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Journal of Project Management

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Review of sustainable concrete based on photocatalytic to reduce the environmental impact in large works in Peru

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C H R O N I C L E

Article history:
Received: September 1, 2022
Received in revised format: September 29, 2022
Accepted: November 29, 2022
Available online: December 1, 2022

Keywords:
Concrete
Photocatalytic
Environmental
Work
Nitrogen dioxide
Titanium dioxide

A B S T R A C T

This bibliographical review allows us to know clearly and concisely the use and effectiveness of photocatalytic concrete applied to tracks or roads, and in buildings. This study analyzes sustainable concrete based on photocatalytic to reduce the environmental impact in large-scale works through the application for the collection and review of articles published in the scientific base of Scopus using the VOSviewer software tool that analyzes a large amount of data from a group of investigations, this research is carried out from the publications of the year 2000 to the year 2022. Graphs were obtained from the database analysis with the words "Concrete", "Photocatalytic", "Environmental" and "Work" with the highest interest in all analysis groups. The results obtained allow us to understand the innovation of concrete based on photocatalytic in order to reduce air pollution since this need is current throughout the world, more so in globalized and rapidly growing countries, the analysis in Peru is not found no research related to the subject and there are no large-scale works related to reducing air pollution, but there are proposals to improve air quality in Lima, the capital of Peru, however this contribution is minimal to be able to positively impact the air . The manufacturing process and the materials to implement for the manufacture of concrete based on the photocatalytic were also analyzed, visualizing the advantages and disadvantages of this concrete based on the photocatalytic, adding other additional components to improve the durability of the concrete application and being viable. to apply to large-scale works. This research has the purpose of presenting a general view of the application, manufacture, advantages and disadvantages of concrete based on photocatalytic, it is important to develop and apply it in large-scale works subsidized by the Peruvian state, since these can generate a positive impact on society and the environment.

1. Introduction

A worldwide problem is air pollution and the quality of air that we are breathing due to industrialized cities and the rapid globalization of countries according to the World Health Organization. Likewise, more than 7 million humans die a year from diseases such as heart disease, cancer and chronic lung diseases caused by air pollution problems (Trujillo et al., 2021) even 90% of the world population is exposed to contracting these diseases since we breathe such poor-quality air (Januszkiewicz & Kowalski, 2019). But this problem not only affects humans but also endangers the vegetation, animals and materials that surround us in the environment (Sopov, 2020). Scientists are researching innovative solutions to mitigate environmental pollution and reduce carbon emissions in industrialized cities, as well as sulfur and nitrogen dioxide in the lungs that cause respiratory and cardiovascular diseases, likewise it also harms the ozone layer. weakening it thanks to

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doi: 10.5267/j.jpm.2022.12.002

gaseous pollutants. In countries such as the European Union, the level of nitrogen dioxide increases three times the limit of their country (Januszkiewicz & Kowalski, 2019), likewise in China they generate large amounts of waste related to construction and demolition since there are large-scale buildings and Smarter cities for these reasons require landfills for globalized countries and in globalization processes (Yidong, 2020) that are concerned with reducing this waste.

In Lima, the capital city of Peru, at the end of 2022, it will exceed the maximum levels of environmental contamination, affecting young people and adults with respiratory problems and diseases in the future (El Comercio, 2022) according to the General Directorate of Environmental Health and Food Safety (DIGESA) in its monitoring of the air in the city of Lima found particles of nitrogen dioxide (NO2) and sulfur oxide (SO2), likewise asserts that the presence of these particles has increased throughout the world, harming the air and causing effects negative to the climate (DIGESA, 2022)

The main pollutant is nitrogen oxide, the main problems are to eliminate it from the air and reduce its concentration in the soil (Sopov et al., 2020). Research proposes implementing a road with sustainable concrete in order to purify the air since it is in direct contact with transport vehicles, as well as purify the water since this will be direct with the first contact and reduce soil contamination (Le Pivert et al., 2020), it will also be possible thanks to the photocatalytic process, being cheaper than other proposals and with the fastest effectiveness capacity, promising to be an innovative solution for intelligent materials applied to the construction industry (Le Pivert et al., 2020).

