Water Purification Using Synthetic Melanin

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Abstract

The goal of this project was to investigate the photocatalytic properties of synthetic Melanin and use it as a means to disinfect and purify water. The project started by synthesizing Melanin and analyzing its chemical properties. Then, the synthesized Melanin was used as a photocatalyst to photodegrade different added water pollutants such as p-Nitrophenol and Methylene blue. The project concluded by benchmarking the Melanin photocatalytic performance with traditional water treatment means such as using Titanium dioxide.

Executive Summary

Melanin is a natural black pigment that has different biological roles on many biological species including humans, animals, plants, and fungi. etc. Spending on the source of melanin and where it's found, it possesses different proprieties and is capable of playing different biological roles. For instance, melanin on skins, eyes, and hairs, provides first the coloring properties, which range from yellowish to. brownish to completely dark. What is more important is that melanins provide photoprotection for this organism from electromagnetic radiation, most commonly sunlight exposures. Upon direct exposure to sunlight radiation, these organisms could get severely damaged and potentially results in cancers. Over the last decades, scientists have researched natural melanin and have synthetically developed different types of melanin that possess similar proprieties. One of those melniees ypres is eumunle which is the msot type of melneine used in resrehce. Resented studies showed synthetic melanin, particularly eumelanin, possesses some facesitting proprieties such as broadband light absorption, metal ion chelating, free-radical scavenging ability, redox activity, and electronic conductivity, making it a potential photocatalytic water treatment solution. Emulenue might work as a photocatalyst where it can absorb the energy of the light photons to get excited and exceed bandgap resulting in providing redox and oxidation reactive sites capable of undergoing removal of different kinds of water pollutants including organics, dyes, and heavy metals. After extensive research, This MQP Tries to explore the synthetic melanin photocatalytic performance by synthesizing melanin first and using it as means to disinfect different added pollutants such as p-Nitrophenol and methylene blue. After that the project compares the results with traditional water treatment methods such as photocatalysis with TiO2. to achieve this goal of the project, we needed to complete the following objectives:

1. Synthesizing the melanin in a Potassium phosphate buffer(7.5ph) and characterizing its properties.
2. Synthesizing p-Nitrophenol and Methylene blue as water pollutants and characterize their properties.
3. Irradiating UV light over different samples of melanin and added pollutants
4. Measuring the photocatalytic performance of melanin
5. Synthesizing, characterizing, and measuring TiO2 photocatalytic performance
6. Comparing the photocatalytic performance of synthetic Melanin with that of the TiO2

Acknowledgements

This project would not have been possible without the invaluable help and support of professor Christopher R. Lambert. Professor Lambert was not just an advisor, but a teacher, an assistant, and a friend. He provided a great learning environment where he was constantly pushing the limits and raising the standards while being open to ideas and helping in overcoming obstacles. Therefore, I would like to extend my deepest gratitude to Professor Lambert.

I also would like to express my thanks to my colleague MacKenzie Sullivan. MacKenzie was my lab partner who was working on different but related research. She was always there to give support and encouragement when needed. Therefore, Thank you, MacKenzie.

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Chapter 1: Introduction

This chapter will discuss articles and previous research related to synthetic melanin and its applications, different water treatment techniques, and the importance of water treatment.

1.1 Melanin

1.1.1 What is Melanin?

Melanin describes a set of different types of natural pigments that are synthesized and found throughout almost all types of living organisms including humans, animals, and plants. Depending on where Melanin is found in those biological kingdoms, it possesses a variety of structures and presentations, and it plays different biological roles. The term melanin was derived from "Melanos", a Greek word that means black. Although the word indicates having balck color properties, natural melanin's color is not just black. It ranges from black and brown to yellow and red. Table1 below shows different types of melanin along with their corresponding color.

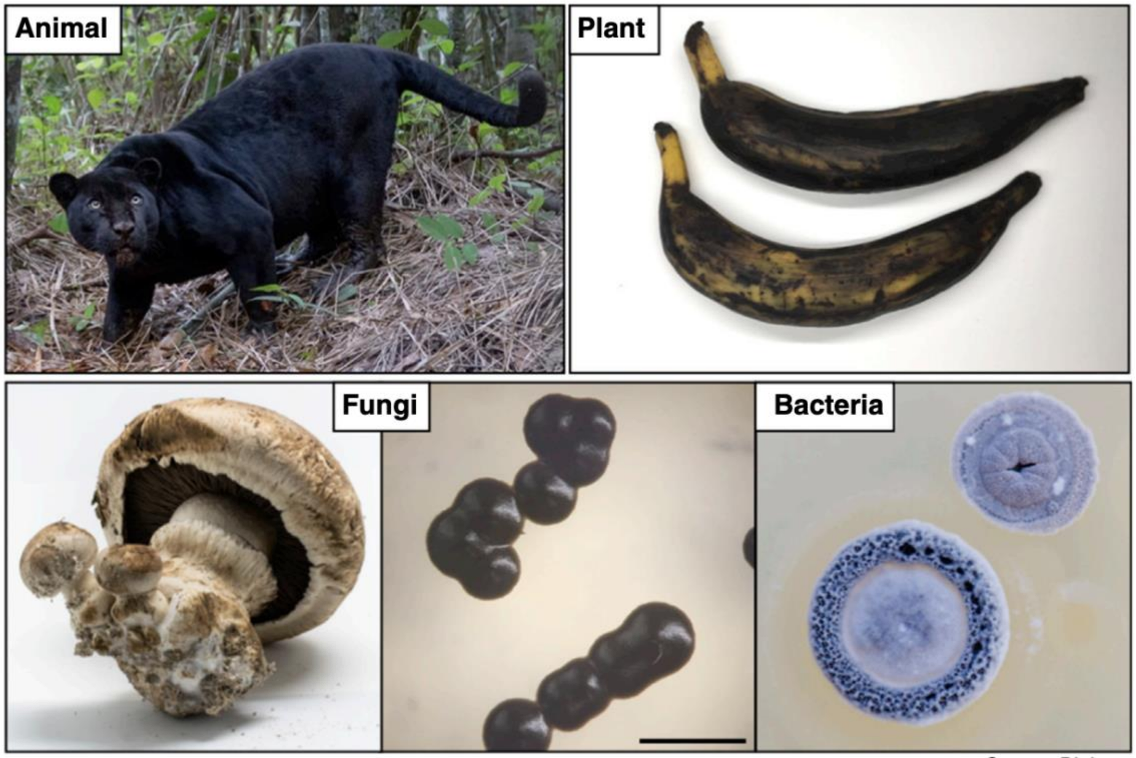
Melanin type	Color
eumelanin	brown to black
pheomelanin	reddish to yellowish
neuromelanin	dark
allomelanin	dark brown to black
pyomelanin	dark

*Table 1: Examples of different types of Melanin and their color(*Xie *et al., 2019)*

Typically, Melanin are classified based on its source like human, animal, fungi.etc, or based on its chemical and physical properties such as eumelanin, pheomelanin, neuromelanin, allomelanin, or pyomelanin. Eumelanin and pheomelanin are generally classified as animal pigments while the others correspond to a wide variety of dark non-nitrogenous pigments of plant,fungal, and bacterial origin(Schmaler et al., 2009). Figure1 below shows some examples of different sources of melanin. For example, the black fur of the jaguar is made out of Melanin. Also, the color transformation of a plantain from yellow to black is an example of melanin. This oxidation reaction is catalyzed by phenoloxidase enzymes. Giving the plantain a black color.(*Cordero et al., 2020)*.

Figure 1: Examples of different sources of Melanin(Cordero et al., 2020)

In the human body, Melanin exists in three forms; Eumelanin, Pheomelanin, and Neuromelanin. These types of Melanin are mainly responsible for pigmentation skin and hair color and providing photoprotection for the body. Melanin, particularly Neuromelanin, is also found in the brain as an antioxidant to protect the brains' biomembranes from lipid peroxidation, a cell-damaging process(Haining. Et al, 2017).



Even though Melanin has different classes, they all still possess similar characteristics including resistance to acids, broadband optical absorption, insolubility many solvents, and the presence of a stable free-radical population. The broadband absorption is what gives natural melanin such as eumelanin and allomelanin their range of black to brown color. Unlike other natural pigments Melanin can absorb visible light and reflects almost nothing giving it the dark appearance. Some even argue that Melanin has an even darker color since it also absorb ultraviolet and infrared light. Research showed that natural melanin is polymerized from phenolic and/or indolic compounds resulting in a negatively charged and hydrophobic pigment that has a high molecular weight(White, 1958). Even though melanin is known to be synthesized through a polymerization reaction of phenolic and indolic compounds, the exact structure of melanin remains unknown. Upon polymerization, those compounds form a planer sheet structure that is similar to graphite. It also has a very small particle size tahtat reaches to nanometer scale. The resulting structure is resistant to acid hydrolysis. Meanwhile, the melanin is degradable by alkaline conditions or oxidative chemicals such as hydrogen peroxide(Cordero et al., 2020).

