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Term Project Proposal

In the initially stages of the project, I thought of working with the effects of acidic precipitation on metals and how it is affecting historical and cultural monuments such as the Statue of Liberty by turning the copper statue green. But this process, known as patinafication, is commonly used by jewelers. I therefore turned my focus to monuments made of calcareous stone. I wondered whether these stone monuments would react in a similar way to those made of metal when they came in contact with acidic precipitation, or whether they would deteriorate due to certain chemical reactions. I did some research to find out which historical and cultural monuments, like the statue of liberty, undergo the process of patinafication. Through my research I found that monuments made of marble, such as the Taj Mahal in India, are undergoing a similar process of discoloration, as well as undergoing a certain amount of deterioration.

Focusing on the Taj Mahal in Agra, India, I will discuss how the setting up of industries and increased transportation has lead to an increase in the amount of sulphur and nitrogen oxides in the atmosphere. The mixture of these gases with the moisture present in the atmosphere, results in acidic precipitation. Acidic precipitation tends to have a chemical reaction with sculptures, buildings and monuments made of calcareous stone, causing corrosion and discoloration. It has also been seen to have harmful effects on the human respiratory system. For this project, I want to create jewelry pieces which show the adverse effects of acid precipitation. I chose to focus on an architectural monument because jewelry has always had strong connections with architecture and draws a lot of its inspiration from architecture. With the help of these pieces, I wish to spread awareness about the harmful effects of acidic precipitation and pollution in general. Jewelry like fashion has always had an impact on people and therefore I reckon it would be a good way to communicate the problem.

The Taj Mahal is a UNESCO world heritage site and is a symbol of India's rich heritage. Built in Agra by the Mughal emperor Shah Jahan in memory of his favorite wife, Mumtaz Mahal, the Taj Mahal is considered to be the greatest architectural achievement amongst the Indo-Islamic architecture. The mausoleum's famous white marble and relief work, as well as the intricate inlay work makes the structure unique and worthy of being called one of the seven wonders of the world.

Through my research, I have learnt that almost all human activities which occur on a large scale tend to influence the chemistry of the atmosphere. In *Acid Rain and Other Airborne Pollutants*, Ellis Cowling mentions that the main sources of pollution are volatile waste products from the combustion of fossil fuels in power plants, transportation vehicles, and water heating installations. There has been increasing concern about the possible effects of acidic precipitation due to airborne chemicals which are carried by wind and are deposited on historical and cultural monuments all around the world, such as – the Parthenon in Greece, the Taj Mahal in India, and the Statue of Liberty in New York.

In the article titled *Science Behind Acid Rain*, Prashant Mehta has defined acid rain as "...the term given to increased acidity of rain due to the dissolution of gases in rainwater..." It is

formed through both natural and anthropogenic sources. Gaseous pollutants such as sulfur dioxide and nitrogen oxide evaporate into the atmosphere and oxidize in clouds to form their respective acids. These pollutants present in acidic precipitation not only cause damage to the environment but also cause problems in human respiratory systems. Acidic precipitation causes toxic metals to break loose from their natural chemical compounds but these chemical reactions vary depending on the amount of exposure, the reactivity of different materials and the amount of moisture present. Although all materials are affected by the deposition of acid, the degree of damage varies. The effects acidic precipitation has on various materials include – discoloration, material loss, structural failing or soiling.

Although buildings have always been subject to weathering, the effects of acid deposition on modern buildings is considerably less damaging than the effects on ancient monuments. Marble is considered a cultural symbol of tradition and refined taste, and was the go to medium for the Greeks and the Romans. This is why most heritage structures are built of marble and other calcareous stones, and are more vulnerable to degradation. The article, *Acid Rain and Other Airborne Pollutants*, mentions that, this degradation of buildings and monuments due to acidic precipitation is a result of the industrial revolution, which led to a high concentration of industrial discharge, salinity and humidity in the atmosphere. This in turn resulted in higher corrosion rates in certain areas. Prior to the industrial era, the concentration of chemicals present in the atmosphere was relatively low. But now, aquatic and terrestrial ecosystems are exposed to a greater amount of acidic and toxic substances, as well as climate and growth altering chemicals than they were exposed to during the pre-industrial period. Recent industrial developments in Asia have raised concerns about acidic precipitation in a number of regions. However, the unpredictability of East and Southeast Asia's economic situation makes it difficult to make reliable predictions about the future incidents of acid rain.