This article aims to demonstrate the feasibility of applying this concrete to large-scale works to purify the air in buildings in cities for public use. For this reason, a bibliographic analysis was carried out with the support of the VOSviewer tool of scientific articles related to sustainable concrete based on photocatalyst to reduce environmental impact, an opportunity for large-scale work. The following points are found in the results items: biometric analysis, photocatalytic concrete; chemical function of concrete materials and manufacturing methodology and environmental impact of photocatalytic concrete.

2. Materials and methods

A bibliographical review allows contributing to the publications based on sustainable concrete made with photocatalytic technology to reduce the environmental impact in large-scale works. To do this, the scientific tool provided by Scopus from the line of the main journals that are accessed at the Continental University was used.

The analysis was used with the bibliometric map of scientific contribution that is the VOSviewer, this software allows to provide maps analyzed with the Scopus database, it also provides analysis in temperature maps (Van Eck & Waltman, 2009). Data obtained from Scopus were in (.csv) format that were obtained from the year 2000 to December 2022, the methodology and search criteria were used as follows:

a. Firstly, the data was obtained from the year 1997 to 2022, with the following points of inquiry of "concrete" and "photocatalytic", in scientific articles, magazines on the topic of interest and conferences on related topics, materials analysis books, 416 documents were detected worldwide.

b. Second, the data was obtained from 2000 to 2022, with the following points of inquiry of "Concrete", "Photocatalytic" and "Environmental", in scientific articles, magazines about interest and conferences on the related subject, books of analysis of materials, 113 documents were detected worldwide.

c. Third, the data was obtained from the year 2012 to 2022, with the following points of inquiry "Concrete", "Photocatalytic", "Environmental" and "Work" in scientific articles, magazines on the topic of interest and conferences on the related topic, materials analysis books, 15 documents were detected worldwide.

d. Finally, an equal analysis of the three previous points was carried out, which was made an analysis at the Peruvian level, where no document, magazine or conferences related to the Peruvian level were found.

They were obtained (tables 1, 2, 3) with the information of points a), b) and c). These data were passed to the VOSviewer program, which gave us the following figures (figures 1, 2, 3) which gives us the cohesion between the words that join each other.

Second, a data analysis was obtained with which we were able to stratify the necessary information to understand the photocatalytic-based concrete, the chemical function of the photocatalytic-based concrete, the manufacturing process and methodology, and to know the environmental impact generated by this new technology for the construction industry.

3. Results

3.1 Biometric analysis of the words concrete, photocatalytic, environmental and works

Twenty-two years ago, the analysis in the scientific journal Scopus had a few investigations related to “Concrete” and “Photocatalytics” but since 2013 these investigations have been increasing. Fig. 1a shows the growth of investigations from 1997 to 2022 and having the highest record in 2019 with 48 documents.

The analysis in the map of terms is shown in Fig. 1b, the data mining carried out with VOSviewer software is observed, which were obtained from Scopus, the words most used in the investigations were “Photocatalytics” with the greatest interaction among all the documents, second was the “concrete” and among others. The circles show the interaction and the relationship with the other documents, leading to the conclusion that the concrete and photocatalytics have greater interactions together and form a good database to carry out the investigation.

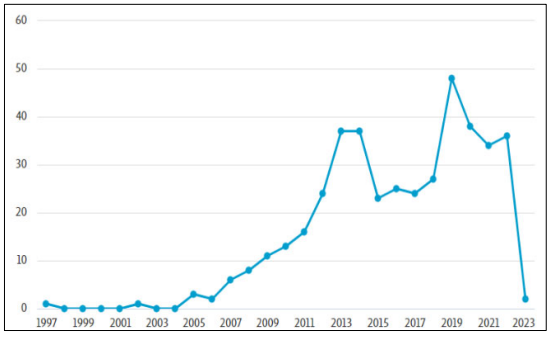

Fig. 1a. Biometric analysis of the words “Concrete” and “Photocatalytic” Source: Scopus scientific review

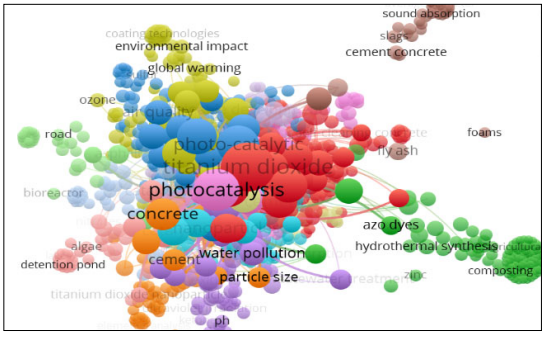

Fig. 1b. Map of the analysis of the words "Concrete" and "Photocatalytic" with the highest interaction Source: Obtained from VOSviewer