1.1.2 Melanin Applications

Overall, the past decade has seen a significant increase in melanin scientific research shining the light for advancements in industries like biomedicine, nanotechnology, energy conversion and storage, photothermal therapy, and water treatment. Scientists have dedicated a lot of effort trying to learn the biofunctional roles of melanin and develop application out of it to help humanity. One common application of melanin, specifically natural eumelanin, is to provide photoprotection from sunlight to eyes and skin. This capability is widely recognized in many living species including humans and animals. Sunlight contains a wide range of electromagnetic spectrum including UV light causing upon exposure to direct skin many damages including potential skin cancer. It is not just sunlight that causes damage to skin, but also other electromagnetic radiation that is able to cause similar damages to the skin's epidermal cells upon exposure. Melanin or melanin in this case works as a photoprotective pigment that can absorb the light energy and change it to heat. It also can scavenge reactive radicals in the skin to provide protection from oxidative damage(Solano F., 2020).

Figure2 below shows the sunlight and its different radiation that has biolgoet effects when it reaches the skin. UV light, which represents 10% of the energy coming off the sun. The accumulated chemical contaminations on the atmosphere has caused this light compostation to change slightly, resulting in breaking down this UV radiation into three; subcategories; UVA, UVB, and UVC. UVA has the longest wavelength which goes from 320-380nm. UVB has a wavelagne ragne of 280- 320nm. Lastly, UVC has the shortest wavelength that goes from 180-280nm. This means that UVC has the highest energy among those UV light subcategorized, meaning it causes the most damage to the skins as well. Fortunately, UVC radiation does not pass through the stratosphere stage because the ozone layer effectively filter the harmful impacts of this raddations. UVA and and the most energetic region of the visible light, also known as blue light, have the penetration to skin and are actual threats for the skin(Solano F., 2020).

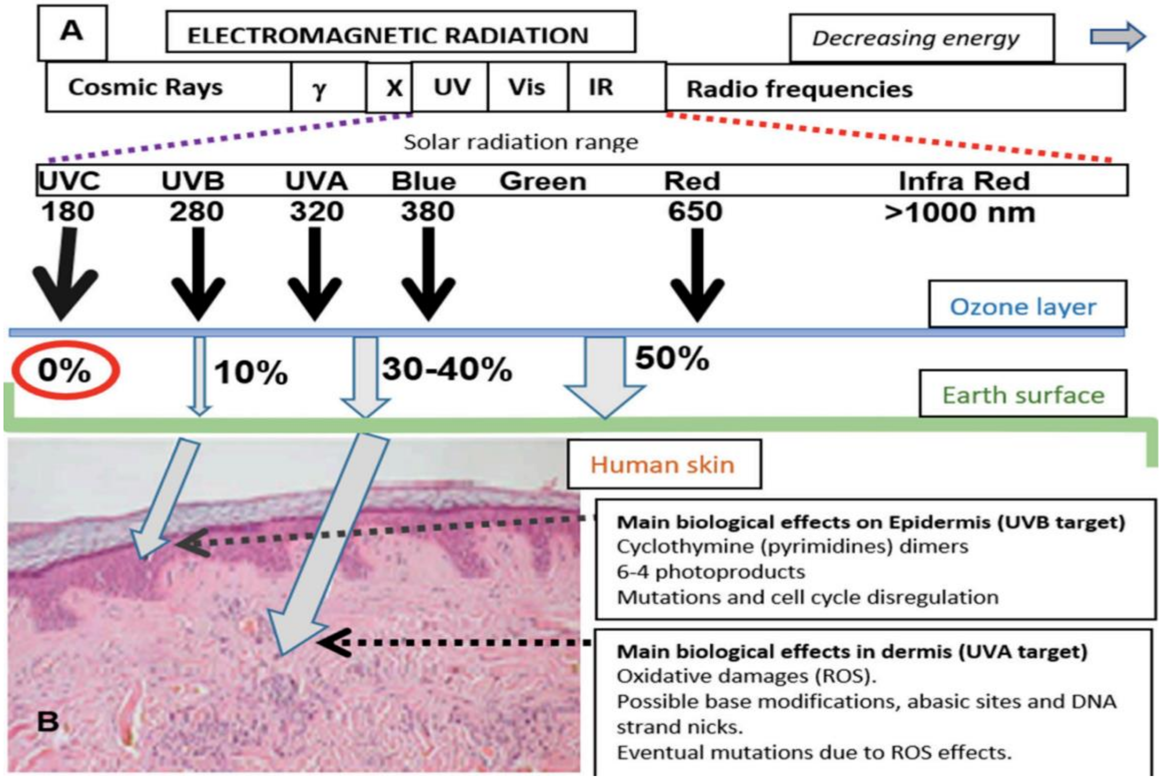


*Figure 2: solar range of radiation along with its approximate skin pentracne% (*Solano F., 2020)

Melanin in plants has different biological functions and applications. Unlike providing photoprotection from light radiation, plants apply melanin to cell wall strengthening functions. In particular, plants undergo sclerotization reactions utilizing polyphenol oxidases(PPO) from plant vesicles to oxides upon the presence of oxygen to produce very reactive quinones. This quinone then reacts with a nucleophilic group and gives a melanoprotein (D'Ischia et al., 2015). The produced melanoprotein works as blackening and hardening at an injury site in plants in a process known as “enzyme browning " or “ browning process”. Figure3 below shows a simplified pathway of this reaction.

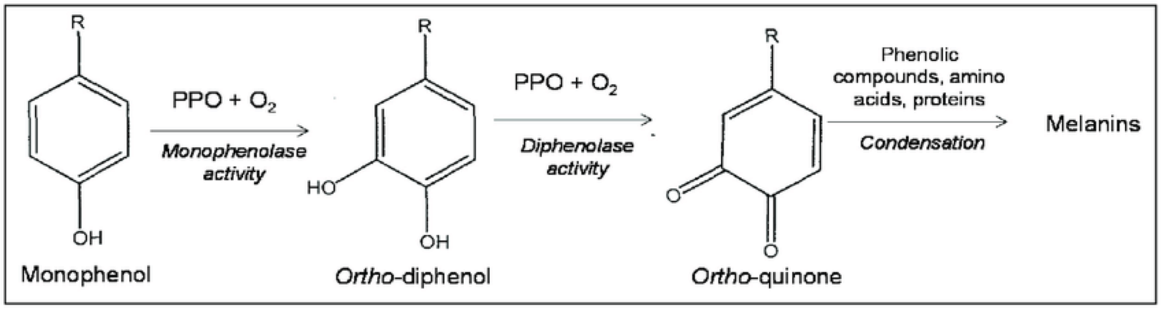


*Figure 3: Simplified schematization of browning process(*Taranto et al., 2015*)*

1.1.3 Potential Water Treatment Application

Recent studies on synthetic Melanin confirmed that it possesses functional capabilities such as broadband light absorption, metal ion chelating, free-radical scavenging ability, redox activity, and electronic conductivity, making it a potential photocatalytic water treatment solution. One of these studies was Xie *et al*,. journal on natural eumelanin, which is the most studied type of melanin. Figure 4 below shows a the structure of emulanin and its emerging applications.

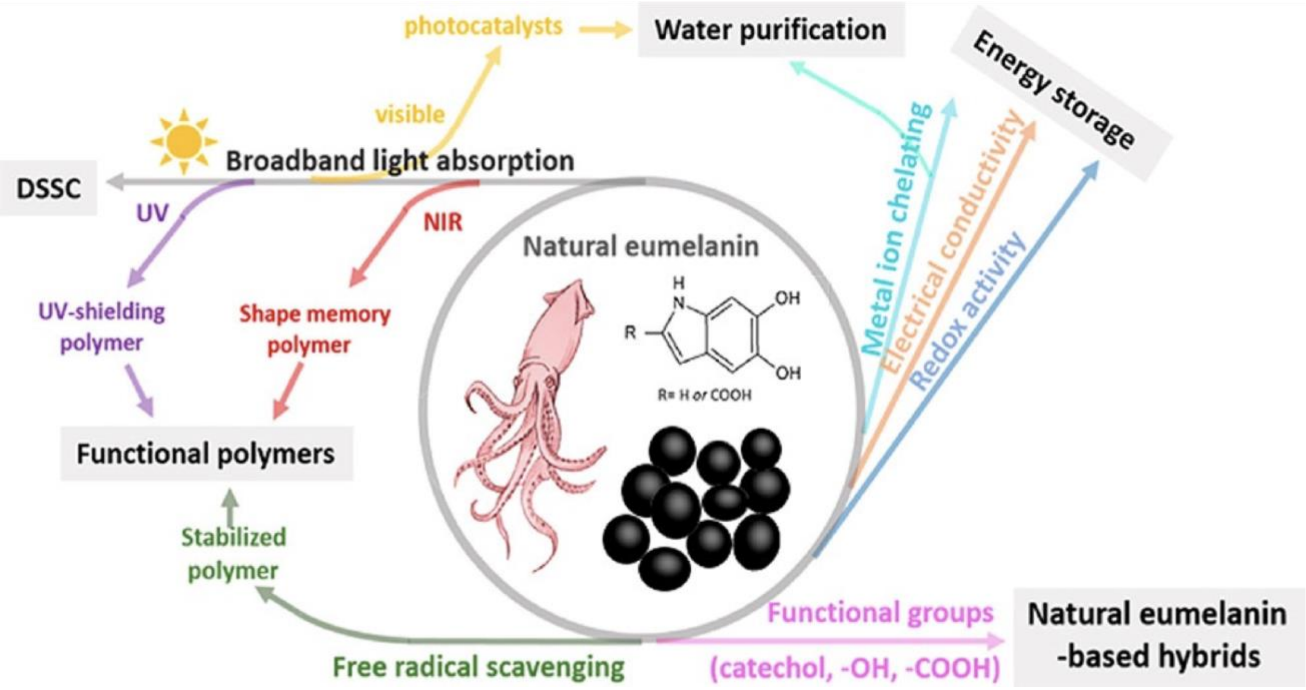


*Figure 4: Natural eumelanin emerging applications(*Xie *et al., 2019)*

Research has been done on using melanin to selectively remove Mg2+ ions from aqueous solutions through a redox reaction. Park et al., have synthesized melanin films and oxidatively polymerized it on stainless steel to create electrochemical membranes using dopamine precursors. The results of the study showed that redox-active polydopamine membranes are able to separate Mg2+ and Li+ ions in an aqueous solution efficiently(Park et al., 2016).

