Chapter 21
Impacts of Exploiting Nanocoating on Buildings' Façades to Improve Air Quality in Megacities, Mitigate Climate Change and Attain Livability

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Introduction

Megacities face colossal challenge, mainly urban air pollution due to transport, large number of inhabitants' activities, and energy use in all sectors. In cities, air is the main component of atmosphere; all humans, animals, plants, and other living organisms depend on it for survival. In the last decade, health concern became an important issue in megacities due to high level of air pollution. Sources of air pollutants in developing countries are variable: resulting from emissions of vehicles, industrial activities and open burning of agricultural and municipal solid waste; all of these are causing several economic and health damages to human and ecosystem [1]. According to the World Health Organisation (WHO), at least 96% of the populations in large cities are exposed to $PM_{2.5}$ which exceeds the WHO air quality guidelines levels. Thus, improving air quality is one of the major steps needed to enhance livability in megacities both in developed and developing countries. Several research studies conducted during the previous years indicated that the use of nanotechnology to solve air pollution problems, where nanocoatings are used to purify air entering into buildings, showed significant signs. For a megacity like Cairo, the causes of air pollution may be different depending on the geographical location, temperature, wind, and weather factors, so pollution is dispersed differently [2].

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Objectives

The aim of this work is to present a review study on identifying nanocoatings' types to reduce the concentration of air pollution in cities and to improve air quality in buildings through the use of nanocoatings. The study focuses on buildings that incorporate titanium dioxide as a self-cleaning (photo-catalytic) coating outside buildings. Figure 21.1 shows the objective and sub-objectives of the study.

Issues and Challenges [6]

The problem of air pollution, especially in big cities, is one of the main global challenges in the current century and the continuous manifestation of climate change impact around the world is foreseeing long-term damages and economic losses. Nonetheless, a new generation of treatments that mitigates different pollutants in the air has recently emerged. These challenges must be brought into consideration when sustainable materials are used; the potential of photocatalysis against CO_2 and other major contributors to pollution is addressed [3].

Methodology

The study methodology depends on inductive and analytical approaches: the first part includes a review on the nanotechnology and nanocoating, whereas the analytical part encompasses an assessment of global models for nanotechnology. The study also analysed different buildings globally that applied different types of nanocoatings [4].

Nanotechnology and Nanocoating

Science-based approach to nanotechnology materials with morphological characteristics are studied on the nanoscale, especially those with special properties arising from their nanoscale dimensions [7]. These are divided according to the uses