Twenty years ago, the analysis in the scientific journal Scopus had a few investigations related to “Concrete”, “Photocatalytic” and “Environmental” but since 2012 these investigations have been increasing. Fig. 2a shows the growth of investigations from 2002 to 2022 and having the highest record in 2014 with 18 documents. The analysis in the map of terms is shown in Fig. 2b, the data mining carried out with VOSviewer software is observed, which were obtained from Scopus, the words most used in the investigations were “Photocatalytics” with the greatest interaction among all the documents, second was “concrete” and the third “Environmental”. The circles show the interaction and the relationship with the other documents, in this analysis we can find research related to the environmental impact and improving the quality of the research in their native countries.

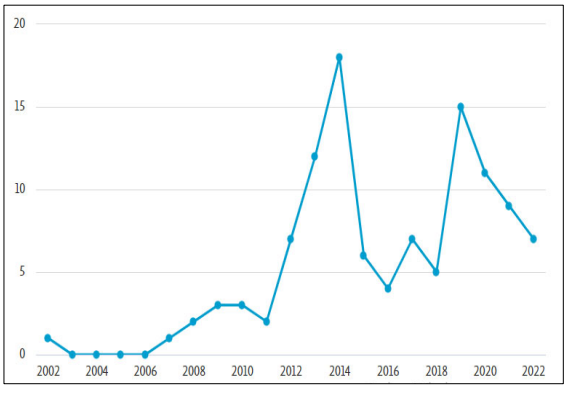

Fig. 2a. Biometric analysis of the words “Concrete”, “Photocatalytic” and “Environmental” Source: Scopus scientific review.

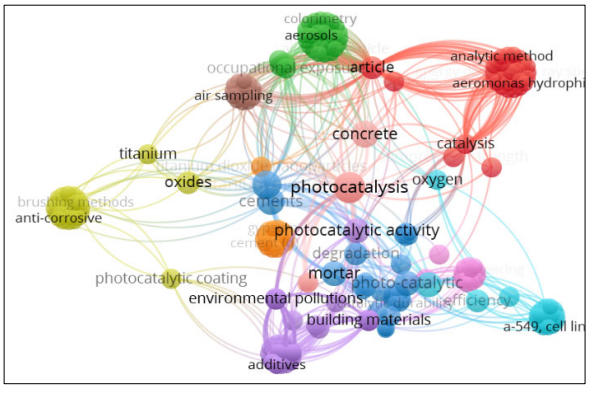

Fig. 2b. Map of the analysis of the words “Concrete”, “Photocatalytic” and “Environmental” with the highest interaction

Source: Obtained from VOSviewer

Ten years ago, the analysis in the scientific journal Scopus had a few investigations related to “Concrete”, “Photocatalytic”, “Environmental” and “Work” but since 2019 these investigations have been increasing. Fig. 3a shows the growth of investigations from 2012 to 2022 and having the highest record in 2022 with 4 documents.

The analysis in the map of terms is shown in Fig. 3b, the data mining carried out with VOSviewer software is observed, which were obtained from Scopus, the words most used in the investigations were “Photocatalytics” with the greatest interaction among all the documents, second was the “Concrete”, the third "Environmental" and the last "Work". These documents were analyzed one by one, highlighting the most interesting and collaborating with the investigation in an effective, continuous and truthful way.

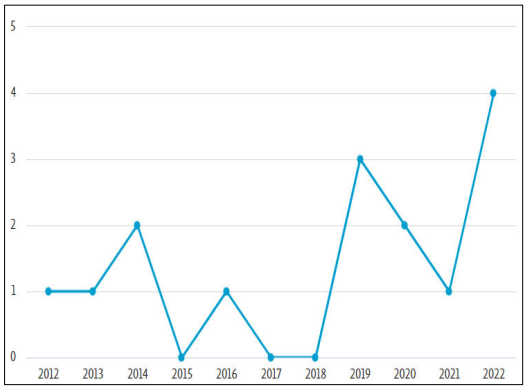

Fig. 3a. Biometric analysis of the words "Concrete", "Photocatalytic", "Environmental" and "Work"