In addition to that, Nguyen's research on the use of melanin to remove heavy metals from drinking water showed how effective melanin is in this context. They have particularly used melanin for the treatment of chromium(Cr6+) and manganese(Mn2+) through adsorption. They intentionally used those heavy metals in high concentrations since usually those metals are present in drinking water due to mining and other water pollution incidents. The results showed that melanin is able to effectively eliminate more than 95% of those metals using melanin as an adsorption application (Nguyen et al., 2016).

1.2 Photocatalysis

Photocatalysis or a photocatalytic reaction happens when the incident light energy is larger than the semiconductor bandgap. Semiconductors are known to have a conduction band that is separated from the valence band or excited state by a bandgap. This bandgap varies from material to material, which is an important factor in determining the light absorbance and the photocatalytic capability of the semiconductor. Recent studies argue that melanin has semiconducting properties that make it a potential great photocatalyst application for water treatment. Upon absorbing the photon energy of the incident light on the semiconductor, the semiconducting materials get excited generating electrons and holes capable of undergoing oxidation and reduction processes. Those photogenerated reactive sites can degrade different water pollutants including organics and heavy metals. Figure 5 below shows a simple scheme of the photocatalysis process(Zhang et al, 2016).

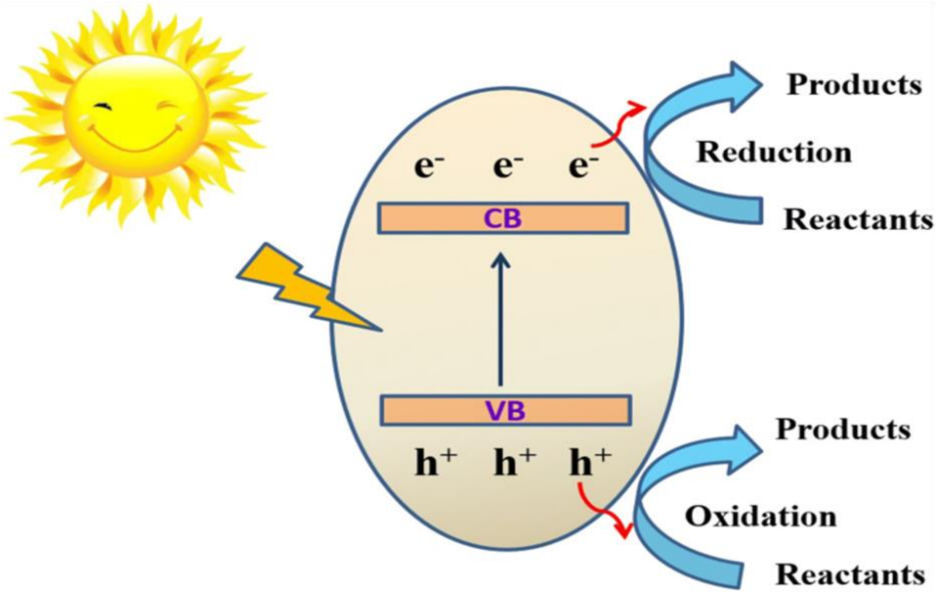


*Figure 5: Simple scheme illustrating the photocatalytic reaction(*He *et al., 2019)*

1.2.1 TiO2 As a Photocatalyst

TiO2 photocatalytic applications are known to be the most common method used for photocatalytic water treatment. This was due to its affordable cost and relative stability. However, TiO has a wide bandgap of 3.2eV resulting in a limited activation region. This means that TiO2 photocatalysis reactions only proceed when the incident light is of the UV region. As mentioned earlier the sunlight radiate about 5% of the light in the UV region whereas about half of the light is visible and NIR light. This has encouraged scientists to develop TiO2-based photocatalysts capable of undergoing the photocatalysis process off of the incident visible light source. The traditional way of doing this is combining TiO2 with dye sensitizers. The dye sensitizer absorbs light photons and produces the electrons, which then get injected into the conduction band of TiO2. This kicks off the photocall reduction process to degrade the different pollutants. The main issues of this technical application are that dye sensitizers usually more expensive and chemically unstable.

Chapter 2: Methodology

The goal of this project was to investigate the photocatalytic properties of synthetic Melanin and use it to disinfect and purify water. After synthesizing the mean, it was used to photodegrade different added water pollutants such as p-Nitrophenol and Methylene blue. The Melanin measured photocatalytic performance was compared with the Titanium Dioxide photocatalytic performance. We achieved our goal by completing the following objectives:

7. Synthesizing the melanin in a Potassium phosphate buffer(7.5ph) and characterizing its properties.
8. Synthesizing p-Nitrophenol and Methylene blue as water pollutants and characterize their properties.
9. Irradiating UV light over different samples of melanin and added pollutants
10. Measuring the photocatalytic performance of melanin
11. Synthesizing, characterizing, and measuring TiO2 photocatalytic performance
12. Comparing the photocatalytic performance of synthetic Melanin with that of the TiO2

2.1 Synthesizing the Melanin

As stated above, eumelanin is a type of melanin that is most popular in research and has similar properties and behavior of natural melanin. The proposed methodology for something that melanin is to use Levodopa, L-DOPA, (3,4-dihydroxyphenylalanine,) as a starting material in generating eumelanin. L-DOPA undergoes spontaneous tyrosinase-mediate oxidation and eventually transforms into eumelanin. To Proceed with this reaction, a Potassium phosphate buffer(7.5ph) was proposed as a solvent to initiate the reaction. Below is figure 6 to show a proposed mechanism that L-DOPA undergoes to yield melanin. To ensure that the eumelanin was synthesized, different tests will be taken to ensure that the reaction has happened and the resulting central is melanin. The first sign is to see a color change from transparent to brown- dark color. In addition to that, a set of UV-Vis spectrometer measures will be taken to compare the resulting spectra to that of the known spectra of melanin, which should have a peak at 290 nm.

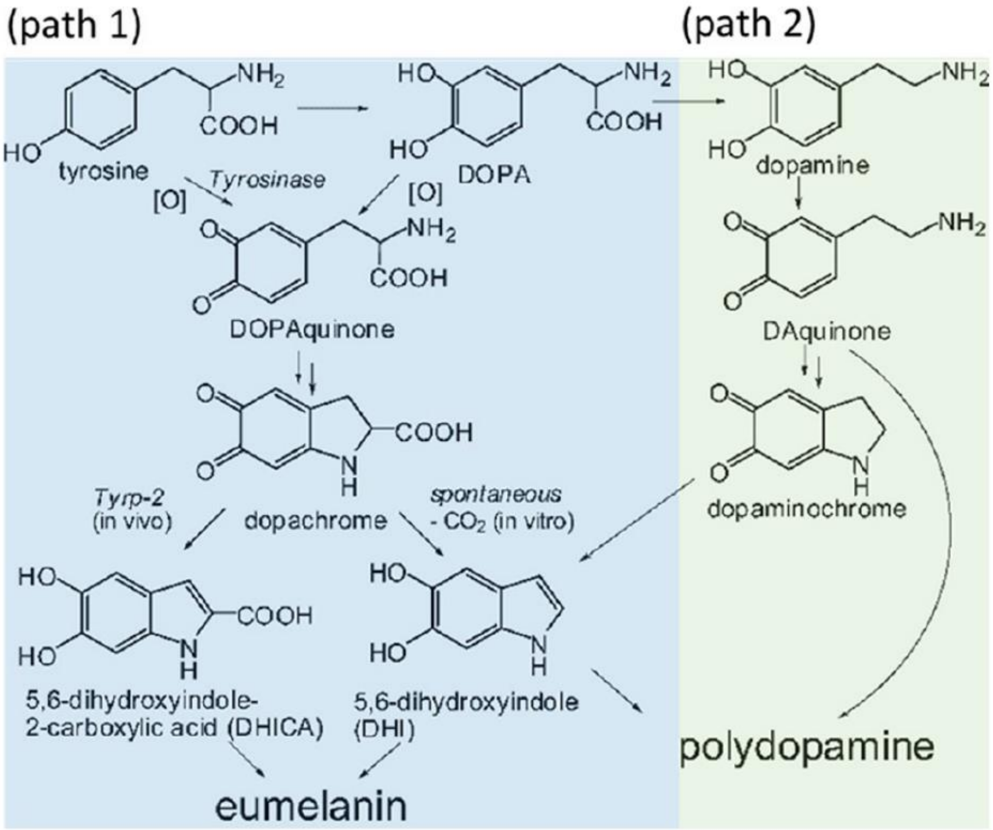


Figure 6: Biosynthetic pathway for melanin(Xie et al., 2019)

2.2 Synthesizing p-Nitrophenol and Methylene Blue

A part of this project was to synthesize different kinds of pollutants in order to use in experimenting with the photocatalytic performance of Melanin in degrading them. p-Nitrophenol was used as an organic waste due to its ease of making as well as ease of characterizing. p-Nitorphenol should have a yellowish color and an absorbance peak around 320nm. In addition to that methylene Blue was synthesized as well as a dye pollutant. Methylene Blue should have two peaks; one around 290 nm and a higher one near 660nm.

