Use of titanium dioxide in apartments building to reduce air pollution

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Abstract. Jakarta as a downtown has several urban problems, one of them is air pollution. The level of air pollution in Jakarta has been recorded to have an AQI (Air Quality Index) score of 183 at this air quality level which is very detrimental to humans or also detrimental to other lives (animals and plants). The need for solutions to reduce air pollution especially NO₂ pollutants, one of which is by using titanium dioxide or greening high rise buildings such as apartments. In this study, we want to find the area that needs to be coated with titanium dioxide and also the number of plants needed to reduce air pollution at the site. Obtained to reduce the problem of NO₂ air pollution by 24,076.8 mg required an area covered with TiO₂ of 3.635 m² or need to plant as many as 36 akalipa merah trees.

Keywords: air pollution, apartment, titanium dioxide, vegetation, facade

1. Introduction

Jakarta, as the capital of Indonesia can be said to be a city with a very high level of business and density. Same like other city in Indonesia, one of the environmental problems in Jakarta is air pollution. Recorded in 2019 from DKI Jakarta Provincial Government Environmental Service, air pollution in Jakarta reaches the AQI (Air Quality Index) number 183 while in the latest United States Environmental Protection Agency (EPA US) standards, the good Air Quality Index (AQI) is at the 0-50 figure where the index number air quality has no effect on human or animal health and has no effect on plants, buildings, or aesthetic value. Jakarta was once included in an unhealthy level (101-199) at this level of air quality which was very detrimental to humans or also detrimental to other lives (animals and plants).

The problem of air pollution in Jakarta, according to I Made Supraterk [1] say that 70% of air pollution is contributed by motor vehicles. According to BPS (Badan Pusat Statistik/) in 2018 alone there were 13.3 million units of motorcycles and 3.5 million units of cars that drove on the streets of Jakarta. The number of motor vehicles causes increased air pollution, especially pollutants produced by motor vehicles namely carbon monoxide (CO), nitrogen monoxide and nitrogen dioxide (NOx), hydrocarbons (HC), and carbon dioxide (CO₂) with the most dominant CO content.
According to Srika Farsiaz [2] from the book ‘Polusi Air & Udara’ Some of the pollutants that accompany motor vehicle movement on the road such as CO and SOx have been reduced by improving engine structure and improving fuel quality. However, NOx pollutants (NO and NO2) in the air can not be suppressed by improving the engine and fuel. This condition makes NOx pollutants become one of the focus of existing pollution problems. BMKG (Badan Meteorologi, Klimatologi, dan Geofisika) air quality data deteriorated during the dry season. This is due to the lack of rain which can reduce the deposition of pollutants in the air or commonly called rain washing.

The problem of air pollution in Jakarta, especially NO2 was recorded at 3,37 million tons/year which means 9,361 tons/day. One solution is to use the application of Titanium Dioxide (TiO2) to 'stick' air pollution. The application of TiO2 can be applied around buildings such as roads/sidewalks/building walls. TiO2 has properties that can help the photocatalytic process, namely the deposition of pollutants that are assisted by the sun's UV rays. TiO2 can absorb as much as 0.0046 mg/m²/minute or 6,624 mg/m²/day it is needed as much as 1,41 trillion m² to eliminate all pollution in Jakarta.

TiO2 has been tested in Jakarta to be applied to sidewalks. This article discusses how the application of titanium dioxide was applied in the design of buildings (apartments) in Jakarta. How much is this material needed in the building and how it is placed. The result of the research is how to apply TiO2 material to buildings with an example of an apartment building so that it becomes an example of how a building can play a role in reducing air pollution (especially NO2) in the city of Jakarta.

2. Methodology
The purpose of this research is to find out how much area is covered by titanium dioxide needed to help reduce air pollution at the site. The methodology used in this study is to collect data that is secondary data by reasoning that secondary data is the fastest way than collecting primary data which requires more time considering this research requires a short amount of time. Secondary data collected in the form of journals, theses, and book literature. After the required data is obtained the next stage is to use assumptions such as assuming the site is a building that has a length and width according to site conditions and by looking at city planning regulations in terms of building height by assuming a height of 1 floor in an apartment that is equal to 4 meters with this assumption then the amount of air pollution can be calculated by calculating the site volume multiplied by the average NO2 pollution in non-vegetation areas. This assumption is used to find the area of area needed to be coated with titanium dioxide and determine the number of trees needed to help reduce air pollution at the site.