Source: Scopus scientific review

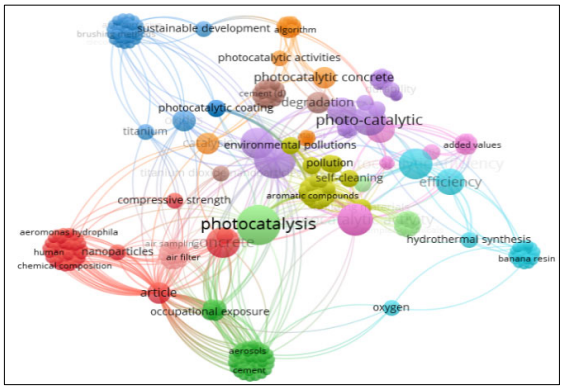

Fig. 3b. Map of the analysis of the words "Concrete", "Photocatalytic", "Environmental" and "Work" with the highest interaction

Source: Obtained from VOSviewer

The analysis at the Peru level did not find any results putting it at a disadvantage compared to other countries, in addition to highlighting that there is little interest in Peru in research to improve air quality.

3.2 Photocalytic concrete

Sustainable concrete is made up of recycled particles that allows it to be used according to the compounds instead of discarding them and the photocatalytic-based concrete has titanium dioxide TiO2 (Xu et al., 2020) as its main ingredient, where different studies were carried out to incorporate it with the aim of reducing nitrogen oxide (NOx) in the environment and allow the presence of titanium dioxide TiO2 in the asphalt pavement to keep the active present until the useful life of the concrete (Trujillo et al., 2021). Nano titanium dioxide (nTiO2) is a clean and natural component, the advantage is that it is an efficient catalyst that disintegrates the components present in the air thanks to sunlight (Liang et al., 2019).

Titanium dioxide (TiO2) is a natural material that is used in different industries, now it is present in construction with the function of obtaining efficient materials in environmental cleaning (Sopov, 2020), then the union of titanium dioxide with the cement allows obtaining a photocatalytic material (Liang et al., 2019), however it is a great challenge for the construction industry since cement is an alkaline material, which allows TiO2 to agglomerate, reducing space and volatility of the TiO2 component by cement hydrates (Yang et al., 2019), this being a problem of great cost as well as the external effects of the deterioration of the physical and chemical properties of concrete when in contact with light, sun, rain and air pollution (Trujillo et al., 2021) becomes a challenge for the construction industry and a solution to improve air quality. In a study they solved these with a porous concrete and a rough surface that has the purpose of improving the adhesion and durability problems of nano titanium dioxide (nTiO2) (Liang et al., 2019).

3.3 Chemical function of concrete

Photocatalytic concrete has the property of generating free radicals that are capable of oxidizing carbon dioxide (Januszkiewicz & Kowalski, 2019). The oxidation of cement influences the aging of the physical and chemical properties of concrete; therefore oxidation has three stages, which are the following:

- Fragmentation that consists of fragmenting in small quantities that are released into components such as carbon dioxide, methane and among other volatiles.
- The addition of oxygen that is achieved thanks to the temperature and concentrations of oxygen that help to release components of the concrete.
- The carbonization that helps to form molecules in the concrete makes it more rigid.

The following figure graphically shows the photo-oxidation process of a photocatalytic concrete with titanium dioxide (TiO2), as it can be seen that upon contact with nitrogen oxide (NOx), O2, H2O, CO2, among others, are released. (Castro et al., 2022).

The studies from different sources studied showed that thanks to the titanium nanodioxide (nTiO2) incorporated into the concrete, the efficiency with the nanoparticles as anti-aging agents of the concrete improves (Trujillo et al., 2021), likewise they assert that this component converts it to the concrete into a clean and effective technology to confront air pollution (Liang et al., 2019).

