UTC Project Information	
Project Title	MPC 490- Longevity of Air Pollution Mitigating Photo-Catalytic Coatings on Transportation Infrastructure
University	University of Utah
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Funding Agencies	USDOT, Research and Innovation Technology Administration
Agency ID or Contract Number	DTRT13-G-UTC38
Project Cost	$ 67,177
Start and End Dates	September 30, 2013 to September 30, 2018
Project Duration	September 30, 2013 to September 30, 2018
Brief Description of Research Project	It is known that in large urban areas, a high concentration of air pollutants at the street level can harm severely sensitive populations and affect the general public health with cumulative exposure. The sensitive population groups include children and elderly as well as some with weakened immune systems. When these people are exposed to high air-pollutant concentrations, they present higher risk to be diagnosed of respiratory diseases like asthma and emphysema. As reported by the United States Environmental Protection Agency (EPA) the most commonly found harmful air-polluting chemicals in urban areas include Nitrogen Oxides (NO_x), Ground Level Ozone (O_3), Particulate Matter (PM_{10} and $PM_{2.5}$), Carbon Monoxide (CO), Sulfur Dioxide (SO_2), and Lead (Pb). The Clean Air Technology Center (CATC), defines NOx as one of the main man-made air polluting chemicals, of which can be found in seven forms (N_2O, NO, N_2O_2, N_2O_3, NO_2, N_2O_4, N_2O_5)*(1)*. Even when all mentioned nitrogen oxide forms impose a threat to human health, the EPA only regulates Nitrogen Dioxide (NO_2) levels, because the NO_2 form is the most common in the atmosphere. This form is directly generated from the combustion of fossil fuels by humans who use vehicle transportation and heating furnaces, as well as through power generation and industrial production plants exhaust. Moreover, when in the presence of Ultra Violet (UV) light during the day, NO_2 actively reacts in the atmosphere with any other synthetic or naturally produced Volatile Organic Compounds (VOCs) to produce ground level tropospheric ozone O_3, acid rain, and $PM_{2.5}$. NO_x plays a significant role in air pollution as it can create O_3 in the presence of UV, and it contributes to the formation of $PM_{2.5}$. It has been reported that breathing O_3 and inhaling $PM_{2.5}$ can trigger a variety of health problems that include chest pain, coughing, throat irritation, congestion, and can also reduce lung function and produce inflammation of the lining of the lungs *(2)*. It has been observed that all regions of the United States have been in-compliance with the current National Ambient Air Quality Standards (NAAQS) *(1)* for NO_2 (defined as 53 ppb averaged

annually, or 100 ppb averaged over one hour). In addition, the country has reduced concentrations of $PM_{2.5}$ below of the national standard in recent years due to tighter restrictions on vehicle and industrial exhaust *(3)*. However, most regions of the US do not meet the O_3 standards as shown in Figure 1*(4)*. It is anticipated that although the limits of the NO_x are lower than the standard, they will contribute to this heightened O_3 concentration. Consequently, large portions of the population are still being exposed to hazardous levels of ozone. However, because NO_x is the main pollutant that is created by human activities, this research project will be targeting it in an attempt to reduce it further.

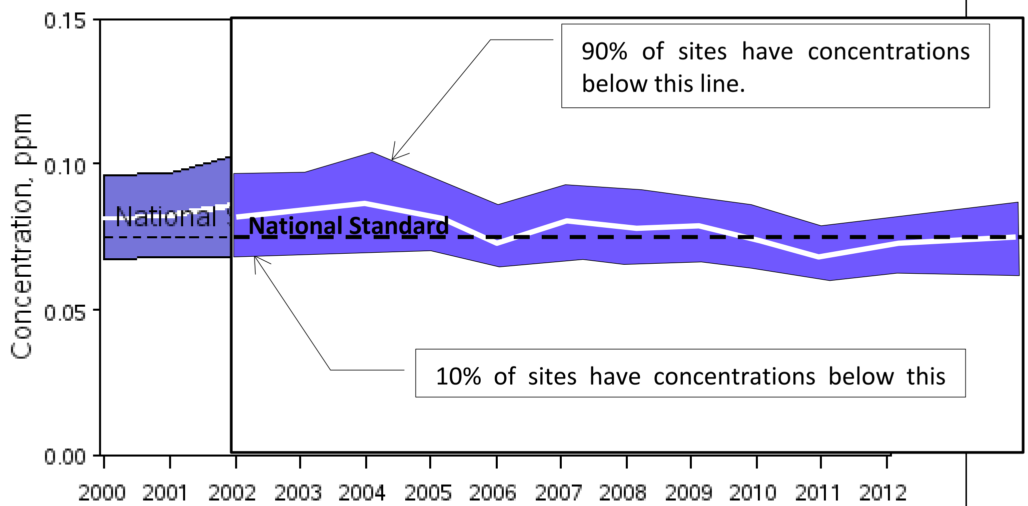

Figure 1 Ozone Air Quality National trend (Annual Average of 897 sites 4th Maximum of Max 8-Hr Average Concentration) (4).