3. Result and Discussion
3.1. General Description of Kuningan Area
Kuningan is one of the business centers in DKI Jakarta, Indonesia (Figures 1-2).

![Figure 1. Map of Indonesia and Java Island](image1)

![Figure 2. Location of Sudirman in Jakarta City](image2)
The research location is located in Jakarta, which is more precisely in the city center of Jakarta, Mega Kuningan which has an area of 54 hectares is centre business Jakarta consists of office blok/tower and commercial area. Kuningan as Jakarta's golden triangle area causes many vehicles to drive in this area, this condition causes problems that usually occur in the city center such as traffic jams, air pollution, lack of clean water, etc. Traffic jam in Jakarta is caused by the number of private vehicle users which continues to increase every year, this also has an impact on increasing air pollution in Jakarta.

3.2. Air Pollution

Air pollution has several elements called pollutants. Air pollutants have several elements, namely carbon monoxide (CO), nitrogen oxides (NOx), hydrocarbons (HC), sulfur dioxide (SC), and particulates (PM10, PM2.5).

Air quality against pollution can be categorized by the AQI (Air Quality Index) table which contains the level of health on air quality (Table 1).

| Air Quality Index Levels of Health Concern | Numerical Value | Meaning |
|------------------------------------------|-----------------|---------|
| Good                                     | 0 to 50         | Air quality is considered satisfactory, and air pollution poses little or no risk |
| Moderate                                 | 51 to 100       | Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution. |
| Unhealthy for Sensitive Groups           | 101 to 150      | Members of sensitive groups may experience health effects. The general public is not likely to be affected. |
| Unhealthy                                | 151 to 200      | Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects. |
| Very Unhealthy                           | 201 to 300      | Health alert: everyone may experience more serious health effects. |
| Hazardous                                | 301 to 500      | Health warnings of emergency conditions. The entire population is more likely to be affected. |

In 2015 the Jakarta Environmental Management Agency recorded the Kuningan area having the highest NO₂ level reaching 96.1 μg / Nm³ while the NO₂ quality standard in Indonesia was 92.6 μg / Nm³. [4]

3.3. Air Pollution Prevention

The high air pollution in Jakarta requires a solution that can help in reducing air pollution some of the ways are:
- Using public transportation modes
- Saving energy such as turning off lights during the day, turning off the AC when there are no people, etc.
- Practicing the concept of reduce, reuse, recycle
- Build environmentally friendly buildings
- Using environmentally friendly materials
- Increase greening

Table 1. Air Quality Index Table [3]
3.4 Titanium dioxide (TiO$_2$)
One way to help reduce air pollution is to use titanium dioxide (TiO$_2$) in buildings because TiO$_2$ has a process called high photocatalyst, a catalyst used to accelerate chemical reactions with the help of light [5]. Titanium dioxide or titania which has photocatalytic properties can adsorb compounds such as NO$_2$, the process is carried out with the example titania applied to the wall then with the help of UV light from the sun doing the photocatalytic process of converting nitrogen dioxide into nitrogen acids. Nitrogen acid is then immediately neutralized into harmless salt and melted with rain water (Figure 3).

![Figure 3. Sketch of the TiO$_2$ Photocatalytic Process](image)

Application of TiO$_2$ from the results obtained from research (H. Khair, 2017) that the composition of the ratio between TiO$_2$, water based resins, and water per 1 m$^2$ field, the most effective and efficient is with the following mixture (Tables 2-3).

| Composition per m$^2$ | TiO$_2$ (gram) | Water Based Resin (mL) | Water (mL) |
|----------------------|----------------|------------------------|------------|
|                      | 200            | 100                    | 200        |

| Table 3. Estimated Price of Composition of TiO$_2$ and Water Based Resin per 1 m$^2$ |
|---------------------------------|----------------|-----------------------|-------------|
| Composition per m$^2$           | TiO$_2$ (200 g) | Water Based Resin (mL) | Total price |
| Rp 15.000,00                    | Rp 4.200,00    | Rp 19.200,00          |             |
With compositions such as Table 2 the fields covered by TiO$_2$ can adsorb NOx gas at an average rate of 0.0046 mg / min / m$^2$ or 6.624 mg / day / m$^2$. The level of NO$_2$ concentration in the vegetated area was 33.68 μg / m$^3$ and in the non-vegetated area was 94.05 μg / m$^3$ (Farida, 2018). If likened to a site is a building space and has a height of 16 floors with the assumption that each floor has a height of 4 meters, the volume obtained is 256.000 m$^3$ (Figure 4).