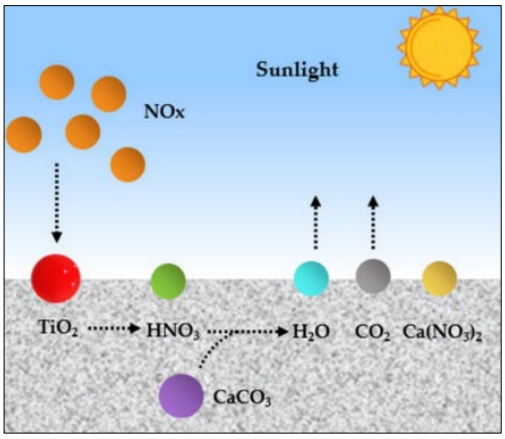

Fig. 4. Photo-oxidation process of a photocatalytic concrete

Note. The graph represents the photooxidation process against contact with the sun and what are the components that are released into the air. Taken from Challenges and Opportunities of using. (p. 12), by Castro et al., 2022.

3.3 Materials and manufacturing methodology

The materials used for the manufacture of concrete are the following: Portland cement, preferably crushed stones that are limestone type, plaster, silica sand of the dimensions (1-2 mm) and the catalyst additive that is titanium dioxide TiO2 (CristalACTiV™), all of them must have with quality supervision of materials respecting the ISO Standard (Yidong, 2020) and (Linsong et al., 2022). The manufacturing method has the following steps: First, mix the ingredients, second, produce a quick-use element such as tiles, third, send it to curing, and fourth, drying. In addition, it has to go through the quality process to give a better view of its use and functionality. In terms of quantities, the annualized studies have different amounts, for which the closest and most efficient study of the concrete was achieved with 8% of the catalyst additive, making a concrete that can disintegrate nitrogen oxide NOx by 31%, CO in 98.5% and among other ingredients (Xu et al., 2012), they also recommend applying the TiO2 the same amount as the cement and then mixing it with the other components (Linsong et al., 2022).

3.4 The environmental impact of photocatalytic concrete

Air pollution in rapidly urbanizing cities and new industries where large-scale projects require solutions capable of mitigating pollution both for its use and for its manufacture (Januszkiewicz & Kowalski, 2019), likewise the environmental impact of concrete photocatalytic has benefits to improve the air quality in the environment, scientists have a great assertiveness that concrete works, however the main problem is to apply it on a large scale, a large investment study is still needed for large-scale infrastructures with which With the objectives of applying photocalizers and that these at the same time have a long durability (Yang et al., 2019), countries such as Japan, China, Belgium and France have also developed intelligent buildings with a robust infrastructure of materials loaded with TiO2, with the function main self-cleaning systems proved to be efficient for the removal of contaminants in the air re (Castro, 2022).

4. Discussion

These types of investigations allow us to contribute to the scientific community a deep and conclusive bibliographic review analysis on sustainable concrete based on photocatalytic energy to reduce environmental contamination and apply it to large-scale works. The analysis carried out using the VOSviewer tool of the words "concrete", "photocatalytic", "Environmental" and "Work" has a great interaction in countries such as China, France, Mexico, Portugal and among others, likewise at the Peru level it is not found no document related to these items analyzed, this is a disadvantage and disinterest on the part of the professionals and institutions in charge of reducing environmental pollution in the world of construction.

In America there are many countries with air pollution problems and in Peru, being a country with urbanized cities such as Lima, which it considers a city with the highest air pollution (Tapia, 2018), likewise according to the Ministry of Environment (Minam) mentions that there are ten sanitary landfills authorized by Peru to dispose of waste and these are very few for a highly inhabited city (Ministry of Education, 2022) but what are the reasons that Peru does not solve these problems, this is due to the lack of organizations in charge of defending the environment, also the lack of reliable sources of information so that the public entity makes the correct decisions, that is why in the cities there is a lack of air monitoring and this will provide us with data to be able to make decisions , activate solutions and mitigate the problem, however there are also institutions such as universities that are proposing projects for environmental improvement and pu air purification related to caring for and mitigating environmental impact.

For these problems, the application of photocatalytic-based concrete is the best solution to mitigate air pollution since NOx will be eliminated from the environment with the application of titanium dioxide, generating improvements in the air (Chen & Jiao, 2022) likewise this can be applied to buildings since soot is usually deposited on the contours of the building, however the application of TiO2 will prevent it from forming (Dudek & Janus, 2022), it can also be used on asphalt roads which are in direct contact with the vehicles acted in an effective, fast way and helping to reduce air and soil pollution, since it will also purify the water and these will be spread directly to the soil (Yidong, 2020), since by introducing properties photocatalytic to concrete and with exposure to the sun it manages to hydrophilize, that is, to oxidize pollutants such as carbon dioxide and among others (Dudek & Janus, 2022), TiO2 prevents the dirt in front of the sun since ultraviolet light generates photocatalysis as self-cleaning in concrete, likewise UV rays generate a good job when it is at 45° from the angle, generating greater confidence (Ehrenbring et al., 2022).

