Removal of contaminants in indoor air by using green plant treated with titanium dioxide nanoparticles

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Environmental Engineering

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Titanium dioxide, Green plant, Air contaminants, Mytrus Communis, Indoor air, toxic gases.
Abstract

Background: Indoor air pollution is important environmental health problem. Nanotechnology is one of the most important methods to reduce the air pollution. The aim of this study to determine the effectiveness of nanotechnology for removal of toxic air indoor pollution by using Saudi myrtle plants treated with titanium dioxide. Methods: Experiments were conducted in the two academic departments of labs at public sector universities. Applying titanium dioxide-containing growth media to at least one of a Myrtus communis plant root, stem, and leaf. Growing the plant in the growth media, a gel growth media, or both; exposing the plant to contaminant-containing air Results: It is found that the levels of formaldehyde, Volatile organic compounds and other pollutants were significantly reduced the concentration from 10% to 98% in air. The duration of the intervention from 4 hours to 8 hours, Air containing the concentration of NO2 SO2, formaldehyde, TVOCs and CO reduced from range of 0.3 ppm- 0.4ppm to range of 0.1ppm -0.3 ppm after exposure of Myrtus plant to ambient air and duration of the exposure is 4 hours to 8 hours. Conclusion: Application of Tio2 in green plant specially Mytrus Communis is a novel approach for reduction of concentrations of harmful gaseous toxic and carcinogenic air pollutants in indoor environment.

Background

Environmental pollution is important public health problem.\textsuperscript{1} Indoor air environment has high level of toxic pollutant and most common places were affected public places such as homes, schools, offices, hospitals.\textsuperscript{1} In developed countries peoples were spent most of the time in indoors, which was exposed to polluted air that may result to adverse health effects. There are various health effects from mild disease to carcinogenic effects on human body due to this toxic air pollutants.\textsuperscript{2} the most common hazards are formaldehyde,
volatile organic compounds, SO2, NO2, CO.\(^3\)

Nitrous oxide and (NOx) and Volatile organic compounds (VOCs) are group of air contaminants that deteriorate the air quality either in indoor environment. Benzene, toluene, ethylbenzene, and Xylene (BTEX) are important component of VOCs and NOx. NOx and Volatile organic compounds have carcinogenic abilities, which produce various cancers in the human body. It has also causes different respiratory disease such as COPD, asthma and various eyes, skin and neurological disorders.\(^4\)

There are various methods to reduced the toxic components of air and most common method is photo catalytic oxidation of organic matter which removes air contaminants from air.\(^5\) TiO\(_2\) is generally accepted as one of the most effective photo induced catalysts and it is frequently used to oxidize organic and inorganic compounds in air due to its strong oxidative ability and long-term photo-stability.\(^6\) Titanium dioxide nanoparticles had photo catalytic properties in which ultra violet (UV) light can oxidize organic air contaminants which is commonly present in air. It has also effectively used to reduce VOCs and NOx.\(^7\) TiO\(_2\) is relatively cheap, has fast reaction rates, and can convert a wide range of organic compounds. These properties make TiO\(_2\) the ideal photo catalyst to incorporate onto existing infrastructure for improved air quality.\(^8-9\)

Educational institutions are the building block of any country because young people were trained and they become future leaders of nations. Environment in universities affected the health of students, if they exposed continues to pollute air, various health disorders among young people. There are various adverse health disorders such as fatigue, respiratory disorders which lead to bad performance of staff and students. Laboratories are special microenvironments in university buildings where pollutant concentrations were high due. \(^10-11\)
Photo catalytic oxidations processes were used effectively in indoor air purification by get rid of gaseous pollutants. Hydroxyl and superoxide radicals were produced and after oxidation of the VOCs into CO2, water, and some intermediate compounds which will be used as air contaminates removers.\textsuperscript{12-13}

Myrtus communis is evergreen tree with dense flora for the Mediterranean regions and Middle East nations. This region`s has mostly sunny and humid weather which is perfect for cultivation of this tree.\textsuperscript{14} Plants absorb carbon dioxide in air, assimilate the carbon dioxide via photosynthesis, and release oxygen.\textsuperscript{15} Plants have the capability to remove volatile organic compounds (VOCs) from air.\textsuperscript{16} Plants that improve air quality are widely used in facilities (e.g., hospitals and universities), offices, and different other public places.\textsuperscript{17} The air quality-improving effect of plants having foliage (i.e., “foliage plants”) which improved by promoting photosynthesis.\textsuperscript{17}

Myrtus communis tree with TiO2 concentrations as controller for the indoor air contaminants are not significantly tested for removal of toxic air contaminates. In this study, indoor air quality (IAQ) was investigated in research laboratories of two departments at a university. Formaldehyde, VOC (volatile organic compounds), NO2 and SO2 and CO concentrations were measured in presence and absence of myrtle plants treated with known concentration of titanium dioxide. Indoor environmental comfort which is defines as air change per hour (ACH) temperature and relative humidity. It was measured after treatment of myrtle plants with titanium dioxide. The main aim of the study is to determine the effectiveness of myrtle plants which was treated with titanium oxide to reduce the indoor air pollution around teaching laboratories.