According to the article, *Changing Trends in Sulfur Emissions in Asia*, the largest increase in the level of sulfur dioxide occurred in India. There have been a number of reports about the problem of sulfur dioxide pollution over India. Although the sulfur emissions were originally relatively low, industrial growth led to increased reliance on fossil fuels such as coal. This is because the usage of coal enabled large scale mass production in mills, factories and mines. It was also able to speed up travel, reduce transportation costs and boost international trade. Coal was therefore considered to be a dependable source of power. The increased reliance on coal however, eventually resulted in an increase in sulfur emissions and deposition. Even though steps are being taken to reduce the sulfur content of petroleum products, the demand for electricity in India has led to the construction of several hundred new power stations which will invariably result in an increase of sulfur emissions. Therefore we can say that the rise in the acidity of precipitation is a result of fumes from vehicles and combustion of products in factories and thermal power plants. Although there is excessive amounts of pollution in the atmosphere, the high dust rate neutralises the acids that are present. Experimental and rainwater analyses in the article, *A Scavenging Model Analysis around a Large Coal-Fired Power Plant in New Delhi with a Particular Reference to the Scavenging Action of the Monsoonal Rains*, show that low pH of precipitation occurs downwind of major industries and power plants. It is observed that maximum pollution is brought into the city from power plants during the month of October, and the acid deposition is greatest during the month of August. This is because during the monsoon months, the wind is South Easterly and a lot of sulfur dioxide is scavenged by the rainwater.

The Taj Mahal is situated in an area surrounded by small lime kilns burning high-sulphur coal and experiences frequent heavy dewfall. As a result of industrial and population growth, illegal constructions are springing up around the Taj and heavily polluting the water of the Yamuna River. This is causing serious damage to the famous white marble of the monument which is now appearing to be turning yellow. The article, *Marble Discoloration at the Taj Mahal* by Hicks and Manju Kumari discusses how the marble discoloration patterns on the Taj Mahal reveal that the air pollutants cause the most damage to the surface of the Taj in the early morning, when the structure is wet because of dew. Surface moisture formed during the night will remain longest on stone surfaces that are not exposed to the early morning sun. This is because wet surfaces enhance the deposition of gaseous pollutants such as sulphur dioxide.

In India a series of banning measures have been undertaken by the government, including creating a 500 meter buffer zone between the marble monument and the running of vehicles. Other countries too have begun to appreciate the dangers of the mixture of uncontrolled sulfur emissions with the water vapor present in the atmosphere, and have introduced measures to limit the sulfur content of petroleum products.

The first scientific idea I would like to incorporate into my project is that marble gets discolored and deteriorates when it comes in contact with acidic precipitation, and that the amount of discoloration depends on the amount of exposure and the amount of moisture present, as well as the reactivity of the material. This scientific idea can be incorporated into marble rings which have been exposed to certain chemicals. The first will be made of the original, unaffected marble. The second will show the discoloration and deterioration of the marble after being exposed to the chemical for a long period of time, in the presence of a lot of moisture, while a third will show the marble's discoloration after a shorter period of exposure in the presence of less moisture.

The second scientific idea is that acid precipitation tends to have harmful effects on the human respiratory system, because the sulfur dioxide and nitrogen oxides present in the atmosphere react to form fine sulfate and nitrate particles that people can inhale into their lungs causing diseases such as asthma and bronchitis. This scientific idea can be incorporated into a rendering of a small sterling silver cast lung pendant which has parts of the piece covered with a black patina, showing the harmful effects that acidic precipitation has on the human respiratory system.

Scientific idea	How it can be incorporated into a creative work.
<p>Marble gets discolored and deteriorates when it comes in contact with acidic precipitation, and that the amount of discoloration and deterioration depends on the amount of exposure and the amount of moisture present, as well as the reactivity of the material.</p>	<p>This scientific idea can be incorporated into marble rings which have been exposed to certain chemicals. The first will be made of the original, unaffected marble. The second will show the discoloration and deterioration of the marble after being exposed to the chemical for a long period of time, in the presence of a lot of moisture, while a third will show the marble's discoloration after a shorter period of exposure in the presence of less moisture.</p>
<p>Acid precipitation has adverse effects on the human respiratory system because the sulfur dioxide and nitrogen oxides present in the atmosphere react to form fine sulfate and nitrate particles that people can inhale into their lungs causing diseases such as asthma and bronchitis.</p>	<p>This scientific idea can be incorporated into a rendering of a sterling silver cast lung pendant which has parts of the piece covered with a black patina, showing the harmful effects that acidic precipitation has on the human respiratory system.</p>

Annotated Bibliography

I have decided to connect my term project to the chapter from week 9 on Pollution: Nutrients and Toxins. The key question I will be relating my research to is “What risks does pollution pose to human health”.

