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Evaluation Of Titanium Dioxide To Reduce Air Pollutants

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ABSTRACT

This report presents an evaluation of titanium dioxide (TiO2) for reducing air pollutants. The introduction provides background information on NMIT, the Department of Civil Engineering, and the testing lab, Bangalore Test House. The literature review explores the potential environmental applications of TiO2 nanoparticles, the morphological control of anodic crystalline TiO2 nanochannel films, and the use of metal oxide titanium oxide (M-TiO2) for visible light induced CO2 photoreduction. The aim and scope of the present investigation are outlined, focusing on the effectiveness of applying TiO2 to surface materials to produce a greener urban environment. The main objective is to study the effect of TiO2 photo catalysis on more exposed surfaces to daily environmental pollutants such as concrete pavements, road dividers, walls exposed to high pollution areas, and vehicles. The experimental investigation includes SEM and XRD tests, leakage tests, and NO2 reduction tests for samples with and without TiO2 coating. The results show that TiO2 coated surfaces are effective at reducing NO2 concentrations in the presence of UV light. The conclusion is that TiO2 coating can be a promising approach to degrading harmful air pollutants and improving air quality.

Keyword: TiO2, air pollutants, NO2 reduction, SEM, XRD, UV light

CHAPTER 1

INTRODUCTION

A. ABOUT NMIT

Vision

To provide India and the World, technical manpower of the highest academic excellence and World class by shaping our youth through holistic and integrated education of the highest quality.

Mission

To develop Nitte Meenakshi Institute of Technology through Quality, Innovative and State-of-art educational initiatives into a centre of academic excellence that will turn out youth with well balanced personality & commitment to rich cultural heritage of India and who will successfully face the Scientific and Technological challenges in the fast-evolving Global scenario with a high degree of credibility, integrity and ethical standards.

Quality Policy

To bring about constant and Continuous Improvement in the Quality of Education Imparted and Turning out High Quality Professionals with Balanced and Globally Competitive Personality through Regular Monitoring of the Academic/ Administrative Activities of the Institution and Implementing Corrective Actions in the Best Ethical and Transparent Traditions.

B. INTRODUCTION OF THE ORGANISATION

The Department of Civil Engineering is one of the youngest departments s of NMIT, Bangalore, started in 2009 with first batch of budding engineers started contributing to the nations building from 2013. It has grown into a fully fledged Department with 6 Professors and 24 faculty members from various fields of specialization in the major areas of Civil Engineering. Dedicated faculty members are contributing with great zeal towards achieving the Vision of the department. Creating conducive atmosphere for teaching, learning and research in various fields of Civil Engineering to impart the skills of planning, designing, execution with quality and leadership qualities to the students.

Civil department is a registered Research Centre under VTU and has contributing to the research field through its publications and, Research. M.Tech in structural engineering with an intake of 24 is a successful post graduation course under NMIT banner. Department has initiated its consultancy services through interaction with industry and has interaction with the reputed industries to name a few, Stup Constants Pvt. Ltd., Sobha Ltd., Ultratech Cement Ltd. Namma Metro [BMRCL], Brigade Groups, Bharathiya City Projects, Sterling Consultancy Pvt Ltd. and so on.

Department of Civil Engineering in known for its Industry-Institute-Interaction, conducting technical activities, site visits, deputing students for their internship as a part of their curriculum, on a regular basis. Department has completed the formalities for becoming Organisational Life member of Association of Consulting Civil Engineers(India) – ACCE(I), Indian Concrete Institute (ICI) and also student chapters of ACCE(I) & ICI-KBC. Other initiatives towards MOU with industries for research & development activities are on Anvil.

Vision

To be one among the topnotch Civil Engineering departments in India, create Centre of Excellence, to provide globally competent Civil Engineering graduates serving the needs of the society and sustainable development.

Mission

- **Mission 1**: To create atmosphere for teaching and continuous learning, research, consultancy and developmental activities, through excellent teaching, research and state-of-the-art infrastructure.
- **Mission 2**: To impart professionalism among students, through Industry Institute Interaction.
- **Mission 3**: To imbibe leadership quality, professional ethics, environmental consciousness and social responsibilities, to serve the society through co-curricular and extra-curricular activities.

C. INTRODUCTION OF THE TESTING LAB

Bangalore Test House was established in the year 1987 and during the last two and half decades of its dedicated service to the industry, it has become one of the leading multi-disciplinary testing laboratory in the country with over 130 qualified and skilled personnel with an array of sophisticated instruments. It has earned a reputation to handle large volume of samples efficiently and effectively and is able to provide high quality, prompt, reliable and independent service thus maintaining highest customer satisfaction.

1.1 Testing services provided by Bangalore Test House:

1.1.1 PHARMACEUTICAL TESTING

- Bangalore Test House reaches out to Drug Manufacturers in order to accentuate the overall quality aspects of drug products.
- We provide complete range of testing for Raw Materials viz Identification, related substances, Assay, Impurities, etc., as per relevant Pharmacopoeia.

1.1.2 FOOD & CHEMICAL TESTING

- Animal Feed & Feed Ingredients
- Food & Food Products
- Pesticides, Fertilizers & Fine Chemicals
- Agricultural and Agricultural Products.

1.1.3 ENVIRONMENTAL MONITORING & TESTING

- Chemical and microbiological testing of Packaged drinking water, Potable water, Waste water, Swimming pool water, De-ionised water, Concreting purpose water, Boiler feed water, R.O Water, Food processing water, Soil, Sludge and Hazardous waste, etc.
- Facility for testing of micro-organisms like bacteria, Coliforms & pathogens like Legionella, Listeria, Salmonella, Shigella, etc., are available.
- Air monitoring for Ambient and Indoor Air Quality for toxic gases like Carbon monoxide, VOC's, Ozone, Hydrocarbons, Sulphides, PM 2.5, PM 10, Flue gas monitoring, Noise and Illumination studies.
- Testing of Petroleum products like Diesel, Kerosene, Fuel oil, Used/waste oil, Coal, Briquettes, etc.

1.1.4 PHYSICAL AND MECHANICAL TESTING

- Testing facility for Chemical and Mechanical parameters for all grades of cement, Plywood, Block boards, as per IS specifications.
- Packaging materials used for packaged drinking water industry like containers, Polyethylene film, Pouches, paper & paper products etc., are tested for its quality and suitability as per relevant specifications.

1.1.5 RADIOLOGY TESTING

- Testing of various materials like construction materials, Food products, Water, etc., for α, β, & γ radiations.

1.1.6 MICROBIOLOGICAL TESTING

- Microbiological sample testing facility is available at the lab.

CHAPTER 2

LITERATURE REVIEW

EXPLORING POTENTIAL ENVIRONMENTAL APPLICATIONS OF TiO_2 NANOPARTICLES

This study aims at preparing thin layers of (TiO_2) with a high photocatalytic activity and antibacterial properties for use as a self- cleaning transparent coatings for windows in outdoors applications. Titanium dioxide (TiO_2) nanoparticles were prepared by sol-gel process using Titanium Tetrachloride ($TiCl_4$) as a precursor, and calcined at different calcination temperatures (400, 600, 800, and 1000) ^oC. The research on photocatalysts shows that it is a promising technique for the decomposition of organic contaminant using clean solar energy without yielding any harmful by-products. This technique can be envisaged as one of the most promising Advanced Oxidation Process (AOPs) due to its specific advantages, such as bland reaction conditions, the possibility of using molecular oxygen as oxidant species, the total

mineralization of pollutants into substances innocuous to the environment. Photocatalysis is based on the interaction between semiconductor materials and light by considering that 'free' light from the sun, the idea of using solar light energy as resource to clean up the environment is an ideal and promising approach. TiO_2 coatings (1 mg cm-2) are effective against (Staphylococcus aurous) and (Pseudomonas aeruginosa) with a 100% efficiency kill under sunlight irradiation. TiO_2 coated films presented higher transmittance, lower water contact angle, good photocatalyst activity, and excellent antibacterial properties. These properties are fundamental for application as a self-cleaning surface.

MORPHOLOGICAL CONTROL OF ANODIC CRYSTALLINE TIO_2 NANOCHANNEL FILMS FOR USE IN SIZE-SELECTIVE PHOTOCATALYTIC DECOMPOSITION OF ORGANIC MOLECULES

We report the size-selective photocatalytic decomposition of organic molecules using crystalline anodic TiO_2 nanochannel films as the photocatalyst. The porous TiO_2 films were formed by anodizing titanium at 20V in glycerol electrolyte containing various amounts of

K_3PO_4, K_2HPO_4, and KH_2PO_4 at 433K. In the experiment conducted, photo-generated holes on TiO_2 reacted with either the surface OH groups or H_2O molecules and generate active hydroxyl radicals, which are usually nonselective oxidants of organic molecules. However, in the case of mesoporous TiO_2 with pore sizes in the range 3–7 nm, Shiraishi et al. reported that the diffusion distance of the hydroxyl radicals formed inside the pores was 1.3–2.4 nm. Therefore, hydroxyl radicals formed inside the pore were deactivated rapidly and, thus scarcely diffused out of the pores, suggesting that almost all organic molecules were decomposed on the inside wall of the TiO_2 nanochannel films. Of course, few molecules reacted at the surface of the P_1 film, but this maybe ignored because of the high BET surface roughness of the P_1 film. There are two possibilities that induce photocatalytic selectivity- differences in the adsorption properties between the P_1 and NT films and in the hindrance of the passage of reactive molecules owing to the difference in pore diameters. In general, TiO_2 shows high photo-oxidized activity for water and organic molecules, thereby leading to low photo-oxidized selectivity. The present work has discovered a new photochemical property of anodized TiO_2 films by accurate control of the porous structures. We believe that highly ordered nanochannel structures can have various practical applications in the fields of biosensors and artificial photosynthesis.

TRANSITION METAL OXIDE BASED TiO_2 NANOPARTICLES FOR VISIBLE LIGHT INDUCED CO_2 PHOTOREDUCTION

We report the use of metal oxide titanium oxide (M-TiO_2) to reduce CO_2. The TiO_2 is synthesized by sol-gel process. The absorption spectra for the M–TiO_2 samples synthesized by the sol–gel method at various loading ratios are presented. Addition of V, Cr and Co ions results in a red shift of the absorption edges and decrease in band gap energies of these M–TiO_2 based samples when compared with the spectrum of pure TiO_2 (3.1 eV). Absorption spectra of the resulting M–TiO_2 photo catalysts showed increased shift in the visible light with increased metal concentration. The largest shift of the absorption edge was observed by the 2wt% of all samples within the series tested; with Cr-TiO_2 sample shaving the lowest band gap energies followed by the V- and Co–TiO_2 samples. Based on the spectra of the V-based photo catalysts in this study, it can be inferred that both V^{4+} and V^{5+} ions coexist in the samples, which is consistent with XRD and XPS results. The results showed the reduction of CO_2 by M-TiO_2.

INFLUENCE OF SURFACE DENSITY ON THE CO_2 PHOTOREDUCTION ACTIVITY OF A DC MAGNETRON SPUTTERED TiO_2 CATALYST

The aim of the present study is to assess DC magnetron sputtering as a suitable method to prepare photocatalytic coatings for CO_2 reduction with a view on process scalability and to study the effect of the coating conditions on the structure, optoelectronic properties and photoactivity of the catalyst, in order to propose an optimum situation for the pursued reaction. For that purpose, results obtained using coatings with different area densities are reported and related to the coating characteristics. Regarding the photocatalyst choice, TiO_2 still represents the most appropriate material for photocatalysis. The performance of TiO_2-coated glass fibre samples was evaluated in CO_2 photo reduction under UV light using water as electron donor. The main reaction products are CO and CH_3OH plus trace amounts of CH_4. The results have shown that DC magnetron sputtering is highly applicable technique for the deposition of TiO_2 coatings for CO_2 photocatalytic reduction.