Methods
The study was conducted in the two different academic department of public sector university. Study design was experimental.

**Indoor air Quality assessment:**

The experiment was conducted over 5 working days in the selected laboratories where day 1 data were recorded without use of TiO2 nano-particles (TiO_2 NPs) and day 2 to 4 days TiO_2 nanoparticles (NPs) was applied in different concentrations with similar experiment setting. Multiple readings were recorded during 8 hours duration. Every hour reading was calculated and the end of the day average reading was calculated.

**Preparation of TiO2 nanoparticles:**

TiO2 NPs(nanoparticles) P25 (80% anatase, 20% rutile, Sigma-Aldrich, USA, Art. No. 718467) were prepared in different concentrations as 1,3,5,7, ppm in water suspension after sonication. Different concentrations of TiO2 nanoparticles (40-10 nm) were prepared and applied to the Myrtus communis L plant. The growth media was prepared with TiO2 and this media applied to plant root, stem and leaf. The growth media has a concentration of titanium dioxide in the range of 0.5 ppm to 10 ppm. Myrtus plant exposed to indoor air.

**Procedure of Intervention**

There are two groups, one group where plant were exposed to air without the use of TiO2 nanoparticles and other group where plant with TiO2 nanoparticles were exposed to air, this group have sub categories such as different concentration of TiO2 applied to plant and then exposed to indoor air. Over 8-hour periods, multiple readings were recorded every one hour and at the end of the day average reading was calculated for whole day. The data were collected under controlled levels of humidity, temperature, and air flow exchange.

**Measurements of gaseous air pollutants**
Gaseous air contaminants CO, VOCs, Formaldehyde, sulphur dioxide (SO\textsubscript{2}), nitrogen dioxide (NO\textsubscript{2}) were measured in different location around the selected location. The temperatures, air speed, relative humidity were also recorded with the measurement of air contaminants using special Kestrel 4500 equipment.

**Levels of all gaseous air pollutants**

Levels of the selected gaseous air pollutant were measured directly by the Gray Wolf’s Directness mobile PC based products advanced Sense TM with Wolf Pack TM area monitor. This monitor is composed of multi gas detectors equipped with a wireless radio frequency modem which allows the unit to communicate and transmit readings and other information on a real-time basis with a remotely located base controller.

At each measuring point, several readings in parts per million (ppm) were recorded for each gaseous pollutant during the two-hour period (a reading per 15–30 min). For quality assurance, the instruments were calibrated and adjusted to record and save directly to main monitor.

**Results**

The 8-hour average levels of total volatile organic compounds (VOCs) indoor air with intervention of TiO\textsubscript{2} was represented in Fig. 1, and the 8-hour average levels of formaldehyde indoor air with intervention of TiO\textsubscript{2} was represented in Fig. 2.

The mean level of volatile organic compounds (VOC) and formaldehyde indoor air in different days without interventions of TiO\textsubscript{2} was represented in Fig. 3.

The mean level of NO\textsubscript{2}, SO\textsubscript{2} and CO in indoor air with intervention of TiO\textsubscript{2} was represented in Fig. 4.

The mean level of NO\textsubscript{2}, SO\textsubscript{2} indoor air without intervention of TiO\textsubscript{2} was represented in Fig. 5.
The concentration of volatile organic compound and formaldehyde were reduced in the air as TiO2 exposure increased from 1 ppm to 7 ppm. The concentration of VOC reduced from 410 to 54 and the concentration of formaldehyde was reduced from 0.27 to 0.014 ppm. The variation of air change per hour and others factors as temperature, humidity, air velocity were not significantly changed. (Table 1)

The toxic concentration of CO, NO2 and SO2 were reduced from 1.5 to 0.01, 0.041 to 0.0003 and 0.009 to 0.0003 respectively with increasing the concentrations of TiO2 from 1 ppm to 7 ppm in regard to minor variation of air change per hour rate, temperature, humidity and air velocity. Table (2) and Figure (4)