![Figure 4. Sketch the volume on the site](image)

Having such a large volume, if it is considered that the site does not vegetate NO$_2$ concentration at the site is 24.076.800 μg or 24.076,8 mg so that to be able to eliminate NO$_2$ pollution one day at the site, an area covered with TiO$_2$ is needed (24.076,8 mg : 6.624 mg / m$^2$ = 3.635 m$^2$) with an area of this magnitude at least the building participates in reducing the problem of air pollution contained in the site itself.

Implementing TiO$_2$ can be done in several areas such as walls, sidewalks, and roads by mixing all materials, namely TiO$_2$, water based resin, and water into one and then applied the same as painting. The more area that can be coated with TiO$_2$, so the more area that can precipitate NO$_2$. Ways that can be done to increase the area that can be covered by TiO$_2$ is by using a secondary skin or by bending the wall. The use of TiO$_2$ in buildings also has several advantages and disadvantages (Table 4).

| Advantages                  | Disadvantages                                      |
|-----------------------------|----------------------------------------------------|
| Easy to apply               | Initial costs are more expensive than trees        |
| Does not affect form        | Difficult color varies                             |
| Cheap maintenance           | Depending on the area                              |

The application of TiO$_2$ depends on the area that can be overlaid with this problem, so a building form is needed that can provide a lot of space for TiO$_2$ coating. The application of TiO$_2$ to buildings is like the application of coating paint, the application in buildings can be located on the walls of the building (Figure 5).
The shapes taken in this study are boxes and cylinders. If viewed from the formula for the surface area of the two shapes, which have the same volume, the largest surface area is box and then cylinder. With this data, an example is taken using a box shape as a reference for research (Figure 6).

The shape of the box used has a base area of 1624 m$^2$ and has a number of floors 8 with a height of 32 m which is assumed to be 1 floor 4 m, so the area that can be covered is 6,782.5 m$^2$. Using the assumption that the apartment facade is 70:30 between the wall facade and the glass facade, the area that can be covered is 5,234.8 m$^2$.

Using the assumption 70:30 Figure A gets an area that can be coated as 8,578.8 m$^2$, image B gets an area that can be coated as big as 7,019 m$^2$, Figure C gets an area that can be coated as large as 7,412.3 m$^2$. Box shape has advantages and disadvantages, as shown in Table 5.

| Advantages                  | Disadvantages   |
|-----------------------------|-----------------|
| Easy to divide the space    | Monotone        |
| Easy in variety             |                 |
| Little wasted area          |                 |

The use of TiO$_2$ in buildings will uniquely shape the building because the shape of the building will be a lot of variations, not flat but also has a drawback, namely the color of the building will only be white in the covered area.
3.5 Result

The results obtained by looking at the advantages and disadvantages of using TiO$_2$ on building walls can get more covered areas than just covering the sidewalks. Using a combination of both NO$_2$ levels that can be reduced is much more maximal so that buildings can not only reduce the site area but also help in the surrounding environment in terms of reducing existing pollution. The estimated additional costs for NO$_2$ coating are shown in Table 6.

| Covered area: 3.635 m$^2$ |
|---------------------------|
| Cost = 3.635 x 19.200 = Rp 69,792,000 |

4. Conclusion

The conclusion of this study is to reduce NO$_2$ concentration by 24.076,8 mg, the need for an area covered by TiO$_2$ with absorption of 6,624 mg / day / m$^2$ is 3.635 m$^2$ on the walls of the building using the assumption of the apartment building facade 30:70 between the facades cannot be coated and the facade can be coated with TiO$_2$, the TiO$_2$ coating can be expanded by adding a secondary skin or increasing bending in the facade. If using both alternatives, TiO$_2$ coating on building walls and sidewalks can reduce NO$_2$ pollutants even more. The area covered by TiO$_2$ if maximized can reduce more NO$_2$.

5. Reference

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