It is imperative to find new and better ways to reduce the amount air pollutants on behalf of the health and wellbeing of people living in urban areas. Over the past ten years, a significant number of studies have been focused on understanding photocatalytic properties of several materials for air and water purification. Amongst these photocatalytic materials, titanium dioxide (TiO_2) is a naturally occurring compound found in four stable crystalline forms: ilmenite, brookite, rutile, and anatase. Because it has no absorption in the visible region, TiO_2 appears to be white to the human eye, and it has been widely used as a white pigment for centuries *(5)*. It is also similarly used in common household products such as toothpaste, food coloring, sunscreen, paint, plastics, and cosmetics. Photocatalytic TiO_2 has been studied because of its ability (while in the presence of UV light) to break down water molecules into hydroxyl radicals without consuming itself. These hydroxyl radicals are highly reactive and can further combine with nearby molecules in air or water. In the presence of harmful pollutants such as NOx's or VOC's in the air, the hydroxyl radicals generated by photocatalysis will combine with these molecules breaking them up to form other non-toxic compounds. Additionally, photocatalytic TiO_2 activated by UV light can decompose other non-volatile organic materials like dirt, grime, oil, and particulates, which gives materials coated with TiO_2 self-cleaning characteristics.

Some commercial building materials have been designed including TiO_2 in their

	formulations and are reported to reduce NOx significantly (up to 97.92%) from the surrounding air *(5)*. These photocatalytic construction materials often are highly expensive to produce, causing most contractors not to utilize them in their bids in order to stay economically competitive, unless environmental-based goals are specified. More importantly, it has been recently observed that the photocatalytic efficiency of concrete containing embedded TiO_2 is drastically reduced by 77% to 86% within less than a year, and is specifically associated with the acceleration of a chemical reaction and limestone by-product formed on the surface of the concrete *(6–8)*. Researchers have identified that Relative Humidity (RH) of the surrounding air, in combination with UV irradiance levels, do affect the TiO_2 photocatalytic reaction rates *(6, 9–12)*. Previous research at the University of Utah focused on rejuvenation methods to restore the reduced photocatalytic properties of concrete containing TiO_2 *(6)*. A separate study focusing on the TiO_2 efficiency for removing toluene instead of NOx, found that the photocatalytic efficiency was blocked after low RH conditions, but then completely rejuvenated after a short exposure of high RH along with UV light *(9)*. It is hypothesized that TiO_2 products such as spray-on coatings may be more effective than embedded TiO_2, particularly if concrete is used as the constructed surface material. This research will specifically investigate using TiO_2 coatings on various transportation infrastructure materials in order to investigate if not only the coating can effectively remove NOx, but more importantly to understand an appropriate method to rejuvenate or reactivate TiO_2 surface treatments should they become blocked or present reduced NOx removal efficiency. **Research Objectives:** The main objective of this research is to evaluate experimentally the carbonation rate of concrete containing embedded TiO_2 or coated with TiO_2 surface treatments; and evaluate whether the presence of the photocatalytic TiO_2 changes the carbonation rate of the concrete.
Describe Implementation of Research Outcomes (or why not implemented) Place Any Photos Here	From this research project, one potential outcome is to find a whether concrete is a viable construction material to have the photocatalytic applied to in order to provide a long-lasting pollution control. From the results of this research, some advantages and pitfalls of TiO_2 coatings will be known, allowing further research to develop in order to improve durability and viability of these materials. Results of this project can be used by practitioners to decide whether fresh concrete is the most efficient backing-material for these TiO_2 materials. Beyond the research report, it is expected that at least one journal paper be produced along with possible presentations at conferences such as the Transportation Research Board Meeting or the American Concrete Institute convention.

Impacts/Benefits of Implementation (actual, not anticipated)	The proposed project and its expected outcomes are related to the Environmental Sustainability, and Livable Communities strategic goals in the sense that the technology studied has the potential to reduce environmental impact of emissions generated by transportation activities, and improve the air quality in urban areas. Findings will be presented in courses taught at University of Utah: specifically 5920 Sustainable Materials, 6225 Concrete Science, 7560 Advanced Construction Materials, and 7920 Advanced Materials Testing. Additionally, findings will be communicated to youths participating in recruitment of future engineers in Hi-Gear summer camp program for high-school girls interested in engineering.
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