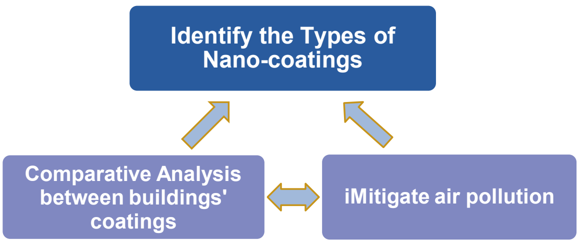

Fig. 21.1 Sub-objectives of the research

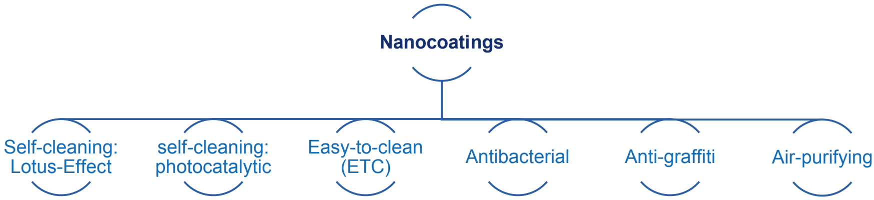

Fig. 21.2 Nanocoating types

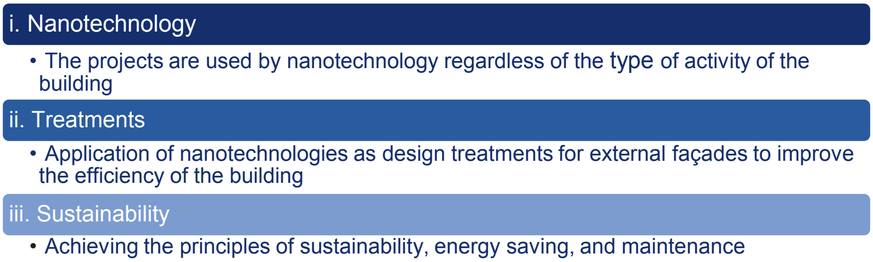

Fig. 21.3 The criteria for assessing the selected projects

of buildings as illustrated in Fig. 21.2. Nanocoating can be used as a technology to build the skin of buildings' façades where a coating is basically a membrane/film applied onto the surface of an object. The purpose of the application may be decorative or functional paint or both. Nonetheless, coatings can be found on exterior/internal walls and on all kinds of wires, prints, circuits, outside buildings, and much more. In addition, the decorative façades of the paint expand to a large extent [8].

Global Models for Nanotechnology

By studying the nanocoating techniques, it was found that the self-cleaning (photocatalytic) has been widely used in buildings and has potential in the market. Its main applications would be on the external and internal buildings' façades. Also, it has an effect on the development of the material properties and the external atmosphere of the buildings with the purpose to improve the efficiency of these materials such as concrete, iron and wood [9]. In addition, it enhances the material used in buildings' finishing materials, including paints and glass. There is an evolution of buildings' façades that intended to improve the efficiency of their components. The criteria taken into account when assessing these projects using self-cleaning (photo-catalytic) coating are shown in Fig. 21.3. The comparative assessment between buildings that incorporate this coating is illustrated in Table 21.1 and Fig. 21.4 illustrates the countries where such technologies are exploited in buildings and urban areas.

Fig. 21.4 Countries using self-cleaning: photo-catalytic coating

Results of Comparative Global Models

Self-cleaning (photo-catalytic) is commonly used in all types of buildings, including residential, hotels, sports, cultural, and religious as well as commercial (offices and banks), and its application are mainly in glazing, paint, ceramic and membrane as shown in Fig. 21.5. Based on the above assessment, these nanocoatings (self-cleaning) are widely applied onto finishes of the building's façades and the most common country where such application is used is Japan. Figure 21.6 shows that residential building is the most type where self-cleaning (photo-catalytic) coatings are applied and also self-cleaning (photo-catalytic) coatings are widely used onto the glass of the buildings' façades.

Air Pollution in Megacities

In megacities, air pollution is reaching an alarming rate exceeding the WHO recommended level. Most of the populations in big cities are exposed to $PM_{2.5}$ which exceeds the air quality guidelines levels set by the WHO as illustrated in Fig. 21.7 [10]; thus, causing morbidity and mortality. Improving the quality of air in cities is one of the major actions immediately required to ensure livability in megacities. Several research studies, conducted during previous years, indicated that the use of nanotechnology solves pollution problems, where nanocoatings are used to

Table 21.1 Comparison between buildings that used photo-catalytic self-cleaning

No.	Country and city	Building's name and type	Building's image	Coating type	Similarity	Difference
1	**Germany** Heilbronn	AKT—Am Kaiser's TXirm Heilbronn Cultural		Photo-catalytic self-cleaning	Used on glass	No
2	**Germany** Hamburg	East Hotel St. Pauli Hotel				
3	**Germany** Duisburg	MSV Arena Soccer Stadium Sports				
4	**France** Lake Leman	Evian Mineral Water Head Office Office				
5	**France** Cluses	Nautical Centre Service				
6	**Austria** Graz	Sparkasse Graz Bank Bank				
7	**Switzerland** Frick	Disabled-access housing Residence				

(continued)

Table 21.1 (continued)

No.	Country and city	Building's name and type	Building's image	Coating type	Similarity	Difference
8	Australia McMaster's beach	Glass Tee House Residence		Photo-catalytic self-cleaning	Used on glass	No
9	Australia Adelaide	Watkins Residence Residence				
10	USA Louisville	Muhammad Ali Center MAC Cultural			No	Used on ceramic tiles
11	Japan Tokyo	G-Flat Residence			Used on glass	No
12	Japan Nishinomya	Kurakuen private residence Residence			Used on paint	No
13	Japan Osaka	Senri New town private residence Residence				
14	Japan Hiroshima	House on Creek Residence				
15	Japan Osaka	Hyatt Regency Garden Chapel Religious		Photo-catalytic self-cleaning	Used on membrane	No