Human activities have added to the substances that circulate naturally among ecosystems. Focusing on the Taj Mahal in Agra, India, I will discuss how the setting up of industries and increased transportation has led to an increase in the amount of Sulphur and Nitrogen Oxides in the atmosphere. These gases mix with the moisture present in the atmosphere, producing acid precipitation (acid rain). Acidic precipitation tends to have a chemical reaction with buildings and monuments made of limestone, sandstone and marble, causing corrosion and discoloration. It also has adverse effects on the human respiratory system.

1. Centre, UNESCO World Heritage. “Taj Mahal.” *UNESCO World Heritage Centre*, whc.unesco.org/en/list/252.
The Taj Mahal is a symbol of India’s rich history and is a UNESCO world heritage site. It is a mausoleum made of white marble built in Agra by the Mughal emperor Shah Jahan in memory of his favorite wife, Mumtaz Mahal. It is considered to be the greatest architectural achievement amongst the Indo-Islamic architecture. It is perfectly symmetrical with emphasis of bilateral symmetry along the central axis. The relief work in marble as well as the intricate inlay work gives it its unique feature. The exquisite octagonal marble lattice screen also shows superb workmanship.
2. Cowling, Ellis B. “Acid Rain and Other Airborne Pollutants: Their Human Causes and Consequences.” *Population and Development Review*, vol. 16, 1990, pp. 205–220. JSTOR, www.jstor.org/stable/2808071.
Abstract:
Almost all human activities which occur on a large scale tend to influence the chemistry of the atmosphere, adding to it more substances than those that circulate naturally. The main sources of pollution are volatile waste products from the combustion of fossil fuels in power plants, transportation vehicles, and water heating installations. This article classifies sulfur dioxide and nitrogen oxides as primary air pollutants while it classifies acid deposition as an important secondary pollutant.
Airborne chemicals are carried by wind and are deposited on vegetation, water surfaces, soil, as well as buildings and monuments. There has been concern about the possible effects of airborne chemicals on historical and cultural monuments all around the world such as the Parthenon in Greece, the Taj Mahal in India, and the Statue of Liberty in New York. Acid deposition and atmospheric haze is also considered to have detrimental effects on society. Prior to the industrial era, the concentration of chemicals present in the atmosphere was relatively low. But now, aquatic and terrestrial ecosystems are exposed to a greater amount of acidic and toxic substances, as well as climate and growth altering chemicals than they were exposed to during the pre-industrial period.
3. Hicks, B B, and Manju Kumari. Marble Discoloration at the Taj Mahal: A Proposed Explanation. 28 Jan. 2011, openarchive.icomos.org/id/eprint/717.

Abstract:

The Taj Mahal is situated in an area surrounded by small lime kilns burning high-sulphur coal and experiences frequent heavy dewfall. This article studies the role of surface wetness as a promoter of the exchange of pollutants from the air to the surface of the monument. The marble discoloration patterns on the Taj Mahal reveal that the air pollutants cause the most damage to the surface of the Taj in the early morning, when the structure is wet because of dew. Surface moisture formed during the night will remain longest on stone surfaces that are not exposed to the early morning sun. This is because wet surfaces enhance the deposition of gaseous pollutants such as sulphur dioxide.

4. Ghosh, S, and M P Singh. "A Scavenging Model Analysis around a Large Coal-Fired Power Plant in New Delhi with a Particular Reference to the Scavenging Action of the Monsoonal Rains." *Philosophical Transactions of the Royal Society B: Biological Sciences*, The Royal Society, 2 May 2002, doi.org/10.1016/0270-0255(87)90616-6. (Academic journal found at the Pratt Library.)

Abstract:

There have been reports in the recent past about the problem of sulfur dioxide pollution over India. The rise in the acidity of precipitation is a result of fumes from vehicles and combustion of products in factories and thermal power plants. Although there is excessive amounts of pollution in the atmosphere, the high dust rate neutralises the acids that are present. Experimental analyses have been undertaken in certain metropolitan cities to address the problem of sulfur dioxide pollution. Rainwater analyses show that low pH of precipitation occurs downwind of major industries and power plants. It is observed that maximum pollution is brought into the city from power plants during the month of October, and the acid deposition is greatest during the month of August. This is because during the monsoon months, the wind is South Easterly and a lot of sulfur dioxide is scavenged by the rainwater.

5. "Changing Trends in Sulfur Emissions in Asia: Implications for Acid Deposition, Air Pollution, and Climate." ACS Publications, 20 Sept. 2002, pubs.acs.org/action/showCitFormats?doi=10.1021%2Fes011509c.