2.3 UV light Irradiation

For this project, the irradiating methodology that has been chosen to follow throughout the experimentation was UV lamps. UV lamps are devices that generate electromagnetic radiation in the UV light region. Specifically, we have used the smalled the small size that is commonly used in the lab for Thin-layer chromatography or TLC experimenting.

2.4 Measuring Melanin Photocatalytic Performance

The methodology intended to be used in this project to measure the photocatalytic performance of melanin was a UV-Vis spectrometer. UV-vis spectroscopy is a quantitative analytical technique that is used to study how matters interact with or emit electromagnetic radiation in this case in UV and visible regions. It measures the intensity of light that passes through a sample compared to the intensity of light that goes through a reference sample, also known as a blank. As a result, it is a relatively simple but efficient way to determine if there is a reduction in the absorbance of light intensity. In this research, we can use it to see if there is a reduction of the water pollutants' contraction after being irradiated with a UV light source. Below is figure 7 illustrating a simple scheme of how UV-VIS spectroscopy work.

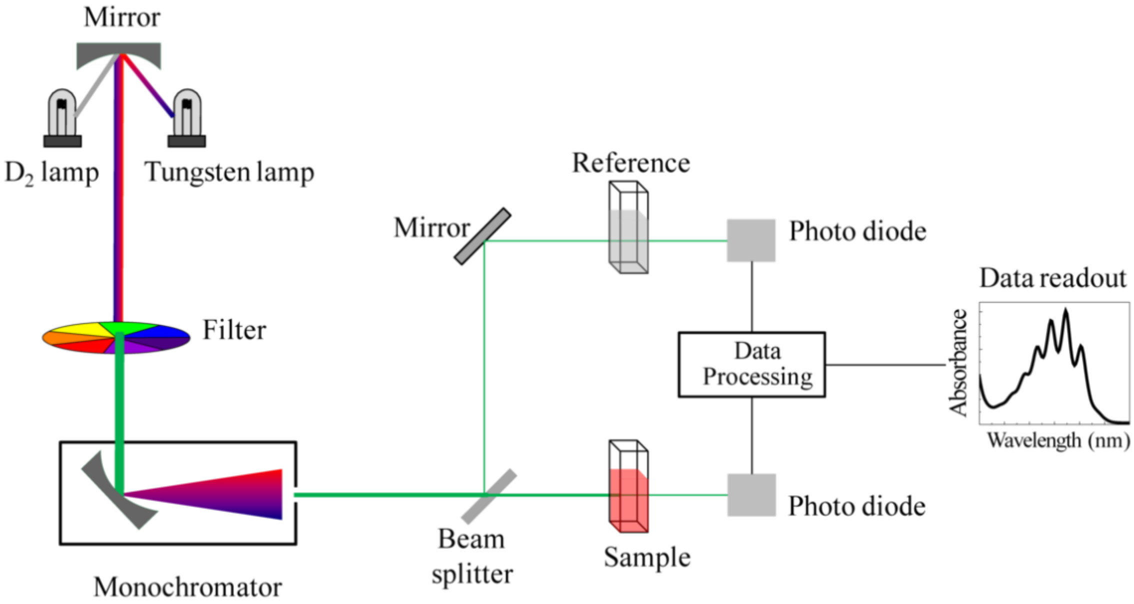


Figure 7: Schematic diagram illustrating UV-Vis spectrometer(Wikimedia Commons, n.d.)

2.5 Comparing Melanin and TiO2 Photocatalytic Performance

Similar to the Melanin measured photocatalytic performance, TiO2 will be used as a photocatalyst and a controlled sample in order to see how they performance differ while having similar conditions or circumstances. TiO2 is simple to produce from Titanium tetrachloride(TiCl4) or commonly known as Tickle. A simple hydrolysis reaction with water will produce TiO2 pigments, but the process gives off a harmful chloride smoke making this process hazardous if inhaled.

Chapter 3: Results and discussion

In this section we will present the results, interpret them, and bring some points into the discussion.

3.1 Synthesizing Eumelanin

Melanin or eumelanin was synthesized on a Potassium phosphate buffer to make the reaction initiate and reach equilibrium faster. A palet of Potassium Hydroxide,(KOH, 56g/mol) was added to 0.385g of Dipotassium phosphate(K2HPO4, 174g/mol) in 2L deionized water to make 1mM Potassium phosphate buffer(7.5Ph). This was used to make the L-dopa stock solution. Therefore, 1.97g of l-3,4-dihydroxyphenylalanine, L-DOPA(C9H11NO4, 197g/mol) was dissolved in the prepared buffer to make a 5mM L-DOPA solution. It was left in the open air and was constantly being stirred to make the eumelanin. The solution started to change color to brownish after 2 days and on the fifth day was completely dark. Uv-Vis spectrum was taken regularly to ensure the solution has reached equilibrium and eumelanin was completely formed. Below is figure 8 showing the melanin measured spectrum at a contraction of 5mM. It was used as a stock to make different samples of melanin systems to measure photocatlyic performance.

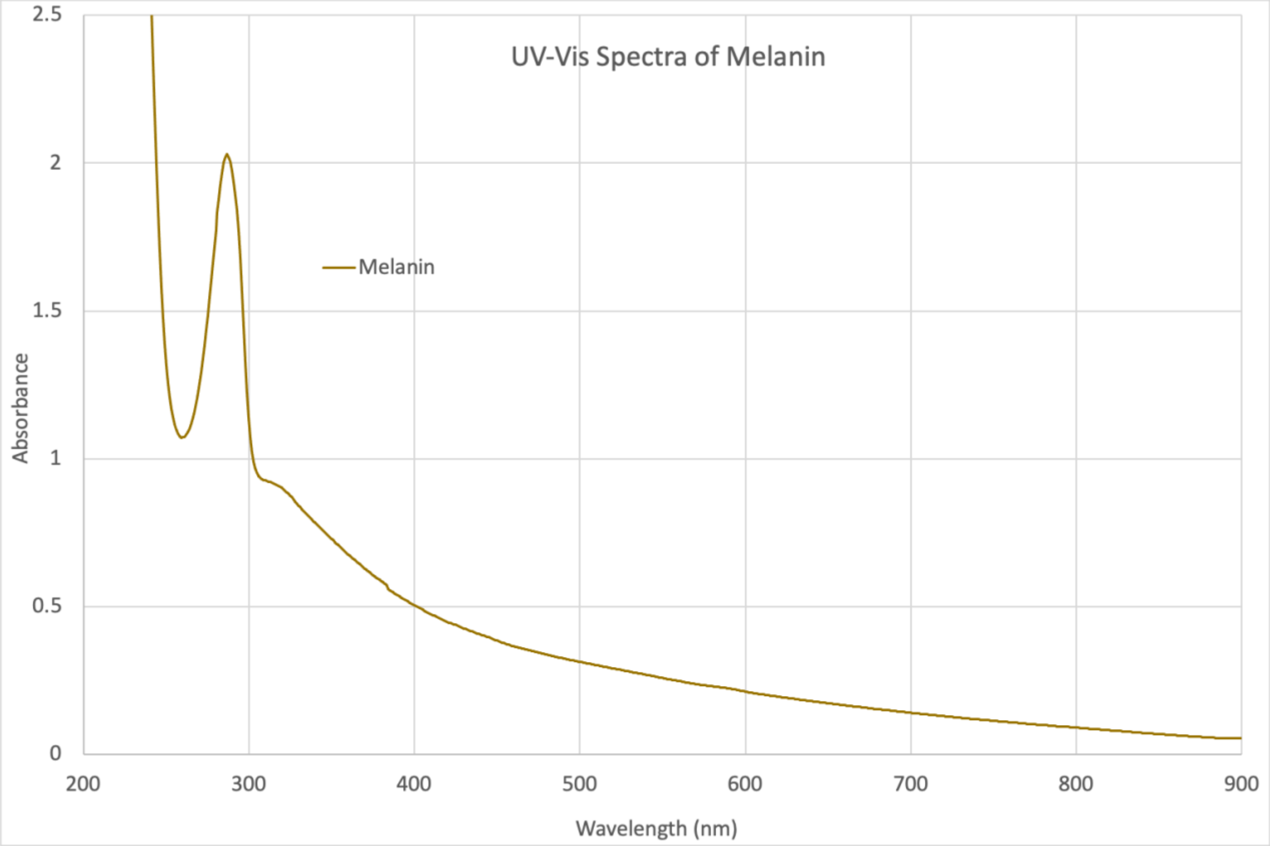


Figure 8: UV-Vis spectrum of Melanin

3.2 Synthesizing the water pollutants

As stated earlier two kinds of water pollutants were made in order to use in measuring melanin photolytic performance. They are p-Nitrophenol and Methylene Blue and below we will talk about how we made them and the measured vis spectrum of each.