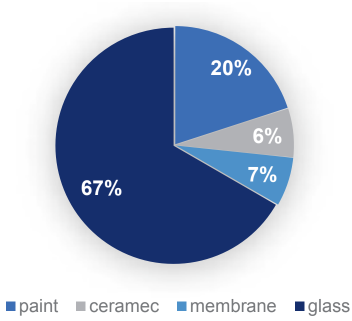

Fig. 21.5 Self-cleaning (photo-catalytic) coatings application

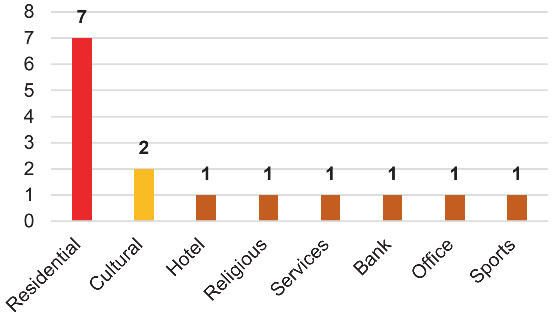

Fig. 21.6 Type of buildings applied Self-cleaning (photo-catalytic) coatings

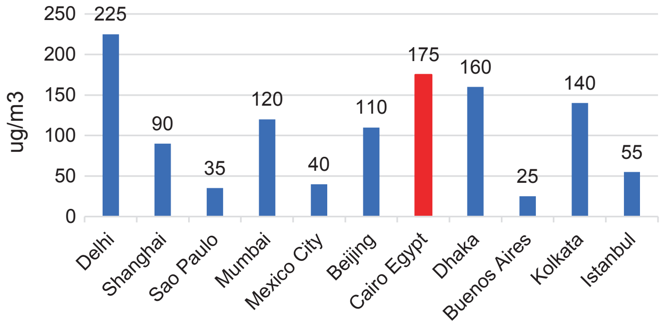

Fig. 21.7 Air pollution level—PM10 for available megacities. *Source*: The 2016 version of the database by WHO

purify air before entering into buildings [11]. The exact causes of pollution may be different and depend on many factors as illustrated in Fig. 21.8.

Evidence from the WHO reports highlighted that the levels of the six main pollutants are determined by the concentration of the common pollutants level [12]. The main primary pollutants from the various activities are supplemented by the following: particles suspended vestibular (PM_{10}–$PM_{2.5}$), Nitrogen oxides NO_2,

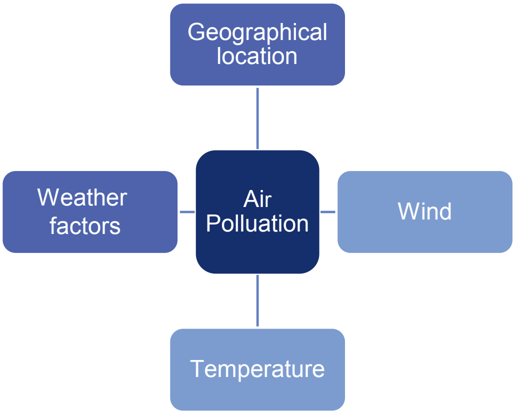

Fig. 21.8 Factors that cause air pollution to differ in each country. *Source*: http://www.wind.arch.t-kougei.ac.jp/info

Table 21.2 Maximum limits for contaminants of ambient air in Egypt

		Maximum concentration (μg/m³)			
Polluted	Region	Hour	8 h	24 h	Year
PM_{10}	Urban areas	–	–	150	70
	Industrial areas	–	–	150	70
NO_2	Urban areas	300	–	150	60
	Industrial areas	300	–	150	80
SO_2	Urban areas	300	–	125	50
	Industrial areas	350	–	150	60
CO	Urban areas	30 mg/m³	10 mg/m³	–	–
	Industrial areas			–	–
	Industrial areas	300	–	–	–
O_3	Urban areas	180	120	–	–
	Industrial areas	180	120	–	–
$PM_{2.5}$	Urban areas	–	–	80	50
	Industrial areas	–	–	80	50