Discussion

The result of this study was found that Photo catalytic oxidation (PCO) is effective method for reducing the toxic contaminates in indoor air common air pollutants were significantly reduced after intervention with nanotechnology. Coating a photo catalyst, e.g., commercial P25 TiO2, onto a substrate and irradiating it with UV light is the most popular method for purification of indoor air.17

This study result has found that the NO concentration reduced to 50% in air and this result has consistent with other studies18. A previous study using TiO2 to coat an activated carbon filter found that the NO reduced to 66%, and benzene, toluene, ethyl benzene, and xylene (BTEX) were removed by more than 60%.19 In other study, toluene removal efficiency was increased from 32% to 78% when using a combination of Photo catalytic oxidation20-22

The result found that Carbon monoxide was significantly reduced after the intervention with TiO2. This result was consistent with the previous study which was conducted in developing country shows that 60% reduction of CO.23 The source of gaseous pollutants
such as Nitrogen, Carbon and Sulpher Oxides are from various commercial and industrial units due to the uses fossil fuels as power generations. It is concern for environmental experts that there is need for alternative for fossil fuels which counter the hazards of fossil fuels, it helps for implementation of global environment sustainability.

Result found that VOC concentration significantly reduced which is same as previous study.

The previous study found that VOC concentration was reduced 40%. The burning of fuels such as gasoline, wood, coal, or natural gas is the main contributor to global VOC emissions. Titanium dioxide is incorporated into various types of coatings which can be applied in many situations as an effective tool to remove volatile organic compounds (VOCs) and other toxic compounds from the surrounding environment, among other benefits.

This is the unique study which showed that indoor air pollution will be controlled by nanotechnology. It is recommended that commercial used of this technology especially industry which helps to improve the indoor air quality. Limitation of this study is it was conducted in educational institution; there is need of larger experimental study to be conduct in big commercial offices to monitor the effectiveness of nanotechnology.

Conclusion

Application of TiO2 in green plant specially Mytrus Communis is a novel approach for reduction of concentrations of harmful gaseous toxic and carcinogenic air pollutants in indoor environment.

Abbreviations

NO₂. Nitrous dioxide

SO₂. Sulphur dioxide
VOC. Volatile organic compound
CO. Carbon oxide
Ppm. part per million
TiO$_2$. Titanium dioxide
PM. Particulate Mater
NO$_X$. Nitrous Oxide
BTEX. Benzene, Toluene, ethylbenzene, xylene
UV. Ultraviolet
IAQ. Indoor for quality
ACH. Air change per hour
NPs. Nanoparticles

Declarations

Ethics approval and consent to participate
The study was approved by ethical committee of Imamm Abdul Rehman bin Faisal University. Consent to participate not applicable because no study participants.

Consent Publication
Not applicable

Availability of data and materials
The dataset generated and / or analysed during the current study are not publicly available due to data in the custody of university administration but are available from the corresponding author on reasonable request.

Competing interests
There is no competing interest financial and non financial between the authors.

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Authors Contributions
KS the correspondence author conceived the concept and design, data collection, data
interpretation. He drafted the manuscript and revised the article. MZ revised and proof
reading.

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Tables

Due to technical limitations, tables are only available as a download in the supplemental files section.
Figure 1: Mean levels of TVOCs removed by Myrtus communis treated with different concentrations of TiO2
Figure 2:
Mean levels of formaldehyde removed by Myrtus communis treated with different concentrations of TiO2.

Figure 3:
Mean levels of TVOCs and Formaldehyde in absence of Myrtus treated with different concentrations of TiO2 nanoparticle (Control Conditions).
Figure (4): Mean levels of gaseous air pollutants (CO, NO$_2$ and SO$_2$) removed by Myrtus communis treated with different concentrations of TiO$_2$.

**Figure 4**

Mean levels of gaseous air pollutants (CO, NO$_2$ and SO$_2$) removed by Myrtus communis treated with different concentrations of TiO$_2$.

Figure (5): Mean levels of Carbon monoxide, Nitrogen dioxide and Sulphur dioxide in absence of Mytrus treated with different concentrations of TiO$_2$ nanoparticle (Control).

**Figure 5**

Mean levels of Carbon monoxide, Nitrogen dioxide and Sulphur dioxide in absence of Mytrus treated with different concentrations of TiO$_2$ nanoparticle (Control).
Supplementary Files

This is a list of supplementary files associated with the primary manuscript. Click to download.

Tables 1 and 2.pdf