3.2.1 p-Nitrophenol

p-Nitrophenol was fairly easy to make. 7mg of p-Nitrophenol($C_6H_5NO_3$, 139g/mol) with 99% purity was dissolved in 50ml of Potassium phosphate buffer(ph7.5) similar to the one made above. This resulted in 4mM that was stirred for about 1hour before measuring its UV-vis spectrum. The solution immediately turned yellowish. A picture to the right shows the p-Nitrophenol that was used. The solution was used as a stock solution and different simples of p-Nitrophenol were made to different samples of melanin and used as water organic pollutant figure9 below shows the UV-Vis spectrum of a p-Nitrophenol sample with 4mM concentration.

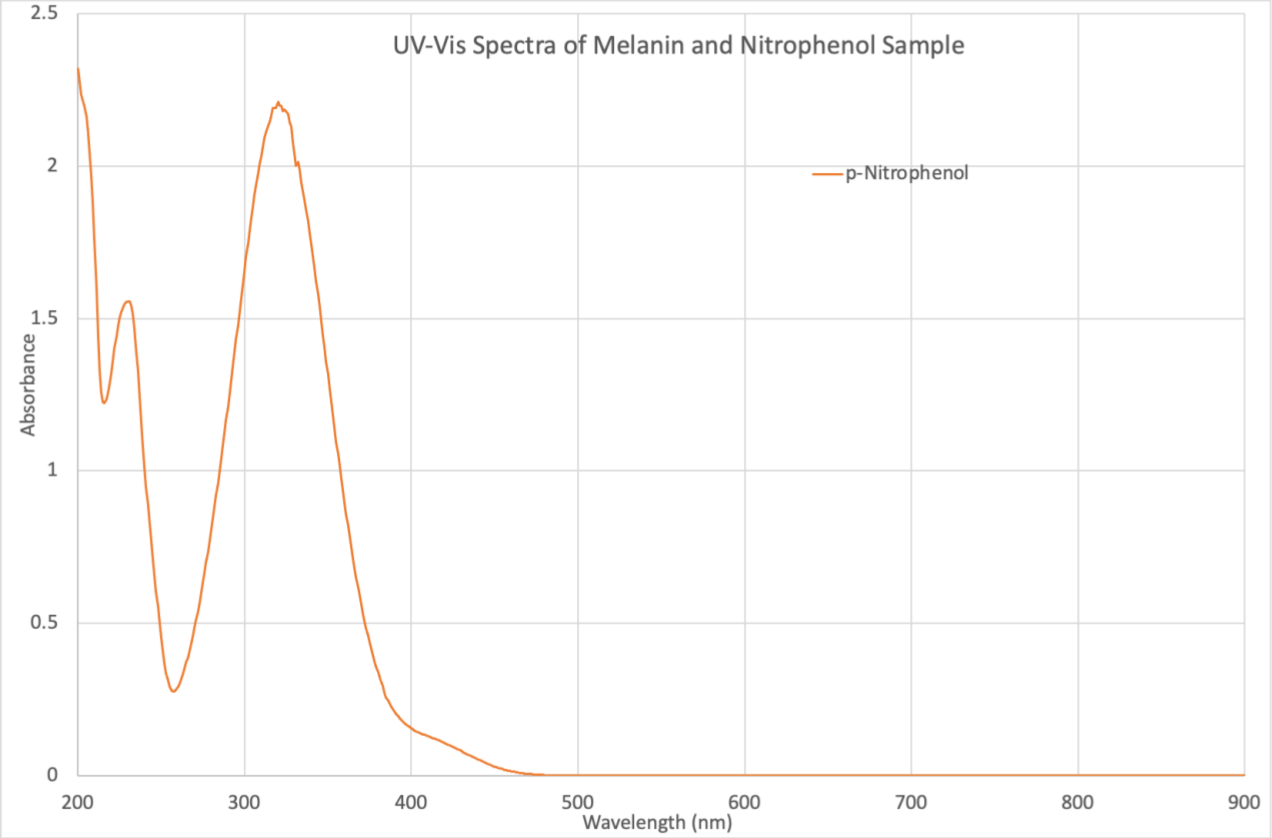
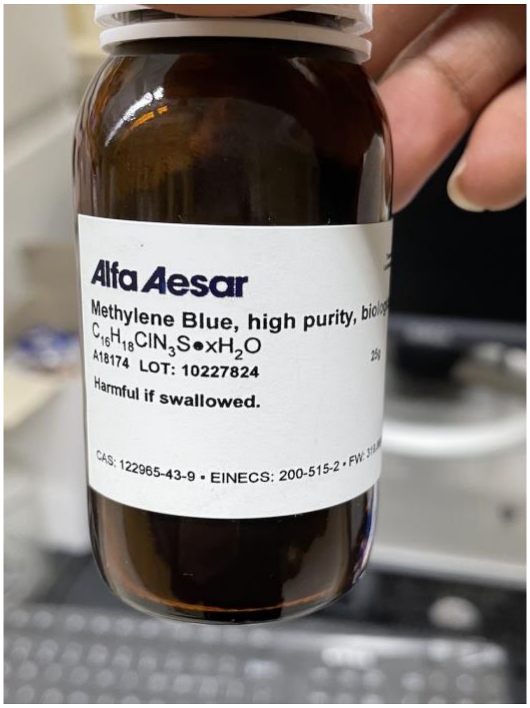


Figure 9: UV-Vis spectrum of p-Nitrophenol

3.2.2 Methylene Blue



Likewise Methylene Blue(C16H18ClN3S, 319g/mol) was made by dissolving 0.08g of high purity Methylene Blue purchased from Alfa Aesar in 250ml of DI water. The picture to the right shows the product. The solution was stirred for about 30mins and then UV-vis spectrum was taken. Similar to the p-Nitrophenol, this Methylene Blue solution was used as a stock to make a different sample of water pollutants for experimenting with the photocatalytic performance of synthetic melanin. Below is figure 10 showing the UV-Vis of Methylene Blue at a concentration of 0.03mM.