TiO_2 PHOTOCATALYSIS: DESIGN AND APPLICATIONS

In this review, recent developments in the area of TiO_2 photocatalysis research, in terms of new materials from a structural design perspective, have been summarized. The dimensionality associated with the structure of a TiO_2 material can affect its properties and functions, including its photocatalytic performance, and also more specifically its surface area, adsorption, reflectance, adhesion, and carrier transportation properties. TiO_2 materials with one-dimensional structures, such as fibers and tubes, possess unique properties and advantages for photocatalytic reactions. In fibers and tubes, the higher surface-to-volume ratio enables a reduction in the hole–electron recombination rate and a high interfacial charge carrier transfer rate, with both of these effects being favorable for photocatalytic reactions. Two dimensional TiO_2 nano sheets show photocatalytic properties including the photocatalytic decomposition of organic molecules and superhydrophilicity, under UV irradiation. The three dimensional TiO_2 can be used to store organic pollutants as it has a high surface to volume ratio.

REVIEW OF MATERIAL DESIGN AND REACTOR ENGINEERING ON TiO_2 PHOTOCATALYSIS FOR CO_2 REDUCTION

In this review, CO_2 utilization by direct catalytic conversion of CO_2 driven by light energy is described. Although CO_2 conversion to energy rich and chemically useful products is endothermic, renewable carbon free sources like solar energy provide readily available and continuous light supply required for driving this conversion process under ambient conditions. Thus, carbon based fuels and chemicals suitable for end-use infrastructure can be produced from the conversion of CO_2 and water by semiconductor photocatalysts capable of simultaneously driving chemical reactions and utilizing solar energy. The utilization of CO_2 as a direct feedstock for photocatalytic conversion into fuels over different variants of pure and modified TiO_2 synthesized by various routes and tested in various photo- reactor designs has been highlighted in this review. Application of TiO_2 induced photocatalysis for the challenging conversion of CO_2 remains a promising pathway as it can be activated by solar energy at relatively mild conditions to form valuable products.

ASSESSMENT OF THE POTENTIAL HAZARD OF NANO-SCALE TIO2 IN PHOTOCATALYTIC CEMENT: APPLICATION OF A TIERED ASSESSMENT FRAMEWORK

Nano-scale titanium dioxide (n-TiO_2) is among the highest-volume engineered nanomaterials (ENMs) produced and incorporated into nano-enabled products. Both bulk TiO_2 and n-TiO_2 are used as a whitening agent in paints (although largely micron scale in that application) and other coatings, as a functional component of sunscreens and cosmetics, as a semiconductor in a number of electronic devices, including dye-sensitized solar voltaic cells, and an increasing number of applications that take advantage of nano scale photodynamic properties Little is known about environmental persistence, exposure potential, or hazard materials released from TCCs. Cursory partial life-cycle consideration of cement augmented by ENMs other than n-TiO_2 suggests several mechanisms for release these include materials released during manufacture and transport, during construction activities, from wear, abrasion, and weathering (degradation by sunlight, freeze-thaw cycles, etc.), modification of existing surfaces, and end of life processes including demolition, transport, and disposal. These environmental risk issues were addressed in the current study using a Tiered Framework and recently applied to a silver-based NEP and more broadly on issues related to dispersion and dissolution of case-study ENMs. Tiers 1 and 2 of the Framework revealed that these materials are composites of several elemental materials including a photocatalytic form of n-TiO_2, which is present as primary particles aggregated at sizes that exceed those identified in many nanomaterial definitions.

PHOTOCATALYST EFFICIENCIES IN CONCRETE TECHNOLOGY: THE EFFECT OF PHOTOCATALYST PLACEMENT

The increase in vehicular emissions has led to increase in airborne particles such as NO_x which has become a global issue. European Directives define the atmospheric concentration of NO_x in ambient air to be at maximum of 40 µg/m3, while the actual concentration of NOx in almost all main European cities far exceeds this value, e.g., an hourly average of ca. 300 µg/m3 (160 ppb) was reported in London (July 2017). The situation in China is even more extreme with NO_x concentrations in large cities in the North China Plain (Beijing, Tianjin, most of Hebei, Henan, and Shandong provinces and the northern parts of Anhui and Jiangsu provinces) exceeding 450 ppb in July 2013. This paper places photocatalytic efficiencies into the context of the application by illustrating how photonic efficiencies translate into impacts on air quality, utilising comparisons between performances of photocatalysts, conventionally placed, i.e. by incorporation into a surface mortar layer, and supported on surface exposed aggregates. In this study various quartz supported TIO_2 composites were prepared by coating with TIO_2 loadings varying from TIO_2/SIO_2 ratios. Durability assessments of the composites showed significant losses of TiO_2 (almost half) at the highest loading levels, whereas composites with lower loadings were stable due to the strength and short-range influence of the chemical Ti-O-Si binding.

PREPARATION AND PROPERTIES OF TIO2/FUMED SILICA COMPOSITE PHOTOCATALYTIC MATERIALS

This paper introduces a novel ceramic processing technology for the preparation of photocatalytic materials. The process introduced here involves the use of a fumed silica and titania gel blend as a starting material followed by mixing, shaping and heating to obtain a porous product. As a result of the flexibility of the ceramic shaping method, photocatalytic materials with a desired strength and in a variety of shapes can easily be produced. This can be achieved by simply changing the mould and adjusting the binder type and dosage, and as such has enormous potential for a variety of applications. In addition, this paper describes how fumed silica, recycled from a ferroalloys factory, may be used as a carrier for TiO_2/SiO_2 photocatalytic materials. The high thermal stability, the effect of heating temperature on phase transformation and the photocatalytic properties are discussed. The most functional photocatalytic materials produced during this study have tensile strengths of 7.67 to 8.18 MPa and specific surface areas from 25.01 to 25.07 m2/g when heated from 700 to 800 °C. For these materials, the main phase is an anatase type TiO_2. The good photocatalytic activity observed for this material was confirmed by the complete degradation of a 10 mg·L-1 methyl orange solution within 24 h using 15 W of ultraviolet light irradiation.

TRANSITION METAL OXIDE BASED TiO2 NANOPARTICLES FOR VISIBLE LIGHT INDUCED CO_2 PHOTOREDUCTION

The development of nanostructured TiO_2 photocatalytic system which are capable of harnessing solar energy and resulting in the reduction of CO_2 to carbon-based fuels and chemicals. Pure TiO_2 photocatalysts were immobilized onto quartz plates which was successfully prepared by sol–gel process. The same was tested for the photocatalytic reduction of CO_2 under visible light irradiation. The rate of photo conversion was checked by addition of varying concentrations of V, Cr & Co in TiO_2 sol. Results depicted that introduction of metal ions to the pure TiO_2 resulted in decrease in crystalline size of anatase and enhancement in light absorption to longer wavelengths in the visible light region. Thus, the experiment showed that the photo conversion rates were remarkably enhanced for the M-doped TiO_2 when compared to pure TiO_2 at optimal metal concentrations.

DEACTIVATION AND REGENERATION OF ENVIRONMENTALLY EXPOSED TITANIUM DIOXIDE

It was concluded that TiO_2 coated concrete paving blocks were exposed to environmental conditions for 4 months and 12 months at 5 different pedestrian roads. The photocatalytic activity of the TiO_2-coated paving blocks decreased in heavy pedestrian traffic areas, as contaminants accumulated on the surface. The non-pedestrian areas did not significantly affect the NO_x removal activity of the paving blocks. Washing the blocks with water did not fully recover the photocatalytic activity. Reactive surface area was lost from the accumulation of dust, dirt, oil, grease, and even discarded chewing gum.

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CHAPTER 3

AIM AND SCOPE OF PRESENT INVESTIGATION

3.1 GENERAL

With the Rapid growth of population density in urban and metropolitan areas and increase in the development of transportation related activities, we are now facing significant challenges in controlling air pollution and the associated problems in human health and living environment. Vehicle emission cause air pollution problems throughout the world and there have been many attempts to reduce emissions. However, there are still emissions polluting the air to a significant level.

Pollution refers to any matter that is "out of place". In other words, it is what happens when toxins, contaminants, and other harmful products are introduced into an environment, disrupting its normal patterns and functions. When it comes to our atmosphere, pollution refers to the introduction of chemicals, particulates, and biological matter that can be harmful to humans, plants and animals, and cause damage to the natural environment.

Whereas some causes of pollution are entirely natural – being the result of sudden changes in temperature, seasonal changes, or regular cycles – others are the result of human impact (i.e. anthropogenic, or man-made). More and more, the effects of air pollution on our planet, especially those that result from human activity, are of great concern to developers, planners and environmental organizations, given the long-term effect they can have.

By composition, Earth's atmosphere is made up of nitrogen gas (78%), oxygen gas (21%), and other trace gases (such as argon and carbon dioxide). This balance is essential to all life here on Earth, so the introduction of pollutants can have a profound and damaging effect. All told, pollution can take many forms, like carbon compounds such as carbon monoxide (CO) and carbon dioxide (CO_2). sulphuric compounds like sulphur dioxide (SO_2), methane, radioactive decay, or toxic chemicals.

Air pollution occurs when harmful substances including particulate matters and biological molecules are introduced into Earth's atmosphere. It may cause diseases, allergies or death in humans. It may also cause harm to other living organisms such as animals and food crops, and may damage the natural or built environment. Human activity and natural processes can both generate air pollution.

Nitrogen oxides, particularly nitrogen dioxide, are expelled from high temperature combustion in Vehicles, Industries, and are also produced during thunderstorms by electric discharge. They can be seen as a brown haze dome above or a plume downwind of cities. Nitrogen dioxide is a chemical compound with the formula NO_2. It is one of several nitrogen oxides. One of the most prominent air pollutants, this reddish-brown toxic gas has a characteristic sharp, biting odor.

A method of removing these pollutants at the city level once they are emitted to the atmosphere is an attractive air quality management. Similar to plant photosynthesis, photo catalytic compounds such as Titanium dioxide (TiO_2) particles can be used to trap and absorb organic and inorganic particles in the air, removing (degrading and mineralizing) harmful pollutants such as nitrogen oxides (NO_X) into CO_2, H_2O and harmless inorganic compounds in the presence of UV light (sunlight). TiO_2 is one of the most investigated semiconductors in the field of chemical conversion.

3.2 AIM

This Project therefore aims to identify the effectiveness of applying TiO_2 to Surface materials to produce a greener urban environment. Therefore, treating the surface of a pavement with TiO_2 can be a very promising approach to degrading harmful air pollutants, and improving the quality of the air.

3.3 OBJECTIVE

The main objective is to study the effect of TiO_2 Photo catalysis on more exposed surfaces to daily environmental pollutants such as,

- Concrete Pavements.
- Road dividers.
- Walls exposed to high pollution areas.
- Vehicles

The objective of this study is to evaluate the effectiveness of TiO_2 treated surface materials for their capability of pollutant reduction and withstanding environmental damage. A laboratory environmental setup was used to evaluate the pollutant removal efficiency due to the photocatalytic effect of the TiO_2. Since a major focus of this application is in the transportation and Industrial environment, Nitrogen oxide pollutants that are present in significant levels in automobile exhaust were tested. The desired end result is to find a TiO_2 surface treatment that would work effectively at removing pollutants from the air, while using the least amount of TiO_2 as possible to reduce costs and make this application possible in the field.

3.4 NO_2

Nitrogen Dioxide (NO_2) is one of a group of highly reactive gases known as oxides of nitrogen or nitrogen oxides (NO_x). Other nitrogen oxides include nitrous acid and nitric acid. NO_2 is used as the indicator for the larger group of nitrogen oxides.

NO_2 primarily gets in the air from the burning of fuel. NO_2 forms from emissions from cars, trucks and buses, power plants, and off-road equipment.