Abstract:

In the early 1990s, it was estimated that the emissions of sulfur dioxide in Asia might grow by 2020. In China, the use of high sulfur coal was restricted, which resulted in a reduction in sulphur dioxide emissions, as well as reduction in acid deposition. It also helped improve visibility and reduced health problems. After China, other countries began to appreciate the dangers of uncontrolled sulfur emissions and introduced measures to limit the sulfur content of petroleum products. The largest increase in the level of sulfur dioxide occurred in India. Although the sulfur emissions were originally relatively low, industrial growth led to increased reliance on fossil fuels and thus an increase in sulfur emissions and deposition. Even though steps are being taken to reduce the sulfur content of petroleum products, the demand for electricity in India has led to the construction of several hundred new power stations which will invariably result in an increase of sulfur emissions.

6. Mehta, Prashant. Science behind Acid Rain: Analysis of Its Impacts and Advantages on Life and Heritage Structures.
www.researchgate.net/profile/Prashant_Mehta6/publication/265824342_Science_behind_Acid_Rain_Analysis_of_Its_Impacts_and_Advantages_on_Life_and_Heritage_Structure_s/links/55dd390e08aeb41644aedcda/Science-behind-Acid-Rain-Analysis-of-Its-Impacts-and-Advantages-on-Life-and-Heritage-Structures.pdf.
 Abstract:
 Acid rain is the term given to increased acidity of rain due to the effects of gases which dissolve in rainwater to form various acids. It is formed through both natural and anthropogenic sources. Two primary sources of acid rain is sulfur dioxide and nitrogen oxide. These gases evaporate into the atmosphere and oxidize in clouds to form their respective acids. The pollutants in acid rain not only cause damage to the environment but also cause problems in human respiratory systems. Acid rain causes toxic metals to break loose from their natural chemical compounds but these chemical reactions vary depending on the amount of exposure, the reactivity of different materials and the amount of moisture present. Although buildings have always been subject to weathering, the effects of acid deposition on modern buildings is considerably less damaging than the effects on ancient monuments. This is because acid deposition especially affects materials such as limestone, sandstone and marble.

7. Bashkin, Vladimir N, and Miroslav Radojevic. "Acid Rain And Its Mitigation In Asia." Taylor and Francis Online, 17 Sept. 2010,
www.tandfonline.com/doi/abs/10.1080/00207230290015711.
 Abstract:
 Recent industrial developments in Asia have raised concerns about actual and potential acidification in the region. Over the last ten years, the presence of acid rain has been identified at numerous sites in Asia. The mitigation strategy being very comprehensive in Japan, Singapore, and Hong Kong, seems insufficient in other countries which are the major polluters in the Asian domain, like China, India and Thailand. It is difficult to make reliable predictions about the future incidence of acid rain in East and Southeast Asia due to the unpredictable economic situation.

8. Laver, Marilyn E., and Ian N. M. Wainwright. "An Investigation of the Dissolution of a Marble Petroglyph Site by Acidic Precipitation." *Studies in Conservation*, vol. 40, no. 4, 1995, pp. 265–273. JSTOR, www.jstor.org/stable/1506501.
 Abstract:
 This article talks about the effects of acid precipitation on a complex of pecked or carved marble at Petroglyphs Provincial Park in Canada. This site is unlike many others which consisted of red ochre rock paintings on granite. The site was not acutely affected by local urban or industrial pollution but was affected by long range transport of air pollutants. Although its primary mode of deterioration can be considered to be dry decomposition, acidic precipitation might have been a significant factor in the dissolution of the rock. This is because the source of water affecting the site is in the form of atmospheric precipitation and the deterioration was caused due to frost weathering and algae.

9. Rao, N Venkat, et al. "Detrimental Effect of Air Pollution, Corrosion on Building Materials and Historical Structures." American Journal of Engineering Research (AJER), 2014, [www.ajer.org/papers/v3\(3\)/ZT33359364.pdf](http://www.ajer.org/papers/v3(3)/ZT33359364.pdf).

Abstract:

The degradation of buildings is a result of the industrial revolution. The industrial revolution lead to a high concentration of industrial discharge, salinity and humidity in the atmosphere. This in turn resulted in higher corrosion rates in certain areas. Like the Taj Mahal which is one of the seven wonders of the world, most heritage structures are built of limestone and calcareous stones which are most vulnerable to corrosion. Although all materials are affected by the deposition of acid, the degree of damage varies. The effect of air pollution on materials could be discoloration or material loss or structural failing or even soiling. As a result of industrial and population growth, as well as traffic fumes, illegal constructions are springing up around the Taj and heavily polluting the water of the Yamuna River. This is causing serious damage to the famous white marble of the monument which is now seen to be turning yellow. A series of banning measures have been undertaken by the government, including avoiding running of vehicles 500 meters away from the monument.