Sulphur dioxide SO_2, Carbon Monoxide CO and Ozone O_3. Studies have shown that these pollutants greatly affect the public health of humans and the surrounding environment and must work to address the sources of these pollutants to reduce them by all means technical and scientific. The maximum permissible limits for average of external air pollutants in Egypt are shown in Table 21.2 [1]. Air pollution can affect our health in many ways in the short term and long term. Different groups of individuals, especially elderly and children suffer from and can be affected by air pollution in different ways and are more sensitive to pollutants than others. Carbon dioxide (CO_2) may be not classiffied as pollutant, but it is found that its concentrations affect human health as presented in Fig. 21.9 [13, 14]. It also causes global climate change.

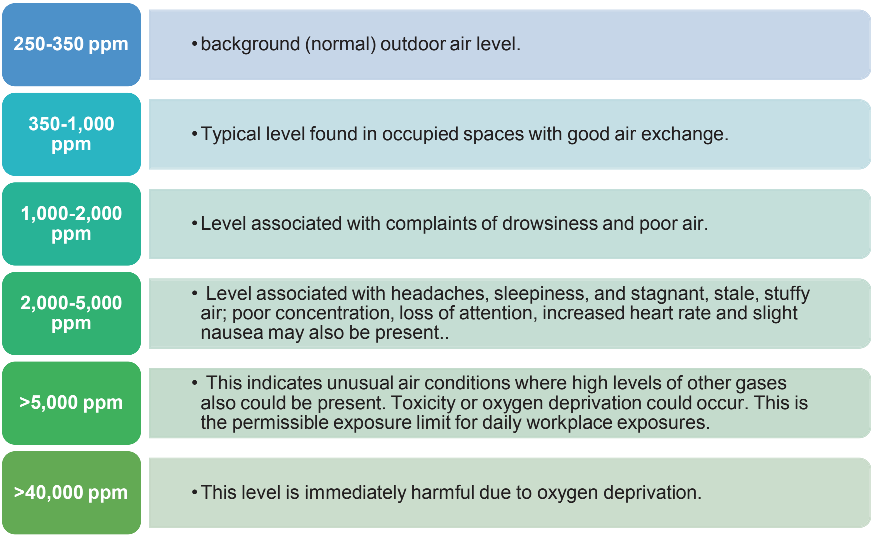

Fig. 21.9 Carbon dioxide levels and potential health problems. *Source*: https://www.climate.nasa.gov/climate_resources/24/graphic-the -relentless-rise-of carbon-dioxide/

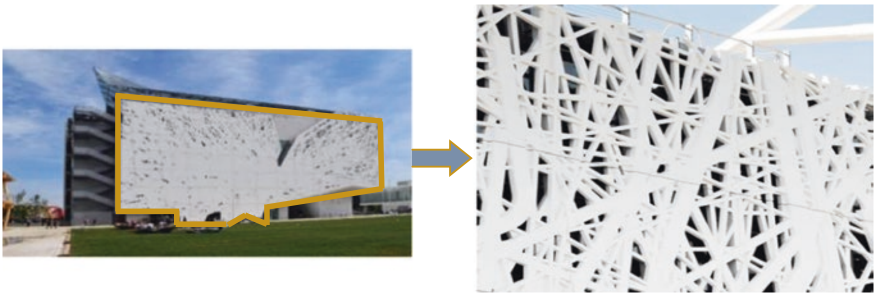

Fig. 21.10 Biodynamic concrete over 700 branched panels in Italy Pavilion at Milan Expo. *Source*: https://www.archdaily.com/630901/italy-pavilion-milan-expo-2015-nemesi

Nanocoating and Air Pollution in Megacities

The buildings that are using self-cleaning: photo-catalytic coating in their treatments was reviewed (Table 21.1). It was found that the coating was used for more than one purpose. In some buildings, used as self-cleaning and some used to reduce pollution [15, 16]. Examples of these are the Italian Pavilion at Milan Expo 2016 and Torre de Especialidadesis hospital in Mexico City.