3.5 EFFECTS OF NO_2

3.5.1 Health effects:

Breathing air with a high concentration of NO_2 can irritate airways in the human respiratory system. Such exposures over short periods can aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms (such as coughing, wheezing or difficulty breathing), hospital admissions and visits to emergency rooms. Longer exposures to elevated concentrations of NO_2 may contribute to the development of asthma and potentially increase susceptibility to respiratory infections. People with asthma, as well as children and the elderly are generally at greater risk for the health effects of NO_2.

NO_2 along with other NO_x reacts with other chemicals in the air to form both particulate matter and ozone. Both of these are also harmful when inhaled due to effects on the respiratory system.

3.5.2 Environmental effects:

NO_2 and other NO_x interact with water, oxygen and other chemicals in the atmosphere to form acid rain. Acid rain harms sensitive ecosystems such as lakes and forests.

The nitrate particles that result from NO_x make the air hazy and difficult to see though. This affects the many national parks that we visit for the view.

NO_x in the atmosphere contributes to nutrient pollution in coastal waters.

3.6 NO_X:

NO_x is a generic term for the nitrogen oxides that are most relevant for air pollution, namely Nitric Oxide (NO) and Nitrogen Dioxide (NO_2).

These gases contribute to the formation of smog and acid rain, as well as tropospheric ozone.

NO_x gases are usually produced from the reaction among nitrogen and oxygen during combustion of fuels, such as hydrocarbons, in air, especially at high temperatures, such as occur in car engines. In areas of high motor vehicle traffic, such as in large cities, the nitrogen oxides emitted can be a significant source of air pollution.

3.6.1 EFFECTS OF OXIDES OF NITROGEN:

Exposure to the two most common nitrogen oxides, nitric oxide and nitrogen dioxide, can cause death, decreased fertility and genetic mutations. Tissue swelling, headaches and dizziness are common side effects when exposed to high levels of nitrogen oxides. Studies show that repeated exposure can lead to scarring.

People exposed to nitrogen oxides over a long period may experience respiratory issues and reduced lung function that can limit an active lifestyle. Those with asthma are more vulnerable to the effects of these chemicals. Nitrogen oxides are created when fuel is combusted at high temperatures. They are commonly found in polluted air and are common near coal-burning power plants and anywhere with a large volume of vehicle traffic. Wood burning stoves, kerosene heaters and gas stoves also produce nitrogen oxides.

At room temperature, nitrogen dioxide can be colorless or brown and have a strong odor. When it's heated above 70 degrees Fahrenheit, nitrogen dioxide takes on a reddish-brown color. Nitric oxide has a colorless to brown tint and has a sweet odor. When nitrogen oxides mix with some other chemicals in the presence of sunlight, they can create ground-level ozone. Nitrogen oxides can cause acid rain that eventually enters lakes and streams. High levels of nitrogen are often responsible for an increase in algae and weeds.

3.6.2 HEALTH AND ENVIRONMENT EFFECTS:

- Exposure to the two most common nitrogen oxides, nitric oxide and nitrogen dioxide, can cause death, decreased fertility and genetic mutations. Tissue swelling, headaches and dizziness are common side effects when exposed to high levels of nitrogen oxides.
- NO_x reacts with ammonia, moisture, and other compounds to form nitric acid vapour and related particles. Small particles can penetrate deeply into sensitive lung tissue and damage it, causing premature death in extreme cases.

- Inhalation of such particles may cause or worsen respiratory diseases, such as emphysema or bronchitis, or may also aggravate existing heart disease.
- NO_x reacts with volatile organic compounds in the presence of sunlight to form and to destroy ozone.
- Ozone can cause adverse effects such as damage to lung tissue and reduction in lung function mostly in susceptible populations (children, elderly, asthmatics). Ozone can be transported by wind currents and cause health impacts far from the original sources.
- NO_x emissions also cause global cooling through the formation of OH radicals that destroy methane molecules, countering the effect of greenhouse gases. The effect can be significant.
- NO_x emissions from ship traffic led to significant increases in hydroxyl (OH), which is the major oxidant in the lower atmosphere. Since reaction with OH is a major way of removing methane from the atmosphere, ship emissions decrease methane concentrations. (Reductions in methane lifetimes due to shipping-based NO_x emissions vary between 1.5% and 5% in different calculations).

3.7 SCOPE OF PRESENT INVESTIGATION

TiO_2 application on pavements for photo catalytic oxidation is still a relatively new area, more research should be conducted prior to application in the field. The coatings need be tested for resistance in the fall, winter, and spring months, as well as be tested for resistance to vehicle abrasion. The effect of the TiO_2 to the texture and friction properties of the pavement will need to be studied.

The tire-to-pavement interaction (abrasion resistance) should be observed with these coatings. More in-depth research should also be conducted to investigate the overall effect of the photocatalytic reaction and if any, harmful chemical compound could be produced during such reaction to adversely affect the environment and human health before the wide application of the photocatalytic materials for improved environment benefit.

Further research and development have to be conducted to know the effectiveness of TiO_2 when introduced in Cloth Fibers during manufacturing, its feasibility to Human Health etc. Research has to be conducted to effectively reduce other major Air pollutants by adding additives to TiO_2.

Also, further study for TiO_2 doped with other metals, materials and the effectiveness of TiO_2 for the photocatalytic reaction to occur is to be analyzed and check whether the same is economical for the mass application on the pavements in order to reduce the air pollutants in the atmosphere.

CHAPTER 4

EXPERIMENTAL INVESTIGATION

4.1 SEM TEST

A scanning electron microscope is a surface microscopy which uses the behaviour of electrons to create the image. It works on the principle of scattering of electrons on the surface of the sample. The electrons interact with atoms in the sample, producing various signals that can be detected and that contain information about the sample's surface topography and composition. A 3-D image is formed. The backscattered electrons or secondary electrons are detected by an electronic detector. Further by processing the secondary electrons a 3-D image is been created.

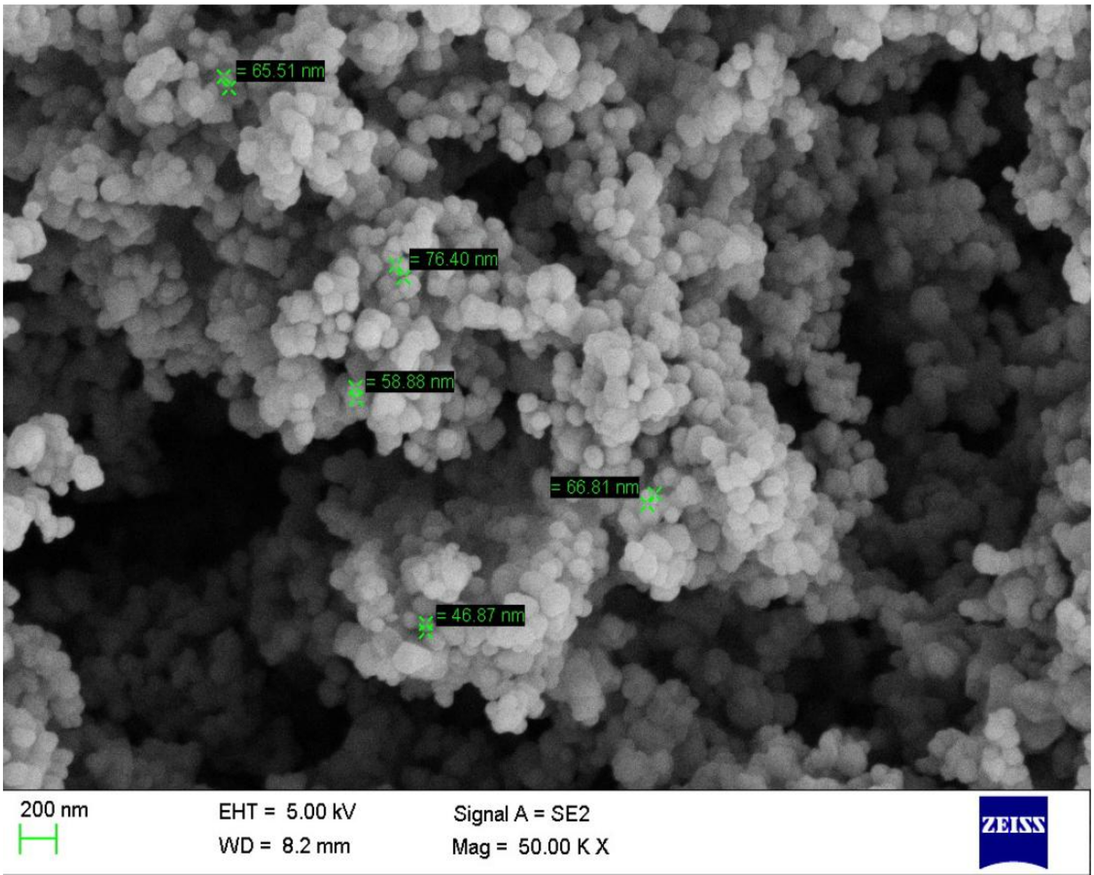


Fig 4.1: SEM image of TiO_2 with Magnification at 50,000 X

The above figure depicts the 3-D image of the sample TiO_2 that was analysed by Scanning Electron Microscope at the magnification of fifty thousand X. The various particles of the sample were of the size 46.87 nm, 66.81nm, 58.88nm, 76.40nm and 65.51nm. The average size of the particle from the above mentioned sizes is 62.89nm.

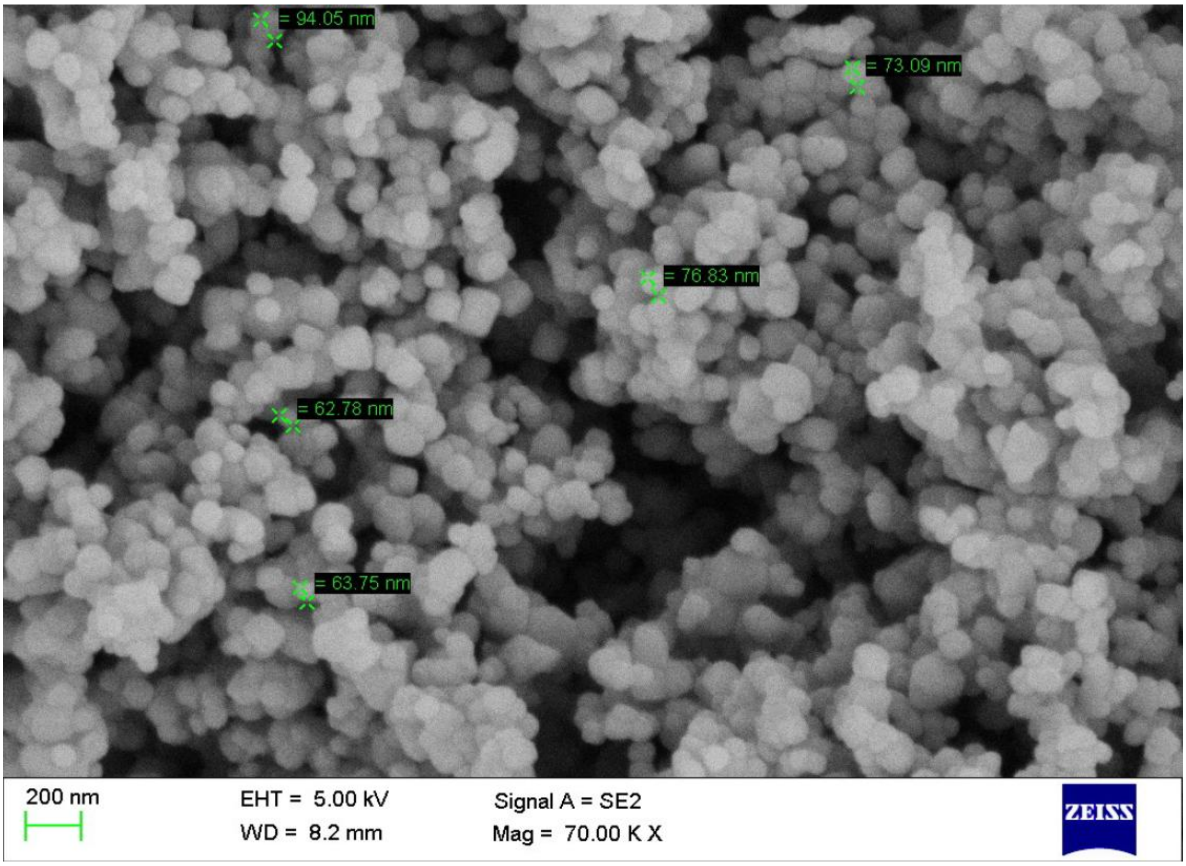


Fig4.2: SEM image of TiO_2 with Magnification at 70,000 X

The above figure depicts the 3-D image of the sample TiO_2 that was analysed by Scanning Electron Microscope at the magnification of seventy thousand X. The various particles of the sample were of the size 94.05nm, 73.09nm, 76.83nm, 62.78nm and 63.75nm. The average size of the particle from the above mentioned sizes is 74.1nm.

