability to produce chlorophyl which is the main reason due to the green color. This leads to a paler green color. Finally, another reason includes the essential nutrient deficiency in the soil.In PVC microplastics, the reasons for reduced leaf color making them appear to be faint green is due to some reasons. These reasons are like PET microplastics. However, the reason in which PVC microplastics cause the leaf color to appear faint green is because of the even for drastic reduction impact of PVC microplastics on the plant compared to PET. The additional chemical enhancers used in the PVC microplastic composition may increase the production of ROS species in the plant leading to more profound impacts resulting in a fainter green color. For example, a common chemical that is used in the formation process of PVC plastics is cadmium salts. Cadmium salts have been used as a stabilizer to improve the durability of PVC. When this chemical interacts with the plants, it can impact the chlorophyl production of the plant negatively which may result in paler or faint green leaves. <https://www.frontiersin.org/journals/plant-science/articles/10.3389/fpls.2023.1240472/full?utm_> In PS microplastics, the result of the lighter green color of the leaves in the plant is noticed because of similar reasons to both PET and PVC microplastics. However, PS microplastics do not have as drastic impacts on leaf color due to the less rigid structure of the plastic compared to PVC and PET. Although the presence of the plastic still affects the leaf color through ROS production through the chemicals, the chemicals are known to not be as toxic or as harmful than that of PET or PVC. However, with that being said, there are still chemicals within the plastic that affect the plant. Some chemicals within the PS microplastics include the styrene monomer. This result causes the plant to exhibit a lighter green color. Why does the presence of microplastics cause a reduction in root length?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.<https://pmc.ncbi.nlm.nih.gov/articles/PMC10452891/?utm_>   |
| **February 14, 2025** | *Today, I will be forming the application, limitations, and conclusion to wrap up this project.***Limitations:*** Some limitations that I faced while doing my project was temperature. I could not control the temperature which prevented my plants from growing to actually conduct the experiment.
* To improve this, next time, I can conduct the experiment earlier instead to get the data and other results to confirm the research I have already done.
* I fixed this by researching the data instead of conducting the experiment so that I could still gain a comprehensive understanding of the project.
* Another limitation that prevented me from conducting the experiment was light exposure. Although I placed the plants and positioned them near the window or in a place of high ventilation, the sun setted earlier than usual and rose later than usual. Furthermore, there were many cloudy days in between which might have contributed to the factor of the plant’s inability to grow. (Controlled Variable)
* The same. An improvement or work around I did was to research the data instead of conducting the experiment.
* The fix around for this limitation can be to conduct the experiment earlier than later to gain more light. This could be done in September, or October – December.

**Application:*** Connecting this to the bigger issue, this project helps us understand the effects of microplastics and the soil in which many people are not concerned about or know well about. This project serves as a sign or reminder allowing us to know more about the issue.
* In the future, we can continue the overall process that we started of reducing our plastic creation processes. This can allow us to mitigate the use of the plastics in the long term.
* Evidence that we are starting to mitigate the use of plastics now can be our conversion to more production of paper straws then plastic straws.
* However, in the future, I hope to actually confirm this data that I researched to be even more accurate and explicit in my research.
* In future, we may be able to find alternative uses to reduce the plastic production further to reduce essential components of our daily lives: Plants

**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, stem diameter, 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. Links:<https://pubs.acs.org/doi/abs/10.1021/acs.est.6b06155?utm_> <https://pmc.ncbi.nlm.nih.gov/articles/PMC8788448/?utm_> <https://pubs.acs.org/doi/abs/10.1021/acs.langmuir.4c02281?utm_> <https://omnexus.specialchem.com/selection-guide/polyethylene-terephthalate-pet-plastic?utm_> <https://www.britannica.com/science/polyethylene-terephthalate?utm_> |