In the Italian Pavilion at Milan Expo, the design façade of photoelectric glass covering the facade is decorated with more than 700 active BIODYNAMIC concrete panels with the patented Ital Activee Active TX technology as shown in Fig. 21.10.

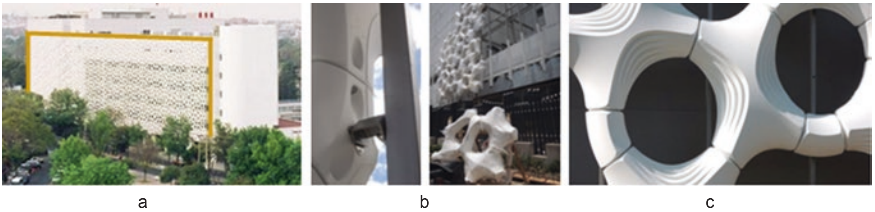

Fig. 21.11 Façade of Torre de Especialidadesis hospital with Prosolve 370e coated with TiO_2. (**a**) Torre de Especialidadesis hospital. (**b**) Placement of Prosolve 370e. (**c**) Plastic material called Prosolve 370e. *Source*: https://blog.visualarq.com/2014/03/07/rhino-projects-a-smog-eating-facade/

When the material comes into contact with the ultraviolet rays, it can “pick up” pollutants in the air and turn them into idle salts, and hence reduce smog levels in the air [17]. The Torre de Especialidadesis hospital has a double façade (a double skin of pieces) made of a lightweight plastic material called Prosolve 370e, which is covered with a very thin layer of titanium dioxide (TiO_2) powder [18] as presented in Fig. 21.11.

Results

Self-cleaning: photo-catalytic coatings can be used extensively and adapted to achieve an inventive and a visionary architecture that has proved from the examples shown above the possibility of exploiting such technology on different façades. It also helped architects to create new destinations using different units, whether concrete or plastic units that contributed to the use of paint effectively to perform its job and reduce the pollution in the atmosphere, but not to reduce one compound. It was found in studies that it is effective in reducing the various elements of pollution and it can be mixed with cement and carbon dioxide absorption [19, 20].

Conclusions

Different buildings around the world that applied different types of nanocoatings were analysed. Also buildings that were divided according to their types of nanocoating, the country where most common types of buildings used and the country that has similar matching to Egypt’s climatic conditions were presented and assessed. The assessment of each building facades was useful to extract the nanotechnologies, especially self-cleaning (Photo-catalytic) that mitigate air pollution. In addition, the percentage of pollutants worldwide was assessed to identify the most important pollutants that are classified as top contaminants threatening human health and highlighted relationship of CO_2 to human health, if the concentration in the internal spaces exceeds the limits recommended globally. The Ministry

Environment, Egypt, report was discussed and the maximum limits of pollutants at the global scale was also presented, which led to the extraction of requirements to reduce contaminants in the internal spaces of buildings using titanium dioxide as self-cleaning (photo-catalytic). Results show the potential of titanium dioxide as a self-cleaning (photo-catalytic) to mitigate the level of pollution in Egypt.

Nanotechnology works to extend the futuristic life of the buildings and enhances livability in cities and has supported the society with ideas and techniques that provide aid to solve the air pollution problems and external facades. Nanotechnology has provided many materials in the field of construction. With unique characteristics that changed the general concept in the use of buildings' materials. In addition, nanotechnology assists in mitigating air pollution, where self-cleaning: photo-catalytic coatings are commonly used in all types of buildings including residential, hotels, sports and commercial buildings (offices bank). Furthermore, the application of nanocoatings in glazing, paint, ceramics and membrane was indicative. This coating used in various climates, where results show the potential of titanium dioxide, as a self-cleaning (photo-catalytic) to mitigate the level of air pollution, can be significant. This coating can cover any shapes and its effect will not be changed. We can use it onto any buildings façades to purify air before entering into the building. Finally, it is recommended to apply this coating on the façades of hospital and residential buildings in megacities in Egypt such as Cairo due to high air pollution and these buildings' types are considered of high priority.

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