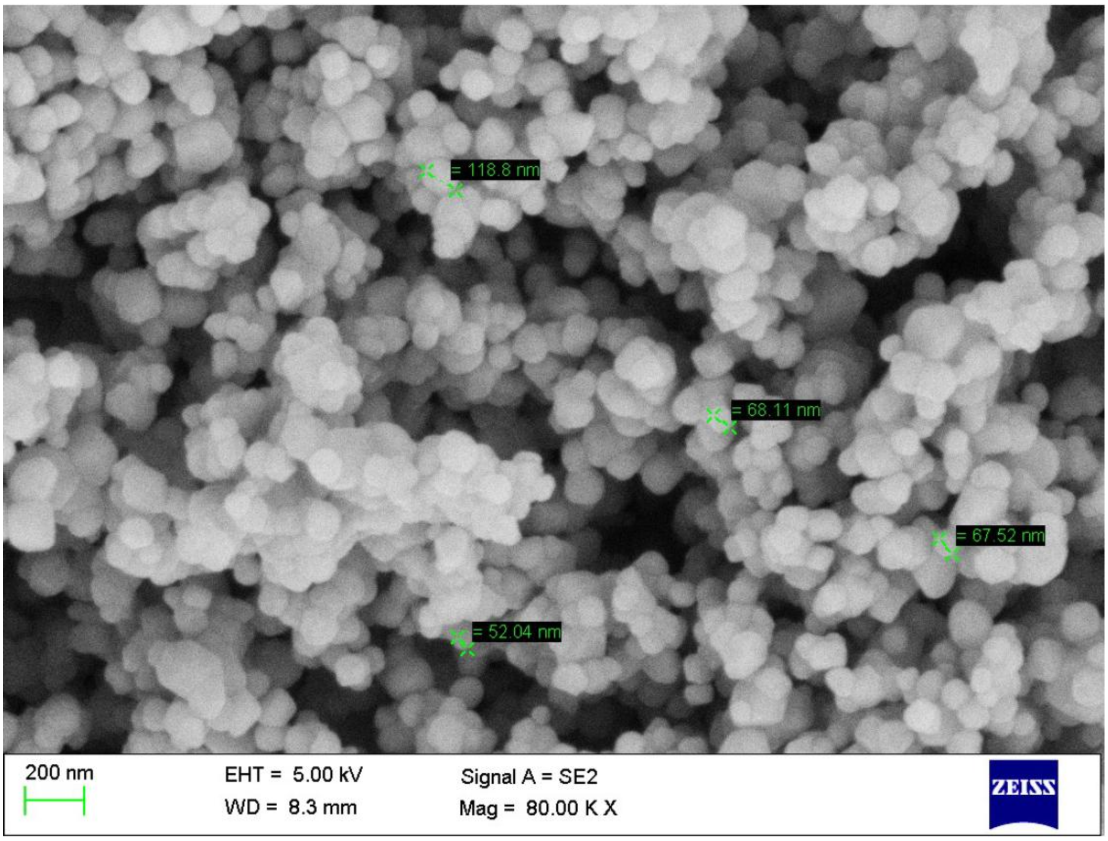


Fig4.3: SEM image of TiO_2 with Magnification at 80,000 X

The above figure depicts the 3-D image of the sample TiO_2 that was analysed by Scanning Electron Microscope at the magnification of seventy thousand X. The various particles of the sample were of the size 118.18nm, 68.11nm, 67.52nm, 52.04nm. The average size of the particle from the above mentioned sizes is 76.46nm.

4.2 XRD

X-ray diffraction techniques are very useful for crystal structure analysis and identification of different types of crystals. Experimental study of crystalline materials became possible only after the discovery of X-rays. Diffraction occurs when waves traveling through an object whose dimensions are order of wavelength. Typical inter atomic spacing in crystals is 2-5°A. The X-rays have wavelengths 0.02°A to 100°A in this range. Hence, x-ray diffraction is utilized to study the crystal structures.

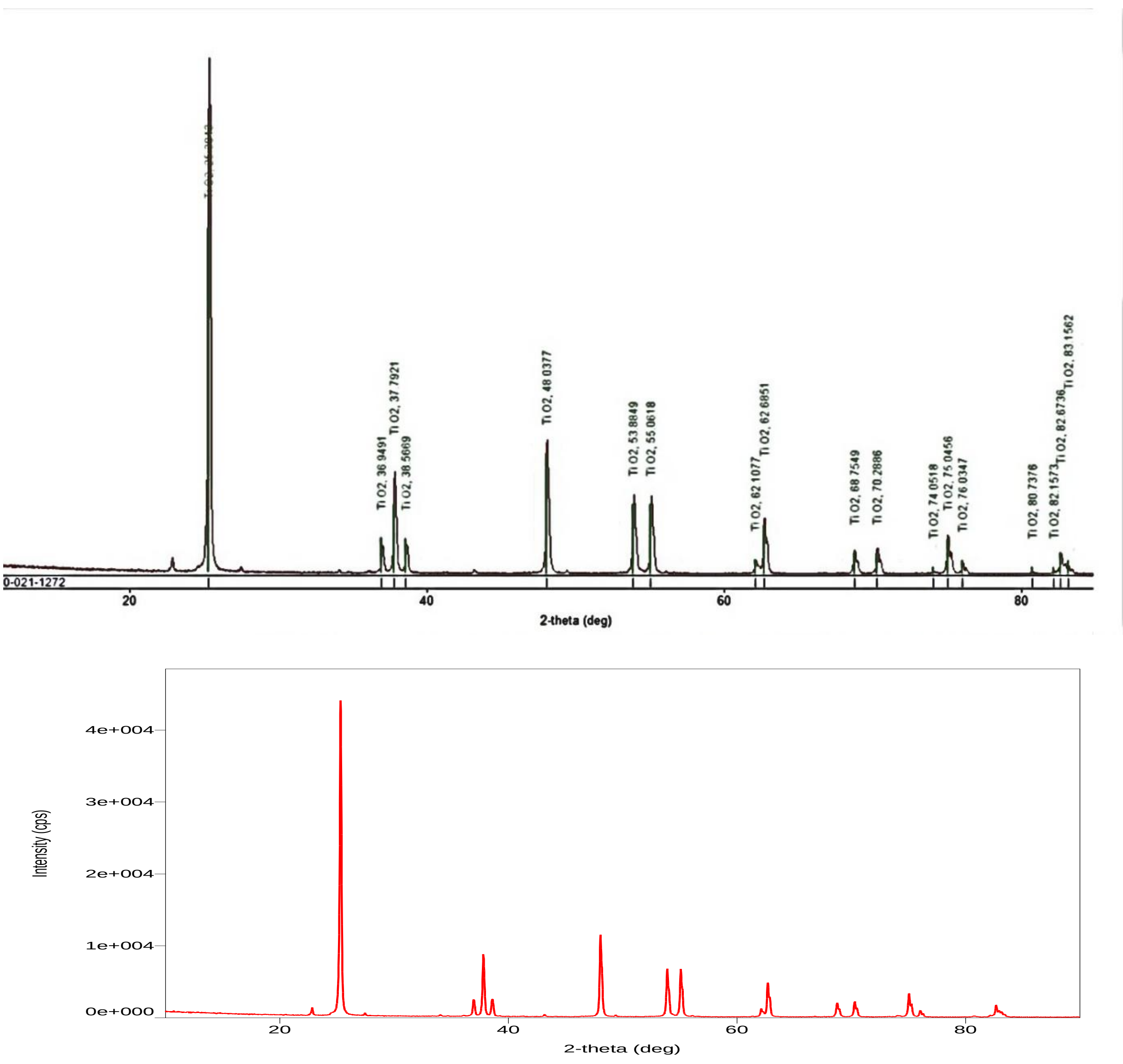


Fig4.4: XRD diffraction patterns of anatase TiO_2 (powder form)

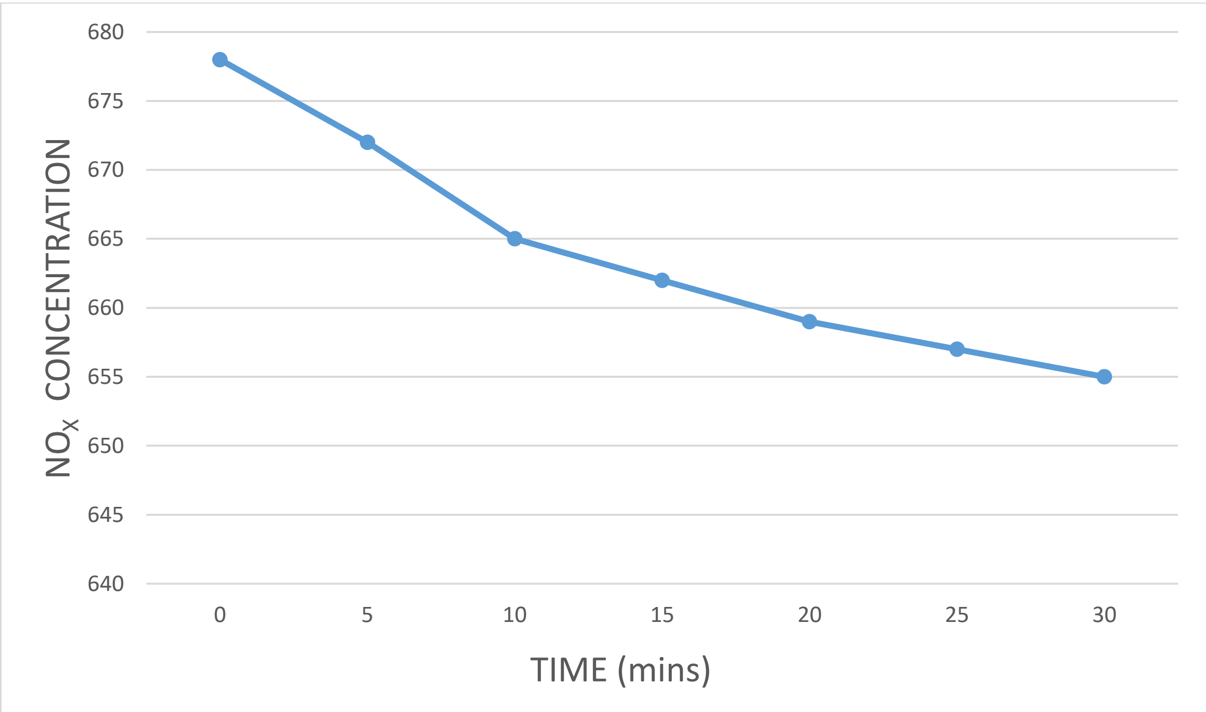
4.3 LEAKAGE TEST

To find out the leakage of the experimental setup, a leakage test was conducted in the absence of UV light in an empty Chamber and the NO_x gases were produced and tested.