However, it also has disadvantages such as the application of wear to external conditions with the sun, rain and among others, then the particles of titanium oxide (TiO2) tend to break up, move or drag easily, reducing the photocatalytic effect (Yidong, 2020).), it is understood that concrete has the capacity to absorb up to 200% more contaminants, however the problems that arise when having Titanium Dioxide (TiO2) between 0 and 8% decreases the resistance to compression, decreases the hydration (Linsong et al., 2022) and mechanical resistance (Dudek & Janus, 2022) that affect the mechanical properties of concrete, also the deterioration process of concrete due to exposure to high temperatures is due to the percentage that is TiO2 is added to the concrete, for this purpose, the solution was found with porous concrete, which allows the titanium oxide (Tio2) to adhere and maintain for a longer time, extending the life of the concrete (Liang et al. al, 2019), these micro pores and capillaries of the concrete are homogenizing, achieving that the porosity of the concrete is decreased; however, the existence of TiO2 causes the concrete to become more porous and thus have the property of absorbing particles from the environment, achieving homogeneity (Linsong et al., 2022), there are also other methods such as the application of TiO2 only in the outer layer since it improves the photocatalytic properties and increases the durability of the concrete (Dudek & Janus, 2022) since there are solutions in the market as powders that contain TiO2 to be able to be applied, likewise another solution is to apply silicon oxide (Sio2) is an element that is used so that TiO2 remains existing in the concrete, the way of application can be to also spray it Generate SiO2 spheres that contain TiO2. This is generated by hydrolysis, which will allow TiO2 to have better durability in concrete (Dudek & Janus, 2022). In other studies, it was shown that in a period of 6 to 12 months the concrete suffered by 1% the wearing effect (Trujillo et al., 2019) all this was achieved by adding solid waste such as silicon powders or also residual sand. which will improve the mechanical resistance of concrete (Liang et al., 2019).

This concrete system must be applied to large-scale works as well as those that are made profitable by public entities since the application of this photocatalyst concrete requires an extra cost since coating with titanium dioxide nanoparticles generates an additional process to the process. conventional concrete (Yidong, 2020), in order to reduce the cost, fine aggregates can be added (Chen & Jiao, 2022), waste such as building demolitions can also be used as an improvement option since it contains something of calcium hydroxide making it more alkaline (Chen & Jiao, 2022), all with the purpose of absorbing sulfur dioxide (SO2) which is an existing pollutant in the environment.

5. Conclusion

In the field of construction, innovation in photocatalytic materials is growing in order to disinfect the air to reduce environmental impact, thanks to sunlight and water great benefits can be obtained (Luévano, 2019) The relevance of this analysis in The results obtained allow us first that Peru does not exist large-scale works with sustainable materials to improve air quality and this requires solutions for improvements in Peru, however currently the levels of pollution in Peru are harming million Peruvians with health risks caused by poor air quality (World Bank, 2022).

Second, the research related to this topic has increased worldwide, giving greater importance and relevance to the feasibility of implementing it in the construction industry, and finally, the fields related to “concrete”, “photocatalytic”, “Environmental” and “work” has a coherent and concise relationship, everything analyzed is thanks to the Scopus database. The application of this material will give us favorable advantages to have a better air quality near the area where the concrete is located, in addition this concrete complies with an innovative material for the construction industry since it allows us to be respectful with the environment and mitigate the air pollution. This type of concrete is self-cleaning due to the addition of titanium dioxide (Tio2) nanoparticles (Batsungnoen, 2020), it is also more cost-effective than other methods to decontaminate the air. However, the disadvantage is the application to large projects due to the cost of the application, since it generates an extra process than normal. We conclude that in Peru this methodology can be applied to large-scale works carried out by public entities to generate a positive impact and decontamination of the air in Peru, it is recommended to carry out further investigations to minimize the risk of volatility of TiO2 applied to concrete. In addition, raise awareness among professionals and public entities to carry out works with positive impacts on the environment.

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