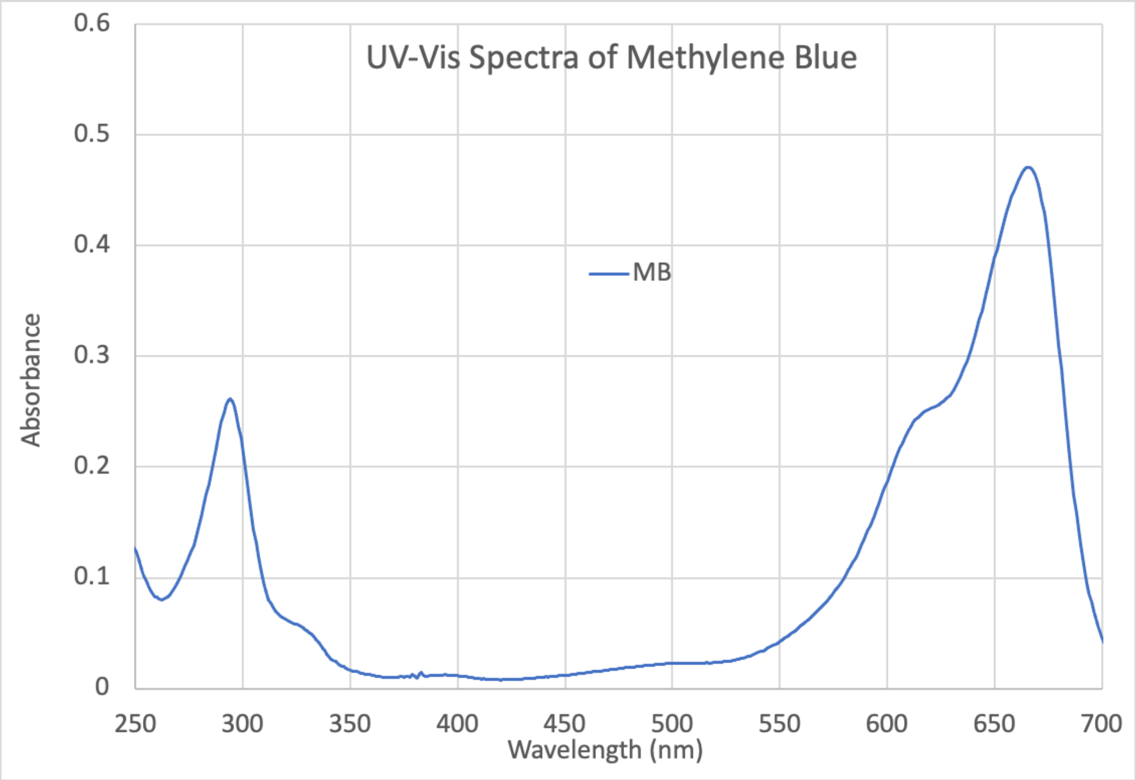


Figure 10: UV-Vis spectrum of Methylene Blue

3.3 Measuring Melanin Photocatalytic Performance

3.3.1 p-Nitrophenol

The results Suggested that the photocatalytic performance of a pure synthetic Melanin in degrading Nitrophenol was very weak. A range of different Nitrophenol pollutant concentrations(0.01-0.1mM), short and long wave 6w UV light, different vials sizes(1,2,4 drams), and different stirring speeds (50-400rpm) were used in experimenting. The only trial that led to 2.69% degradation after 2 hours was the 4mM Melanin and 0.04mM Nitrophenol system that was irradiated by a 6W shortwave UV light in a 4-dram vial and 200rmp constant stirring speed. Below is figure 11 showing the UV-vis spectra of melanin and p-Nitrophenol.

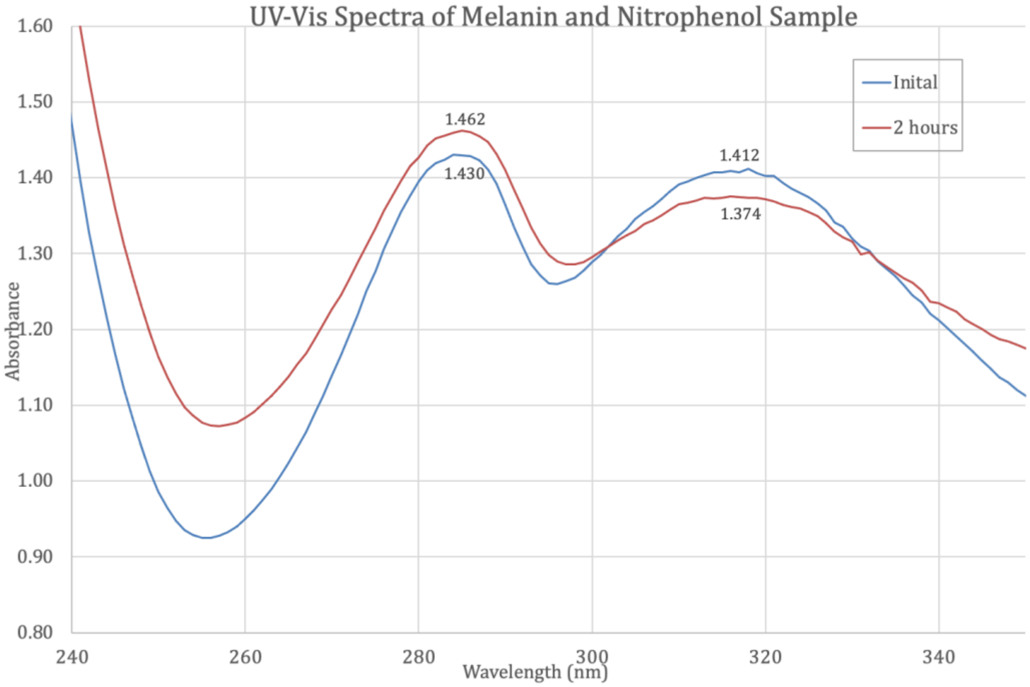


Figure 11: UV-Vis spectrum of melanin p-Nitrophenol sample

3.3.2 Methylene Blue

Melanin was weak in degrading Methylene blue as well, yet better than that of the Nitrophenol. 8.24% degradation was obtained after 1-hour irradiation. The system had 0.5mM Melanin and 100nM Methylene blue in a 4dram vial and was irradiated by a 6w shortwave UV light and constantly stirred at 200rmp. Below is figure 11 showing the UV-vis spectra of melanin and p-Nitrophenol. Below is figure 12 of UV-vis spectra of melanin and Methylene Blue sample.

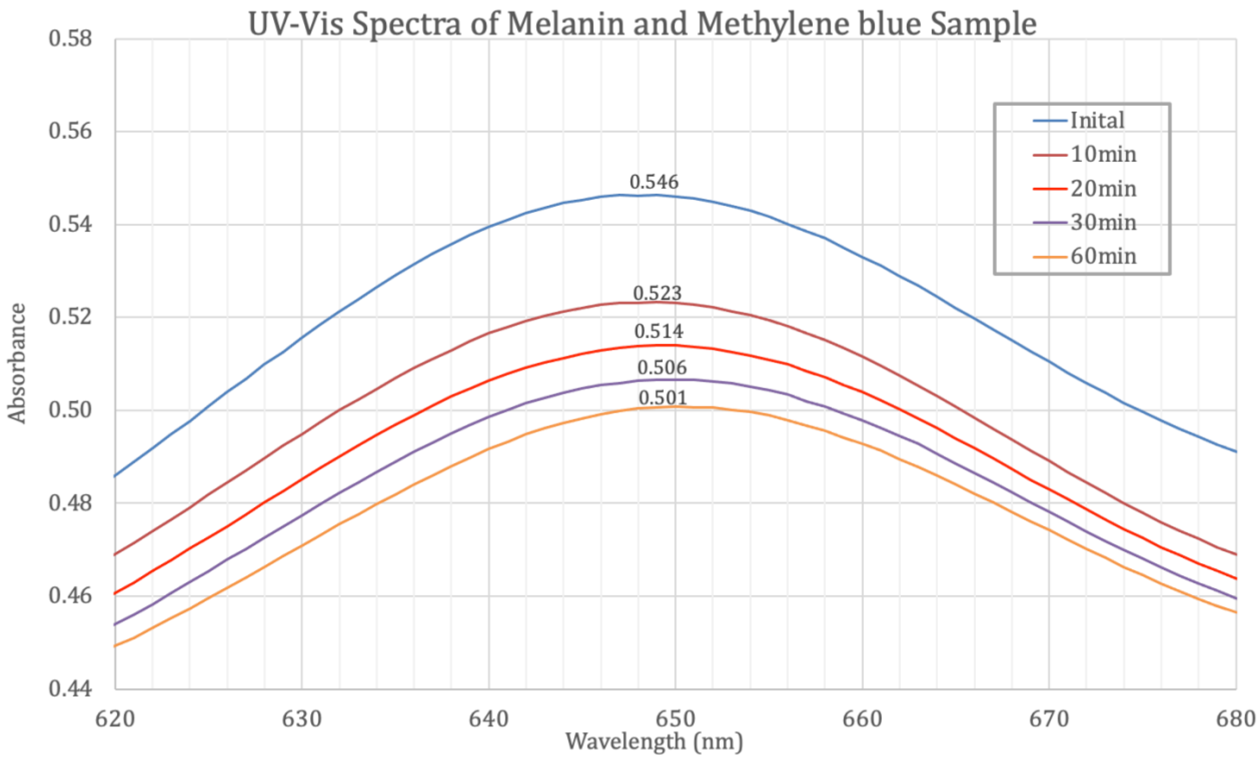


Figure 12: UV-Vis spectrum of melanin Methylene Blue sample

3.3.3 Short and Longwave UV light

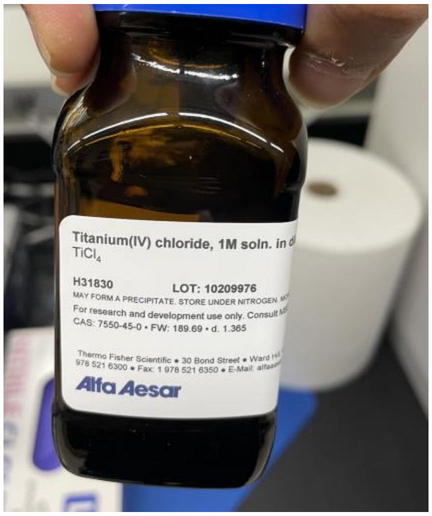
One test that we did in this research was to measure the photocatalytic performance of melanin utilizing different kinds of UV light sources with short and long wavelengths. Two samples of 0.04mM Nitrophenol were used in a suspended system of melanin photocatalysis that is 4mM constructed. The UV lamp that was used was a 6w lamb purchased from Entela. Both samples were irradiated in sampler condensation expense the difference of the UV source wavelength. The UV-vis spectrum was taken at 30mins intervals for 2 hours. The results show that the ShortWave sample had a better photocatalytic performance with 2.37% degradation after 2hourse. Whereas the longwave sample did not show any degradation. Below is table2 showing the data for both samples.