Table 4.1: Amount of NO_2 reduction during leakage test for 30 min

SL NO	TIME (minutes)	NO_2 CONCENTRATION (PPM)
1	0	678
2	5	672
3	10	665
4	15	662
5	20	659
6	25	657
7	30	655

Graph 4.1: Graph showing Amount of NO_2 reduction during leakage test for 30 min



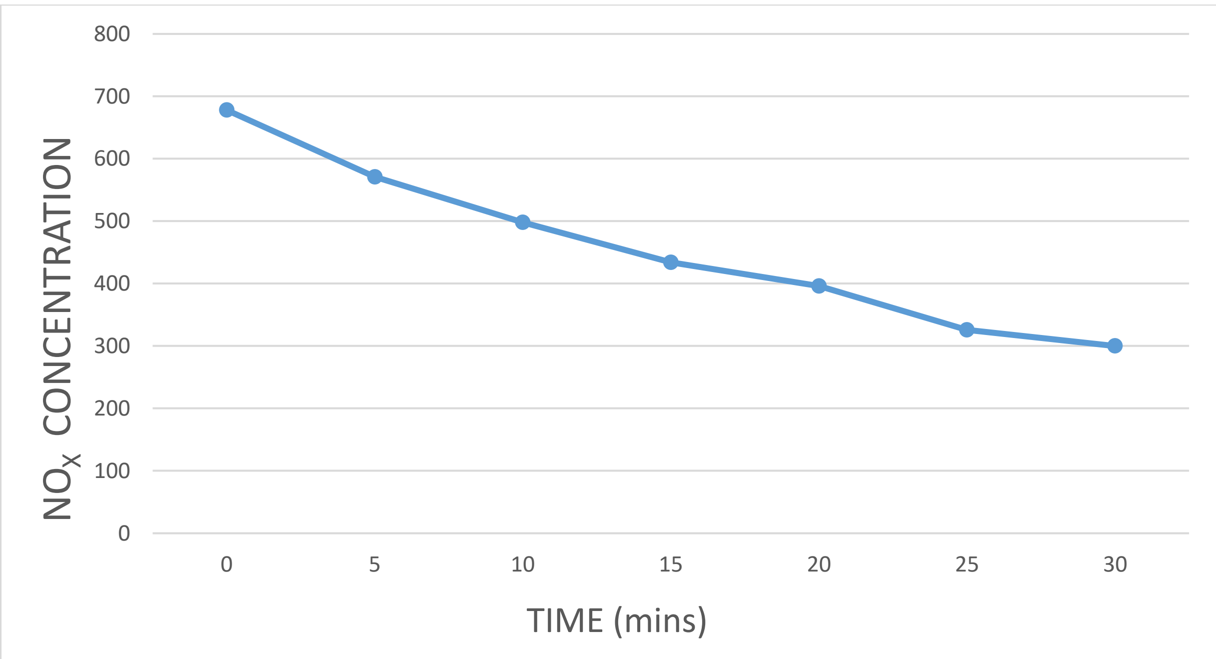
4.4 NO_2 REDUCTION BY PAVEMENT BLOCK FOR SAMPLE 1 -PAINT MIXED WITH 25% TiO_2 IN PRESENCE OF UV LIGHT (UV Lamp)

The test sample 1- Paint mixed with TiO_2 coating on pavement block was placed inside the glass chamber and by inserting the Gas Analyzer probe at one side of the hole and letting of NO_x gases through the other side of the hole with the help of the tube, the test was conducted in the presence of UV light for a contact period of 30 mins.

Table 4.2: Amount of NO_2 reduction from pavement block – Paint mixed with 25% TiO_2 with UV for 30 min.

SL NO	TIME (minutes)	NO_2 CONCENTRATION (PPM)
1	0	678
2	5	571
3	10	498
4	15	434
5	20	396
6	25	326
7	30	300

Graph 4.2: Graph showing Amount of NO_2 reduction from pavement blocks – SAMPLE 1 with UV for 30 min



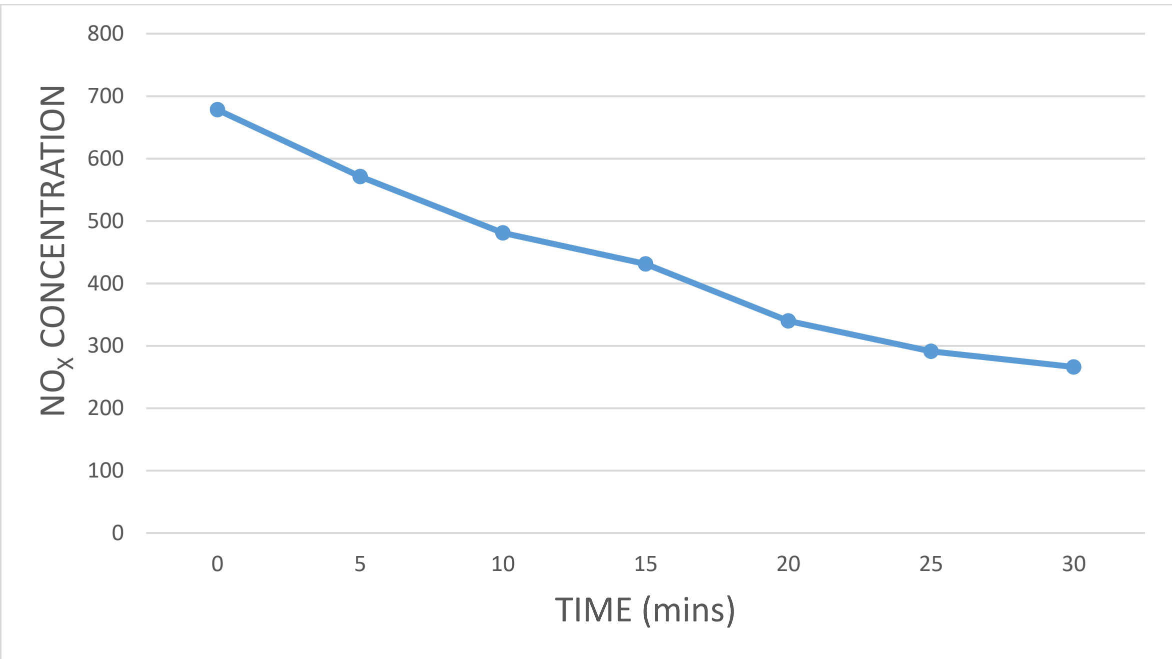
4.5 NO_2 reduction by pavement block for Sample 2 – Water mixed 25% TiO_2 in presence of UV light (UV Lamp)

The test sample 2- Water mixed with TiO_2 coating on pavement block was placed inside the glass chamber and by inserting the Gas Analyzer probe at one side of the hole and letting of NO_x gases through the other side of the hole with the help of the tube, the test was conducted in the presence of UV light for a contact period of 30 mins.

Table 4.3: Amount of NO_2 reduction from pavement block- Sample 2 with UV for 30 min.

SL NO	TIME (minutes)	NO_2 CONCENTRATION (PPM)
1	0	678
2	5	571
3	10	481
4	15	431
5	20	340
6	25	291
7	30	266

Graph 4.3: Graph showing Amount of NO_2 reduction from pavement block – Sample 2 with UV for 30 min



4.6 SATURATION POINT ANALYSIS FOR TiO_2 COATED ON PAVEMENT BLOCK OF SAMPLE 1 – Paint mixed TiO_2

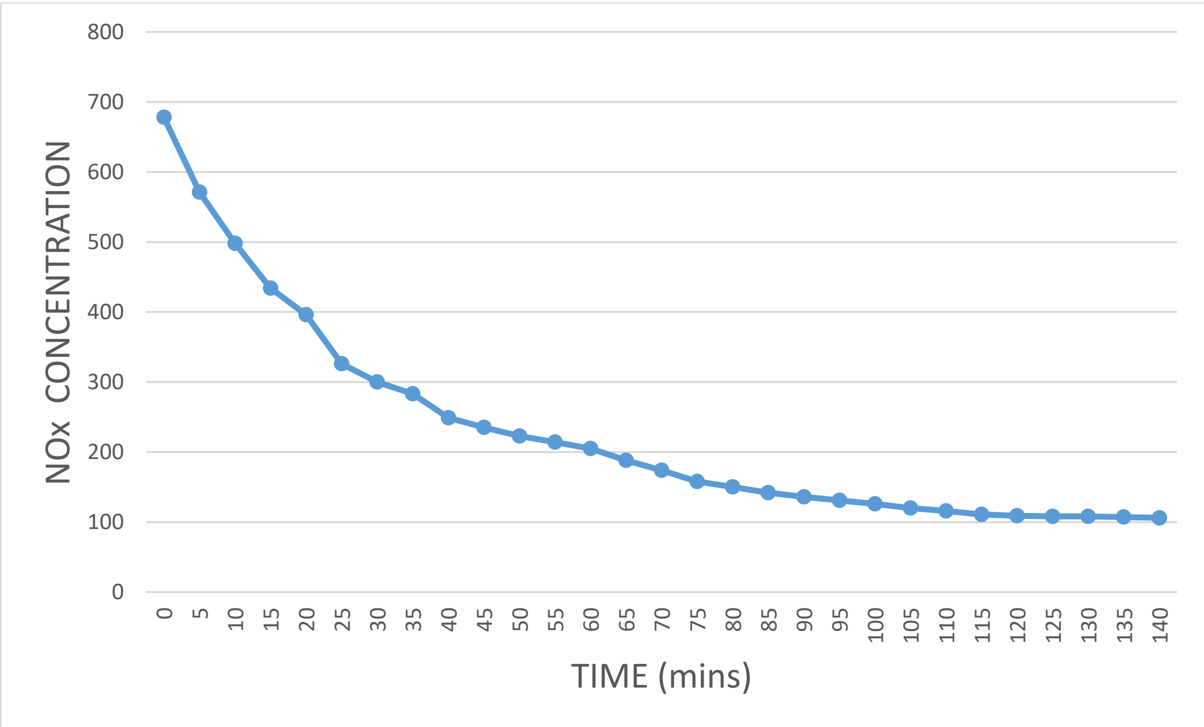
A test was conducted to analyze the saturation point of pavement block where TiO_2 was mixed with paint and was coated on the pavement block and tested in the presence of UV light. The result shows that the rate of reduction of the polluted air enclosed in the experimental setup reaches to a saturation point after a particular time period. The Graph shows Saturation Point for pavement block in presence of UV light for 140 min.

Table 4.4: Saturation Point of Paint mixed TiO_2 on Pavement Block

SL NO	TIME (mins)	NO_X CONCENTRATION OF TEST SAMPLE -1 IN PRESENCE OF UV LIGHT
1	0	678
2	5	571
3	10	498
4	15	434
5	20	396
6	25	326
7	30	300
8	35	283
9	40	249
10	45	235
11	50	223
12	55	214
13	60	205
14	65	188
15	70	174
16	75	158
17	80	150
18	85	142
19	90	136
20	95	131

21	100	126
22	105	120
23	110	116
24	115	111
25	120	109
26	125	108
27	130	108
28	135	107
29	140	106

Graph 4.4: Graph showing Saturation Point of Paint mixed TiO_2 on Pavement Block with UV for 140 min



4.7 SATURATION POINT ANALYSIS FOR TiO_2 COATED ON PAVEMENT BLOCK OF SAMPLE 2 –Water mixed TiO_2

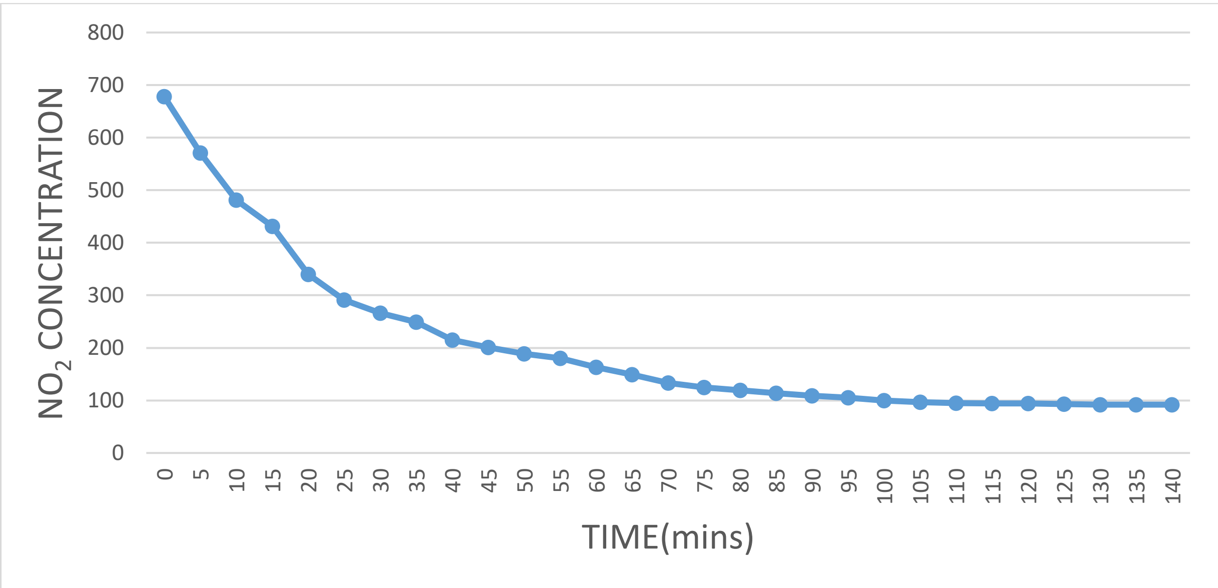
A test was conducted to analyze the saturation point of pavement block for sample - 2 where TiO_2 was mixed with water and was coated on the pavement block and tested in the presence of UV light. The result shows that the rate of reduction of the polluted air enclosed in the experimental setup reaches to a saturation point after a particular time period. The Graph shows Saturation Point for pavement block in presence of UV light for 140 min.

Table 4.5: Saturation Point of Water mixed TiO_2 on Pavement Block

SL NO	TIME (mins)	NO_X CONCENTRATION OF TEST SAMPLE -2 IN PRESENCE OF UV LIGHT
1	0	678
2	5	571
3	10	481
4	15	431
5	20	340
6	25	291
7	30	266
8	35	249
9	40	215
10	45	201
11	50	189
12	55	180
13	60	163
14	65	149
15	70	133
16	75	125
17	80	119
18	85	114
19	90	109
20	95	105

21	100	100
22	105	97
23	110	95
24	115	94
25	120	94
26	125	93
27	130	92
28	135	92
29	140	92

Graph 4.5: Graph showing Saturation Point of Water mixed TiO_2 on Pavement Block with UV for 140 min



CHAPTER 5

EXPERIMENTAL PROCEDURE

5.1 MATERIALS

5.1.1 Materials used for Nitrogen Oxides Preparation

1) Copper metal piece
2) Conc. Nitric acid
3) 250 ml conical flask
4) 50 ml Beaker
5) 100 ml Measuring Jar
6) Dilute H_2SO_4
7) Concentrated Sodium Nitrite Solution
8) Concentrated $FeSO_4$ Solution
9) Dropper
10) Safety Gloves

Fig5.1: Nitric acid (500 ml)

Fig 5.11: 250 ml conical flask

Fig 5.12: copper metal pieces

5.1.2 Materials Used For Glass Chamber Setup

1) 30cm x 20cm x 20cm Glass box with air tight Covering
2) 300W Ultra Vitalux Lamp
3) Indus Flue Gas Analyzer (Model FGA 53X)
4) Tubes
5) Rubber Corks
6) Sealing Clay
7) ¾ inch Diameter Pipes
8) Plane glass

5.2 Nitrogen Oxides Preparation

Nitric Oxide or Nitrogen monoxide (NO) can be obtained when acidified Ferrous Sulphate Solution is warmed with concentrated Sodium Nitrite Solution.

$2NaNO_2 + 2FeSO_4 + 3H_2SO_4 \rightarrow Fe_2(SO4)_3 + {}_2NaHSO_4 + 2H_2O + 2NO$

Take a Known amount of concentrated $FeSO_4$ solution in a conical flask and acidify it with Dilute H_2SO_4. Mix the solution and add concentrated Sodium Nitrite Solution which turns Dark in color.

Due to the Reaction, Nitrogen Monoxide gas is liberated which is a colorless gas. On further warming using Bunsen burner, Nitrogen Monoxide continues to Liberate.

Nitrogen Monoxide Gas which is unstable when comes in contact with Atmospheric Oxygen converts into Nitrogen Dioxide which is a Dark Brown Colored Corrosive Gas with a Foul smell.

5.2.1 Prototype preparation

$Cu\ (s) + 4HNO_3\ (aqs) \rightarrow Cu(NO_3)_2\ (aqs) + 2NO_2\ (g) + 2H_2O\ (l)$

This experiment demonstrates the reaction between copper and nitric acid:

$Cu + 4HNO_3 \rightarrow Cu(NO_3)_2 + 2NO_2 + H_2O$

At the first stage when copper reacts with concentrated nitric acid the metal ion coordinates with nitrate ions. This complex gives green color to the solution. The brown gas produced in the reaction is nitrogen dioxide. When water is added the solution becomes blue since nitrate ions are replaced by water molecules from the copper coordination shell. Nitrogen dioxide dissolves in the solution.

Fig 5.2: Brown gas produced from the reaction

5.3 Design of Experimental Setup

A laboratory environmental system was used to evaluate the pollutant removal efficiency due to the photocatalytic effect of the TiO_2. Design of an experimental setup with an Environmental Chamber made of glass box with dimension 30x20x20cm. The top portion of the chamber is covered with an Air tight glass panel. A hole of 2cm is inserted at the center portion of the side wall of the box so as to insert the probe of the gas analyzer. When there is unavailability of solar light a UV light of 300W is fixed to the top portion of the chamber. A small pipe is connected at the other side panel hole of the box with tube fixed on to it so that the NO_x gas mixture produced can be passed to the box through that pipe. After filling the experimental setup box with polluted air, the Tube is closed with an air tight rubber cork so as to avoid the air leakage from the experimental setup.

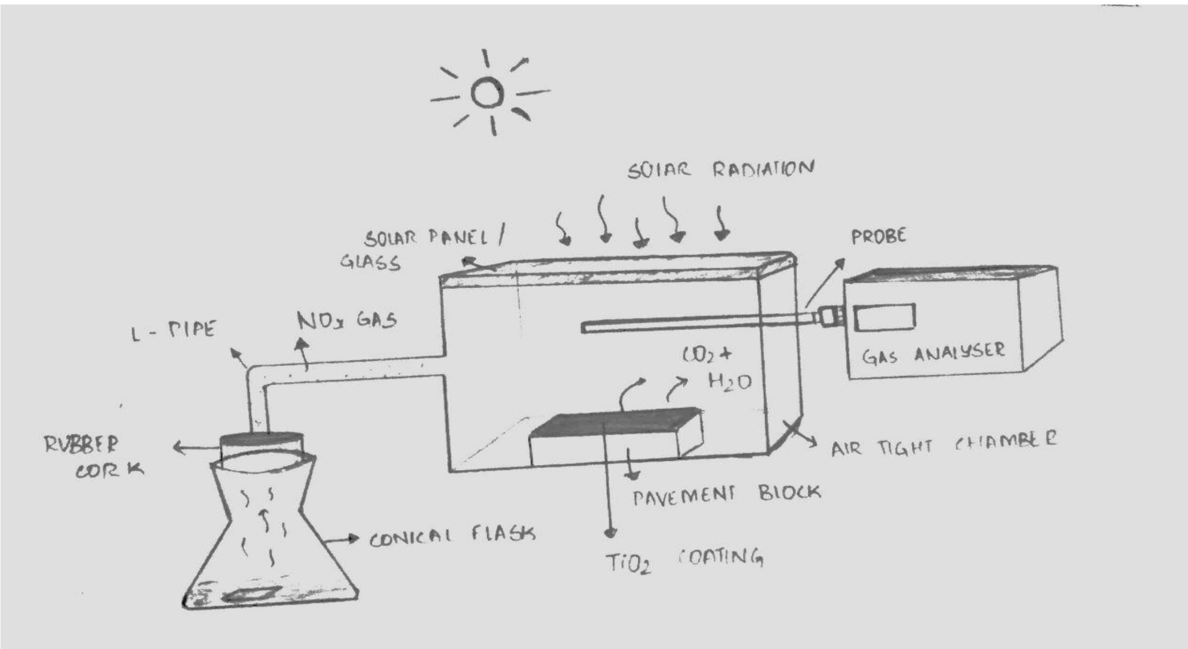


Fig 5.3: Experimental set up

Fig 5.31: Setting up the chamber

5.4 Gas Analyzer

Exhaust gas analyzer is used to measure exhaust gas composition. The amount of pollutant enclosed within the experimental set up was measured with the help of Indus Flue Gas Analyzer (Model FGA 53X). The analyzer measures the concentration of CO, CO_2, HC, O_2 and NOx enclosed within the experimental set up.

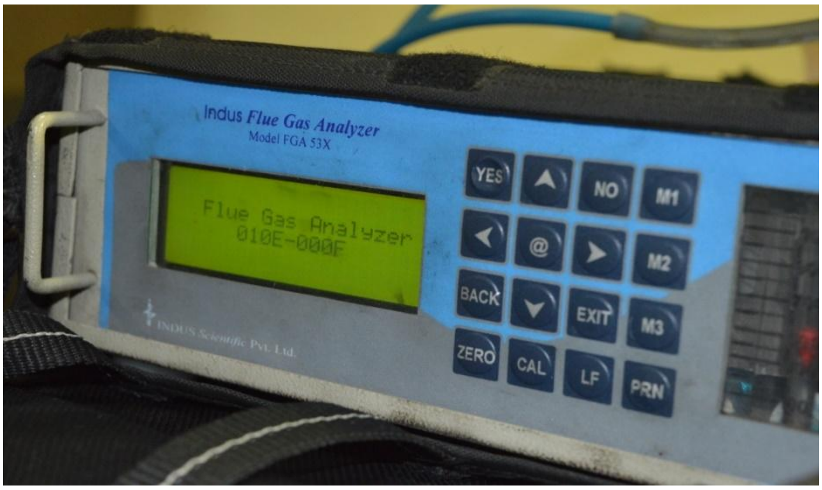


Fig 5.4: Gas Analyzer

Analyzer Indus Flue Gas Analyzer (Model FGA 53X) is a class I Gas Analyzer designed and manufactured for testing the emissions from automotive engines, which run on diesel, petrol as well as CNG and LPG as well as stack monitoring. The instrument can measure Carbon monoxide, Carbon dioxide and Oxygen in percentage, and Hydrocarbons and Nitrogen dioxide in ppm. It is generally supplied as a four gas analyzer without the NO_2 Sensor. When NO_2 sensor is added it becomes a 5 Gas analyzer. The analyzer uses the principle of Non-Dispersive Infra Red for measurement.

Fig 5.41: Gas analyzer probe

The above shown Gas analyzer probe is of 42 inches long having 3/4th inch outer to outer diameter.

5.5 TEST MATERIAL PREPARATION

5.5.1 TiO_2

Ultra-fine (nano-scale) titanium dioxide (Anatase) was used in this study for surface treatment. It consists of commercial water-based TiO_2 mixed with known quantity of Distilled water and brushed onto the surface of Test materials and kept for Material testing.

The main properties of TiO_2 are:

- Low cost and economical
- Fast reaction at ambient operating conditions (room temperature, atmospheric pressure)
- A wide spectrum of organic contaminants can be decomposed
- No chemical reactants must be used and no side reactions are produced. TiO_2 works as a catalyst and does not undergo change.