Melanin(4mM) suspended system with Nitrophenol(0.04mM) pollutants			
ShortWave UV Light		LongWave UV Light	
Time(minutres)	Degradation(%)	Time(minutres)	Degradation(%)
30	0	30	0
60	0	60	0
90	1.36%	90	0
120	2.37%	120	0

Table 2: Results for Short and Longwave experiment.

3.4 Measuring TiO2 Photocatalytic Performance

Now that We have measured the photocatalytic performance of synthetic melanin in degrading different water pollutants, we wanted to compare these results with traditional known methods. Therefore, we diced to use TiO2. To make TiO2, we have added 50ul of 1M concentrated TiCl4 purchased from Alfa Aesar to 50ml Di water. The picture to the right shows the purchased starting TiCl4 materials. Using the fume to run this experiment was crucial as a safety measure to avoid inhaling the harmful gas coming off from the reaction. This has resulted in a 0.1M TiO2 solution that was used as stock for the remaining experiments for the photocatalytic performance.



3.4.1 p-Nitrophenol

Very similar setups and controlling factors were used to measure the photocatalytic performance of TiO2 so that we can compare it with that of the melanin and determine how efficient melanin is. It was very important to use a similar setup so that the results remain consistent among the different photocatalysts and that there would not be bias in the photocatalytic performance due to using different setups. The results show that TiO2 photocatalytic performance in degrading p-Nitrophenol was a lot better than that of the synthetic melanin. A 0.1mM TiO2 and 0.04mM Nitrophenol in 4 drum vial degradation. The sample was irradiated by a 6W shortwave UV light and at a 200rmp stirring speed. The trial ran for 1 hour with great results the p-Nitrophenol was degraded by 17.4% after 30mins and 31.5% after 1hour. Below is figure 13 showing the UV-Vis spectra of the TiO2 and p-Nitrophenol samples.

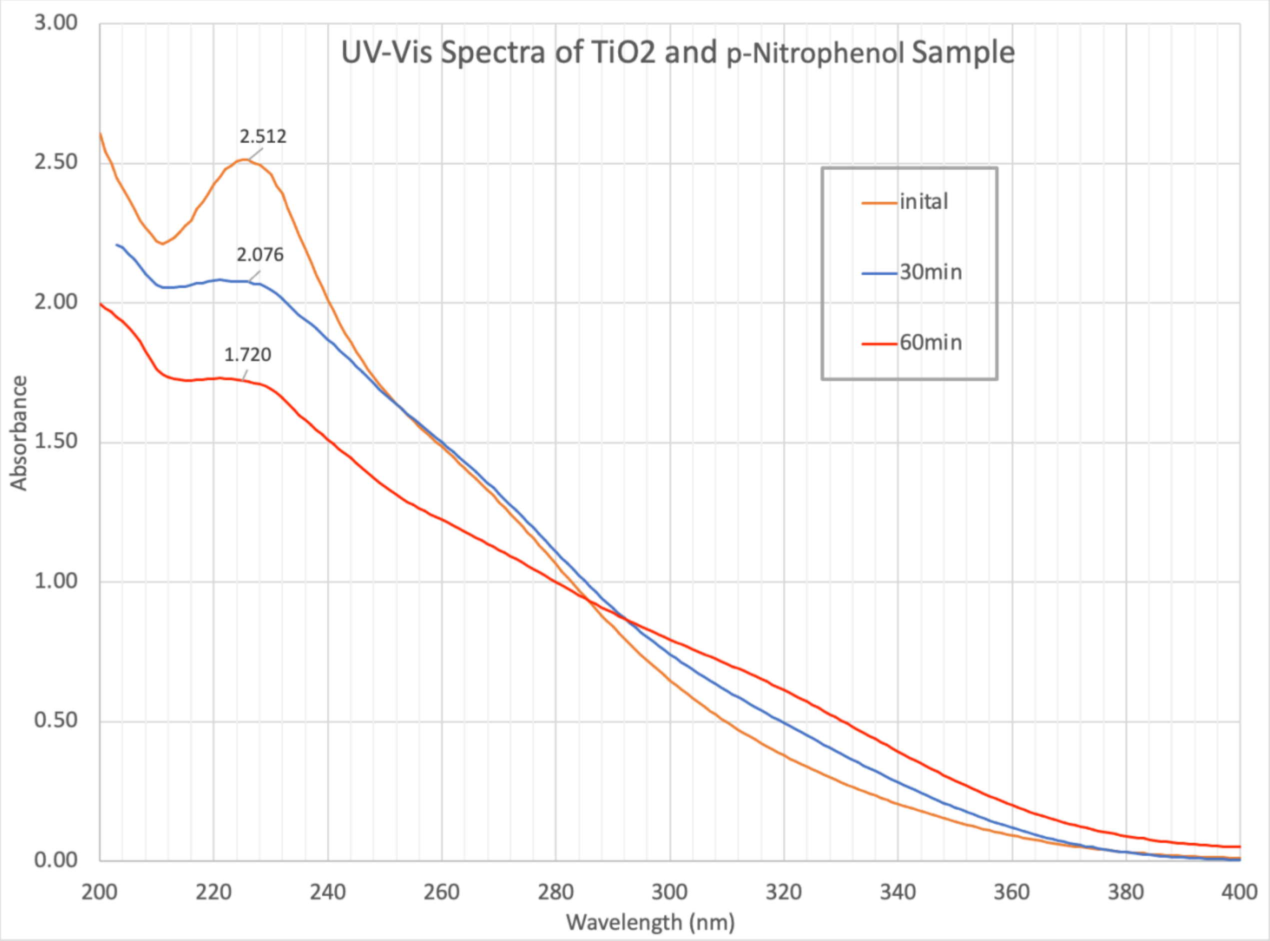
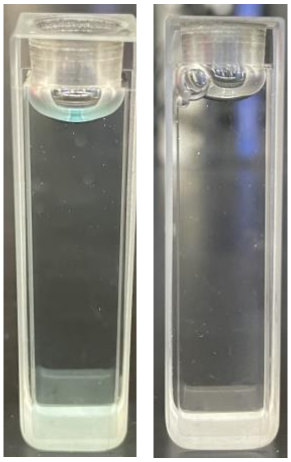


Figure 13: UV-Vis spectrum of TiO2 and p-Nitrophenol sample

3.4.2 Methylene Blue

. Similar to the degradation of p-Nitrophenol, TiO2 showed even greater photocatalytic results in degrading Methylene Blue. A 0.1mM TiO2 and 100nM Methylene Blue sample in 4 drum vials were used for the degradation. The sample was irradiated by a 6W shortwave UV light and at a 200rmp stirring speed. The trial ran for 1 hour with outstanding degradation results. Methylene Blue was degraded by 169.7% after 30mins only. After 1 hour, Methylene Blue was degraded by about 97.4% marking an outstanding performance. The picture to the right shows the sample initially and after one hour of irradiation. We can see a clear change of color. Below is figure 14 showing the UV-Vis spectra of the TiO2 and Methylene Blue samples.