Fig 5.5: TiO_2 powder

Fig5.51: 25kg TiO_2 powder bag

5.5.2 Titanium Dioxide

Titanium dioxide which is a photocatalyst occurs in nature as the well-known minerals rutile, anatase and brookite. One of these is known as akaogiite and should be considered as an extremely rare mineral. It is mainly sourced from ilmenite ore. This is the most widespread form of titanium dioxide-bearing ore around the world. Rutile is the next most abundant and contains around 98% titanium dioxide in the ore. The metastable anatase and brookite phases convert irreversibly to the equilibrium rutile phase upon heating above temperatures in the range 600–800 °C (1,112–1,472 °F).

The production method depends on the feedstock. The most common method for the production of titanium dioxide utilizes the mineral ilmenite. Ilmenite is mixed with sulfuric acid. This reacts to remove the iron oxide group in the ilmenite. The by-product iron(II) sulfate is crystallized and filtered-off to yield only the titanium salt in the digestion solution. This product is called synthetic rutile. This is further processed in a similar way to rutile to give the titanium dioxide product. Synthetic rutile and titanium slags are made especially for titanium dioxide production. The use of ilmenite ore usually only produces pigment grade titanium dioxide. Another method for the production of synthetic rutile from ilmenite utilizes the Becher Process. [11]

Rutile is the second most abundant mineral sand. Rutile found in primary rock cannot be extracted hence the deposits containing rutile sand can be mined meaning a reduced availability to the high concentration ore. Crude titanium dioxide (in the form of rutile or synthetic rutile) is purified via converting to titanium tetrachloride in the chloride process. In this process, the crude ore (containing at least 70% TiO_2) is reduced with carbon, oxidized with chlorine to give titanium tetrachloride, i.e., carbothermal chlorination. This titanium tetrachloride is distilled, and re-oxidized in a pure oxygen flame or plasma at 1500–2000 K to give pure titanium dioxide while also regenerating chlorine. Aluminium chloride is often added to the process as a rutile promotor, the product is mostly anatase in its absence.

5.5.3 TEST SAMPLE 1 – Paint mixed TiO2 coating on pavement block

The test sample 1 was prepared by mixing 25% TiO_2 with paint and was coated evenly on the surface of the pavement block. The coating of the paint was done through brushing the paint evenly on the surface of pavement block.

5.5.4 TEST SAMPLE 2 – Water mixed TiO_2 coating on pavement block

The test sample 2 was prepared by mixing 25% TiO2 with 100 ml of water and the paste obtained was brushed on the surface of the pavement block and was evenly coated.

5.6 METHODOLOGY

The material to be tested was placed inside the environmental chamber and was sealed for air tightness. The sample surface is kept at the base of the air tight chamber. The gas analyzer probe was inserted into the chamber and the hole was properly sealed. NO_x gases is prepared using manual method and is connected to a L tube. This gas is sent into the Environmental Chamber through a small pipe. The Environmental Chamber has a glass panel to induce solar radiation or the artificial uv radiation effectively thus providing the uv light.

The gas contained in box is exposed to ultraviolet light, only then the photo catalytic reaction of Titanium dioxide with the pollutants takes place. After a particular time i.e., after the photo catalytic reaction the pollutants will be decomposed into nitrate ions from the redox reactions of the photocatalysis, and thus the amount of pollution is getting reduced. This is monitored by using the gas analyzer.

Also, the reaction of TiO_2 under the absence of uv light is also tested. In order to find out the leakage of air from the experimental setup, a leakage test is also conducted. During these tests it is found that the amount of pollution presented in the box reduces considerably and it reaches to a saturation point after a particular time period.

Fig 5.6: Glass chamber with a 2cm hole for insertion of Gas Analyzer probe

5.6.1 Tests that are planned to be Conducted

- Leakage Test for Air tight Glass Chamber (Empty Box without UV light) for 25% TiO_2 concentration.
- NOx reduction by pavement block of sample 1 – paint mixed with 25% TiO_2 in presence of UV light
- NOx reduction by pavement block of the sample 2 – water mixed with 25% TiO_2 of UV light (UV lamp)
- Saturation point analysis for NOx reduction by pavement block - sample 1 in presence of UV light
- Saturation point analysis for NOx reduction by pavement block - sample 2 in presence of UV light

5.7 TiO_2 AS PHOTO CATALYST

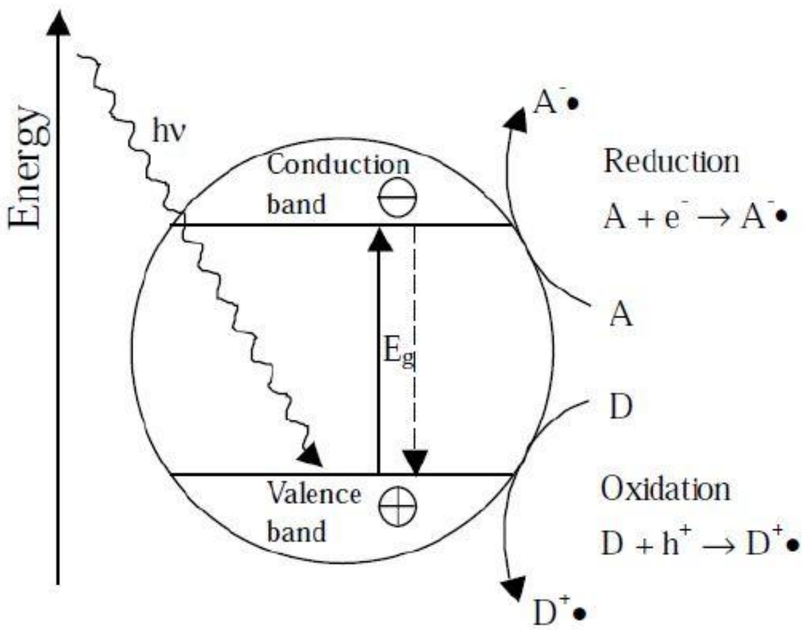
Titanium dioxide is one of the basic materials in everyday life. It has been widely used as white pigment in paints, cosmetics and food stuffs. TiO_2 exists in three crystalline modifications: rutile, anatase, and brookite. Generally, titanium dioxide is a semiconducting material which can be chemically activated by light. The photoactivity of TiO_2 which is known for approx. 60 years is investigated extensively. For a long time there was a considerable problem especially what its application as pigment concerns. Under the influence of light the material tends to decompose organic materials. This effect leads to the well known phenomenon of "paint chalking", where the organic components of the paint are decomposed as result of photo catalytic processes. Compared with rutile and brookite, anatase shows the highest photoactivity. Therefore, the TiO_2 used in industrial products is almost exclusively from the rutile type. In the following, TiO_2 always denotes the anatase modification. Although TiO_2 absorbs only approximately 5% of the solar light reaching the surface of the earth, it is the best investigated semiconductor in the field of chemical conversion.

$TiO_2 + h\nu \rightarrow h^+ + e^-$

TiO_2 is a semiconductor with a band gap energy Eg = 3.2 eV. If this material is irradiated with photons of the energy > 3.2 eV (wavelength λ < 388 nm), the bandgap is exceeded and an electron is promoted from the valence to the conduction band. Consequently, the primary process is the charge carrier generation.

5.7.1 BASIC PRINCIPLE

When a photon with energy of hν exceeds the energy of the band gap an electron (e-) is promoted from the valence band to the conduction band leaving a hole (h+) behind. In electrically conducting materials, i.e. metals, the produced charge carriers are immediately recombined. In semiconductors a portion of this photo excited electron-hole pairs diffuse to the surface of the catalytic particle (electron-hole pairs are trapped at the surface) and take part in the chemical reaction with the adsorbed donor (D) or acceptor (A) molecules. The holes can oxidize donor molecules (eqn. 1) whereas the conduction band electrons can reduce appropriate electron acceptor molecules (eqn. 2).



5.7: Operation of a photochemical excited TiO2 particle

$D + h^+ \rightarrow D^{\bullet +}$ 1

$A + e^- \rightarrow A^{\bullet -}$ 2

A characteristic feature of semiconducting metal oxides is the strong oxidation power of their holes h+. They can react in an one-electron oxidation step with water (eqn. 3) to produce the highly reactive hydroxyl radical (•OH). Both the holes and the hydroxyl radicals are very powerful oxidants, which can be used to oxidize most organic contaminants.

$H_2O + h^+ \rightarrow {}^\bullet OH + H^+$...........3

In general, air oxygen acts as electron acceptor (eqn. 4) by forming the super-oxide ion $O_2^{\bullet -}$.

$O_2 + e^- \rightarrow O_2^{\bullet -}$ ………..4

Super-oxide ions are also highly reactive particles, which are able to oxidize organic materials. [10]

5.7.2 TiO_2 PHOTOCATALYSIS

(1) Photocatalysis

$$TiO_2 + h\upsilon \longrightarrow TiO_2^* (h^+_{vb} + e^-_{cb}) \quad \text{charge carrier generation}$$

$$OH^-_{(ads)} + h^+_{vb} \longrightarrow OH^\bullet_{(ads)} \quad \text{hole trapping}$$
$$O_{2\,(ads)} + e^-_{cb} \longrightarrow O^-_{2\,(ads)} \quad \text{electron trapping}$$

(2a) Oxidation using hydroxyl radicals: $OH^\bullet$

$$\text{(a)}\ NO_{(g)} + 2OH^\bullet_{(ads)} \longrightarrow NO_{2\,(ads)} + H_2O_{(ads)}$$
$$\text{or (b)}\ NO_{2\,(ads,g)} + OH^\bullet_{(ads)} \longrightarrow NO^-_{3\,(ads)} + H^+_{(ads)}$$

(2b) Oxidation using "active oxygen": O_2^-

$$NO_{x\,(ads)} \xrightarrow{O^-_{2\,(ads)}} NO^-_{3\,(ads)}$$

(2c) Reaction with Ti-OH via disproportion[3]

$$3NO_2 + 2OH^- \longrightarrow 2NO_3^- + NO + H_2O$$

Fig 5.8 : TiO_2 Photocatalysis

5.7.3 Factors Affecting Photocatalytic Effect

Photocatalysis can be affected by environmental factors, such as light wavelength and intensity, relative humidity, temperature, and wind. The best results for the photocatalytic effect are with higher temperatures and light intensities greater than 300 nm. An optimal condition to remove air pollutants would be a hot summer day with low relative humidity and no wind.

CHAPTER 6

RESULTS AND DISCUSSIONS

6.1 RESULTS:

1) The percentage of NO_x reduction during leakage test performed for a contact period of 30 mins indicated 3.39% of leakage from the glass set up.

   As the Glass camber was man made and there could be possibility of human errors

   the Leakage test shows a small percentage of air leaks through the glass chamber

   setup.

2) The efficiency of the amount of NO_x gas reduction from pavement block – Paint mixed with 25% TiO_2 with the presence of uv light for a contact period of 30 mins was up to 52.36% due to the photo catalytic activity of TiO_2.
3) The efficiency of the amount of NO_x gas reduction from pavement block – Water mixed with 25% TiO_2 with the presence of uv light for a contact period of 30 mins was up to 57.36% due to the photo catalytic activity of TiO_2.
4) The Pavement Block which was coated with TiO_2 mixed with paint resulted in 80.97% of the reduction of NOx gases within 140 min and it tends almost to saturation level after 120 minutes.
5) The Pavement Block which was coated with TiO_2 mixed with water resulted in 83.04% of the reduction of NOx gases within 140 min and it tends almost to saturation level after 120 minutes.
6)

6.2 DISCUSSIONS:

1) From Table 1 to Table 5, the results obtained from the analysis was tabulated respectively.
2) Graphs were plotted for all the results obtained from Table 1 to Table 3 with NOx removal efficiency of TiO_2 for a contact period of 30 minutes and for the table 4 and table 5 for saturation point analysis for a period of 140 mins.
3) Saturation Point Analysis was carried out for 140 minutes and the results were tabulated in Table 4 and Table 5.
4) Graphs were plotted for the results obtained from Table 4 and Table 5 to know the Saturation point of TiO_2 used in two different test samples.
5) From the Table 1, it was observed that for a contact period of 30 min, Calculated percentage leak found out during the experiment is 3.39%.
6) The Leakage test shows a small percentage of air leaks through the glass chamber setup.
7) Graph 1 shows the Graphical representation results of leakage which took place during the Experimental analysis.

8) From the Table 2, it was observed that for a contact period of 30 min, Pavement block which were Coated with TiO_2 mixed with paint in Presence of UV light was efficient in reducing the NOx gases up to 52.36% due to the photo catalytic activity of TiO_2.

9) Graph 2 shows the Graphical representation the results obtained for Pavement block which was Coated with TiO_2 mixed with paint in Presence of UV light.

10) From the Table 3, it was observed that for a contact period of 30 min, Pavement block which were Coated with TiO_2 mixed with water in Presence of UV light was efficient in reducing the NOx gases up to 57.36% due to the photo catalytic activity of TiO_2.

11) Graph 3 shows the Graphical representation of Pavement Block which was Coated with TiO_2 mixed with water in presence of UV light.

12) From the Table 4, we observed that Pavement Block coated with TiO_2 mixed with paint about 80.97% NOx is getting reduced within 140 min and it tends almost to saturation level after 120 minutes.

13) Graph 4 shows the Graphical representation of the results obtained for the saturation point analysis for Sample 1.

14) From the Table 5, we observed that Pavement Block coated with TiO_2 about 83.04% NOx is getting reduced within 140 min and it tends almost to saturation level after 120 minutes.

15) Graph 5 shows the Graphical representation of the results obtained for the saturation point analysis for Sample 2.

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CHAPTER 7

CONCLUSIONS

1) From the experiments and analysis conducted as a part of the project, it is concluded that the TiO_2 photo catalyst in the presence of UV light is a good solution for rising air pollution problems.
2) TiO_2 photo catalyst helps to reduce a major portion of NO_2 which is a dangerous pollutant presented in the atmosphere in the presence of UV light.

TiO_2 helps to reduce about average 70% to 80% of The NOx gases within he saturation time and serves as a good catalyst for air pollution mitigation.

3) It seems that the TiO_2 photo catalyst doesn't have major role in reducing the concentration of CO and the CO_2.
4) Also, it is concluded that the TiO_2 photo catalyst is not active during the absence of UV light. So, the activity of TiO_2 remains inefficient during night time. Hence, a UV lamp can be implemented as street lamps which could keep the reaction effective even during the night.
5) It is noted that the reduction rate of pollution in the presence of UV light with the help of TiO_2 photo catalyst reaches to a saturation point after a particular time period. This saturation point is also depended on the amount of TiO_2.
6) Overall it is concluded that TiO_2 photo catalyst is good for reducing the major amount of NO_2 presented in the atmosphere which is a dangerous gas.
7) It is recommended to use TiO_2 in Anatase form as an excellent Photocatalyst for removal of NOx Gases from Ambient Air because it has better removal efficiency.
8) Use of TiO_2 is economical since its widely available in market and is Cost effective.
9) It is recommended as it has fast reaction at ambient operating conditions (room temperature, atmospheric pressure).
10) TiO_2 as a Photo Catalyst A wide spectrum of organic contaminants can be converted to water and CO_2.
11) No chemical reactants are required to activate the photo Catalytic activity of TiO_2 and no side reactions are produced.
12) TiO_2 works as a catalyst and does not undergo change.
13) TiO_2 is Durable in Nature and its Catalytic activity remains for Longer duration of time.

CHAPTER 8

FIGURES

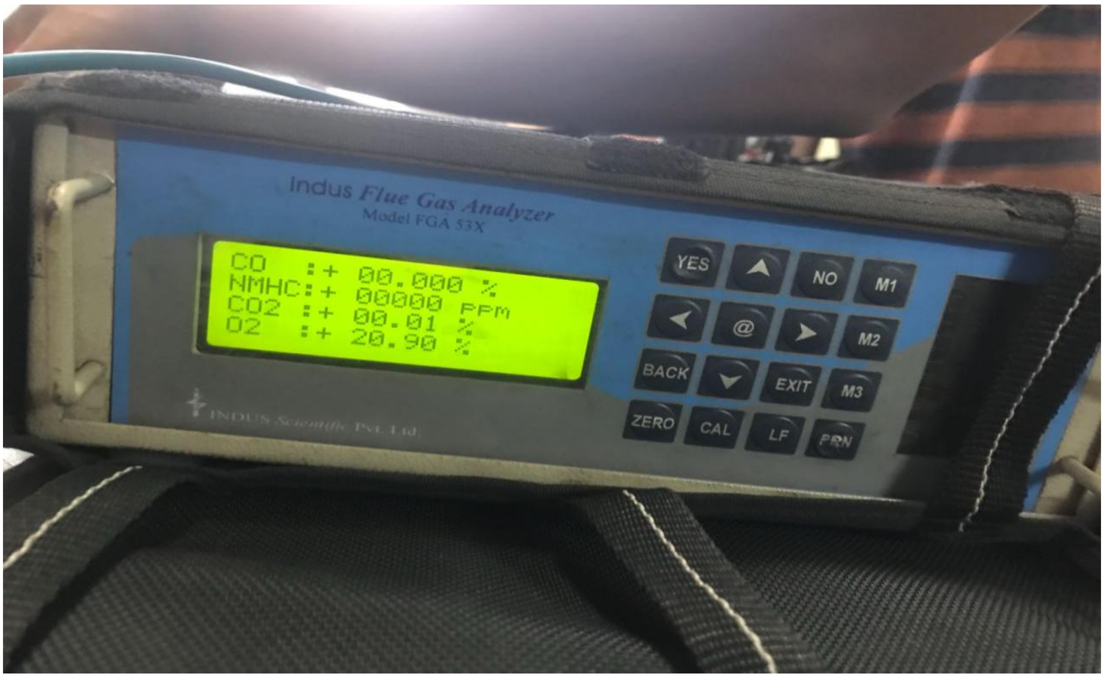

Fig 8.1: Four elemental gas analyzer

Fig 8.4: Caliberating the Gas Analyzer

Fig 8.3: Glass chamber set up before performing the analysis

Fig 8.4: Glass chamber set up along with Gas Analyzer Probe

Fig 8.5: during the leakage test (absence of UV light)

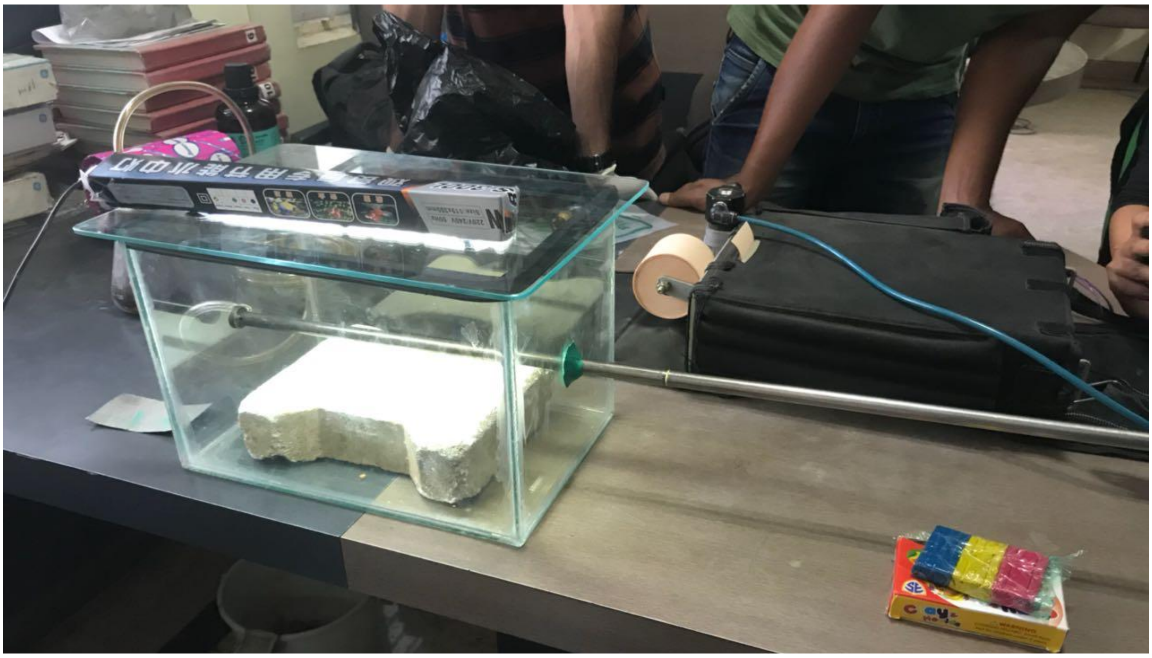

Fig 8.6: Prior to NO_x gases filling up the chamber

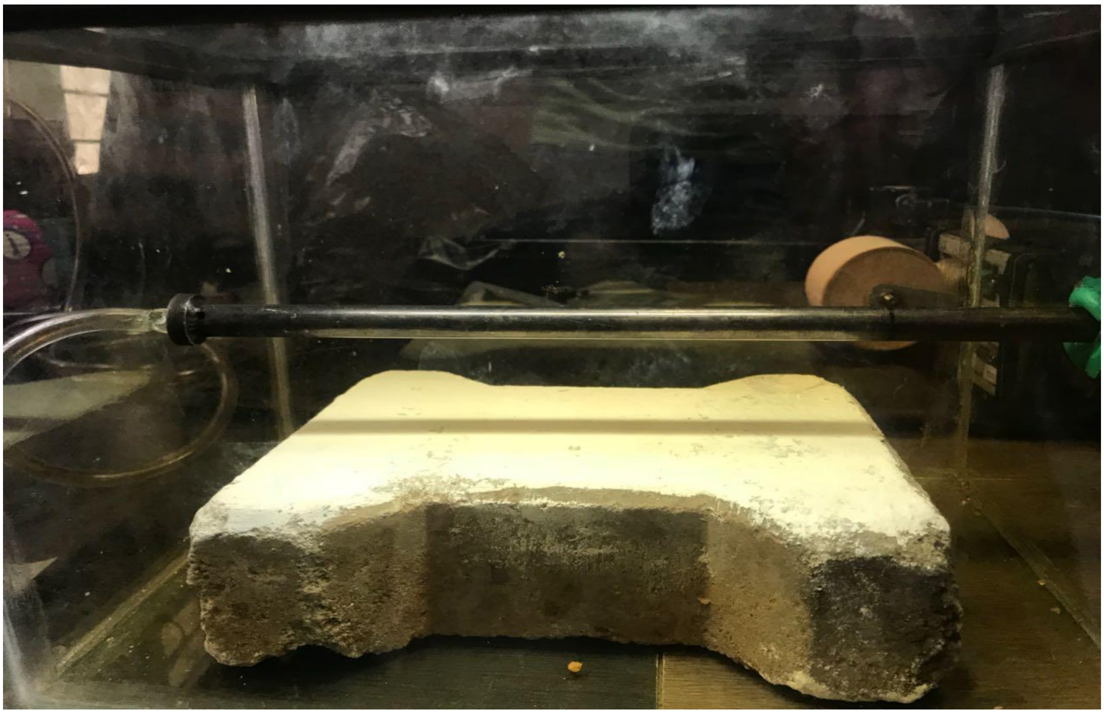

Fig 8.7: Glass chamber filling up with NO_2 gas produced

Fig 8.8: During the analysis

Fig 8.9: During the analysis

Fig 9.1: Lab assistants during the analysis

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Fig 8.9: Bangalore Test House

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