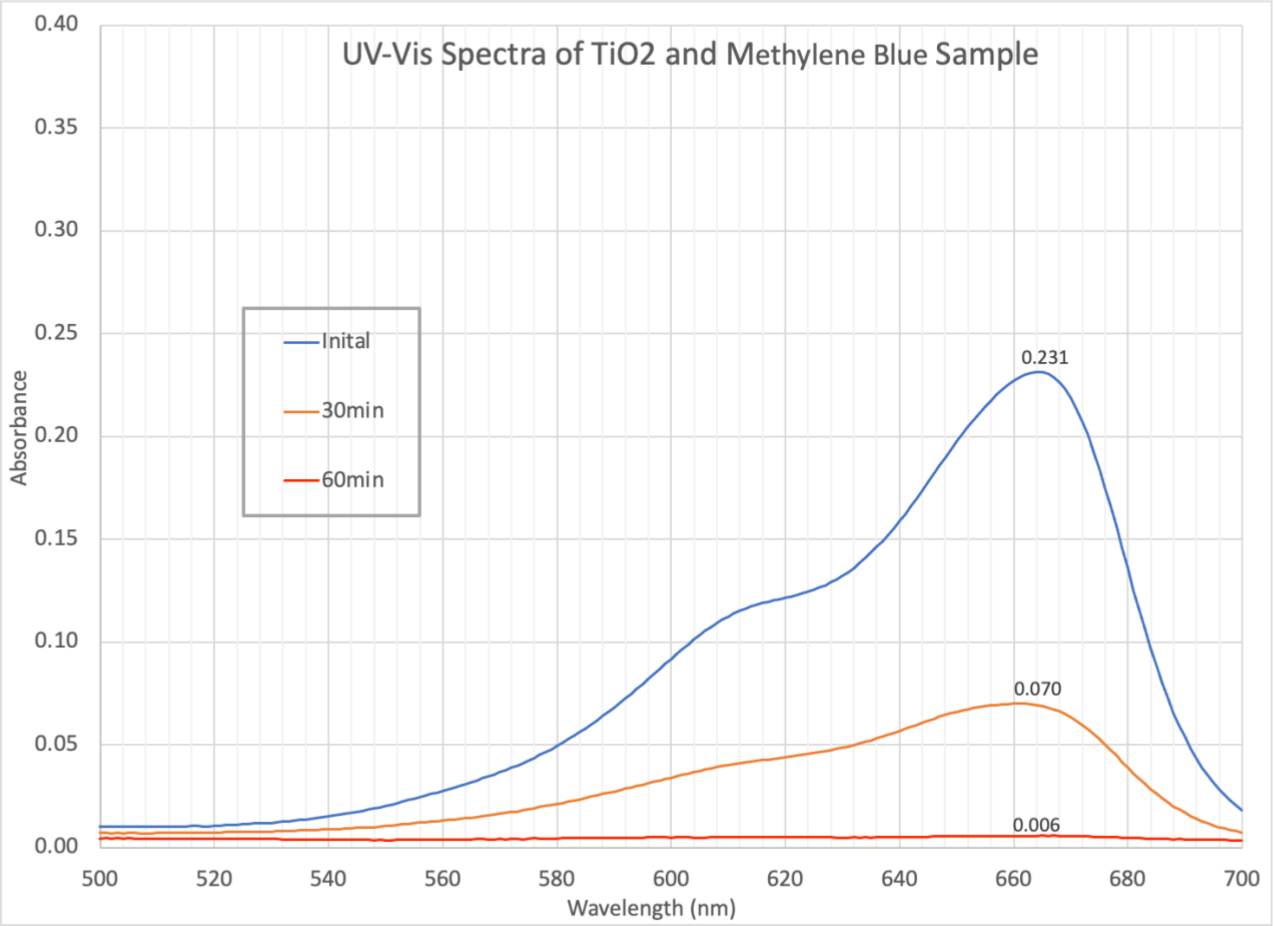


Figure 14: UV-Vis spectra of the TiO2 and Methylene Blue samples.

Chapter 4: Challenges and Recommendations

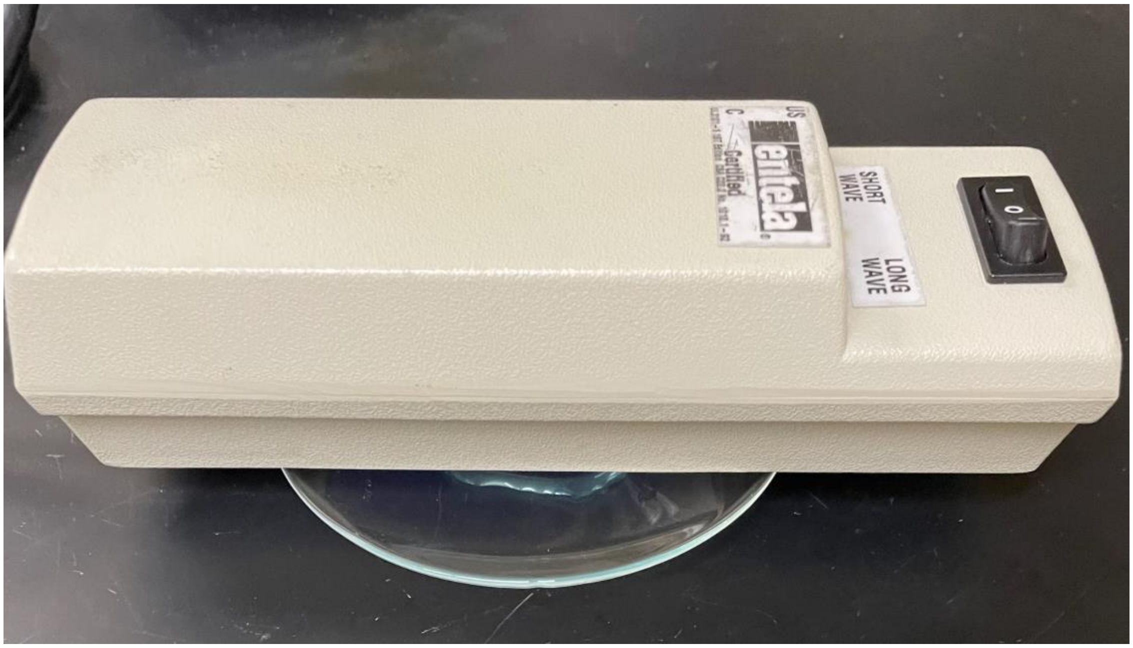
Upon completion of this project, We were able to explore the photocatalytic performance of melanin and compare it to that of traditional photocatalysts specifically TiO2 application. In this chapter, we will go through the learning journey in this project to discuss the challenges that we have faced throughout this project. We will also provide some recommendations to aid in the expansion and improvement of this project.

4.1 Powerful light source

During the photocatalytic performance measurements, we have recognized that our light source was not as strong as it should be on for commonly known ways to perform photocatalysis. In most studies, they utilize a UV light source that has a minimum of 200w light source. Wheres, in our study the light source was about 6w only. Therefore the degradation was most likely negatively influenced compared to other studies. However, the same light source was used for different samples and was also used for the Tio2 controlling experiments. The results proved a strong performance for TiO2 degradation. However, in different contexts, using more powerful light might leads to a much higher degradation for the melanin regardless of comparing it directly to TiO2. A moderate degradation level for melanin might be enough to scale it to a commercial application that is more profitable, chemically stable, and environmentally friendly. An advantage point for melanin in this topic is that melanin has the capability to absorb light with a wavelength that might reach the visible light region, which is a known a good renewable energy source from the solar system.

4.2 Shortening Irradiation Distance

Anther interesting observation that we have monitored during this research is that the sample distance from the irradiation is really a crucial factor. The light source of the lamb was likely getting absorbed in the atmosphere or berries from the melanin itself. This has resulted in limited exposure to the light source and thus absorbing fewer photos and energy. Therefore the photocatalytic performance might be affected by that. A test we have done regarding this point was using a petri dish and making the light source direct sit on the top of the Petri dish in a try to minimize the light distance from the sample. The results showed a faster degradation than our regular setup. A question to raise in this point is how better would the photocatalytic performance would be if the light source was much closer to the photocatalyst, specifically if it was within the aqueous solution in this case the polluted water. Below is figure



4.3 Increasing the photocatalyst service area

Anther point that we can think of is increasing the service area of the photocatalyst resulting in maximum exposure to light photos. Instead of having suspended melanin or other photocatalytic system contained in narrow or dense holders, we could make thin layers of the photocatalyst separated by the contaminated water so that we can maximize irradiation and yield a more efficient degradation. We have as well tried to maximize the photocatalyst surface area by using a large Petri dish in one of the experiments to see how that would affect photocatalytic performance. As mentioned earlier, throughout the project we have used 1,2,4 drums vials to hold the systems. Compared to using the petri dish, all of these drum vials systems yield a much lower photocatalytic performance proving that maximizing the photocatalyst surface area is an important influential factor in degradation performance

4.4 Future Projects

With the end of this project, the research does not end. Melanin is still a potentially great application for degradation and other photocatalytic application. Whether for us in future research or for future MQP teams, There are many opportunities to expand upon this project. Future projects can explore the removal of heavy metals, which is a topic we did not touch on in this MQP. Future projects could also try to develop hybrid composite materials that compromise melanin in it and other photocatalytic applications, potentially TiO2. This might to lead a great advancement in the water treatment fields and yield a commercially more feasible application, and more friendly solution for the global water treatment crisis. Future projects can also design more efficient degradation systems that maximize surface area and minimize light distance while keeping light energy and other costs minimal. Trying to minimize the atmospheric barriers from absorbing the light and forcing the photocatalyst absorbs a maximum amount of photos would likely improve photocatalytic performance.

Chapter 5: Conclusion

During this research, we were able to constantly explore the photocatalytic proprieties of synthetic melanin and understand the photocatalysis reaction in general. As a result, we have successfully used Senthati melanin to degrade two different water pollutants; p-Nitrophenol and Methylene Blue. Yes, the photocatalytic performance was low and very weak compared to that of the TiO2. However, Melanin could still be a potential candidate for making new advancements in the water treatment fields and particularly photocatalysis. Melanin has the capability of absorbing the light at a visible region of the electromagnetic radiation making it a potential renewable source for water treatment upon utilizing the visible light of the soal systems which constitutes about 45% of its radiation. In addition to that melanin could be mixed with other materials, potentially TiO2 to make hybrid systems with more capability in treating the polluted water while also being cost-efficient, chemically stable, and environmentally safe.

5.1 Reflections

This MQP was not just a project to complete, but also a learning journey, Therefore, we were constantly learning and improving our technical skills throughout the project to first meet the project expectations as well as sharpen our skill set. Throughout this project, we were meeting with the project advisor on a weekly basis to get feedback and to ensure the team was on track to implement the project successfully. We also learned how important it was to stay professional throughout the whole project. We face many obstacles in this project and needed to overcome them while being professional. This included taking responsibility to balance the project objectives and expectations while also taking into consideration other limitations such as the project timeline, and the available resources and skills. Meanwhile, we needed to be open-minded and communicative in a professional manner in order to successfully complete the project.

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