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Research Article

The Use of Self-cleaning Materials and Study Their Impact on the Quality of the Visual Appearance of Large Industrial Cities

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Abstract: One of the capabilities of the architecture is to respond to growing and, in some cases, varied needs of users. However, architecture and construction industry, in comparison with other sciences, have been very slow and inadequate to implement this technology despite very suitable ground for improvement. At the moment, one of the most essential discussions in this field is how to achieve qualitative understanding of construction materials. Accordingly, one of the key sections of a construction which plays a significant role in optimizing performance is shell of the building. In this article, in addition to the utilization technique of self-cleaning materials in construction industry which will result in embellishment of urban design, an attempt has also been made to present a suitable model on how to utilize these materials in order to improve the visual appearance quality of megalopolises. The technology of self-cleaning surfaces in order to increase durability and reduce costs and required time for equipment maintenance has currently become the focal point in construction industry. Now providing one answer to the question of whether will self-cleaning, purifying facades change the future of urban architecture? The main panorama of this research is to find and establish a dynamic and sustainable balance in embellishment of urban design. The necessity of research in this field as well as finding the best and most practical solution seem. To achieve all this, an analytical and descriptive research has been utilized, data has been collected by various books and national and international websites.

Keywords: Urban architecture; Visual exterior of capital cities; Visual quality of the façades; Purifying facades; Nanotechnology materials; The useful life of the building

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1 Introduction

One of the most important problems that megalopolises are facing with is the ever-increasing growth of population and industry in the environment which causes the number of pollutants and their harmful effects on the urban landscape increase. For this reason, visual appearance (Aesthetics) and visual quality of urban landscape reduce. Not only the use of the self-cleaning materials with the ability to remove or reduce air pollutants and its consequences (such as acid rain, air dust, etc., which gradually deteriorate the façade of buildings) can prevent different parts of buildings from losing energy, but also they assist the long-term maintenance of buildings as well as strengthen them against natural disasters.

In recent decades, many attempts have been made in different countries to solve this problem: one of these solutions is the use of materials known as self-cleaning materials in this century to keep the façade of buildings clean as well as to reduce the economic costs. It is imperative that architects and builders are encouraged to use these materials by explaining the effects of new materials on improving the visual appearance of large industrial cities to them. This will help to improve the level of architecture and

urbanization as well as the visual appearance and visual quality in metropolises. It seems that the self-cleaning materials improve the visual appearance quality of the human environment by introducing them, understanding how these materials are used and their effective role in increasing the life expectancy of building shell to reduce the maintenance costs. To achieve this, this modern technology can be utilized to improve the visual appearance quality in metropolises for the purpose of self-cleaning and simple cleaning. The questions raised in this regard are as follows:

(1) How much is the impact of the new technology on the building lifetime?

(2) How are these materials and coatings used in buildings?

(3) How economical is the use of these materials?

(4) How much can the self-cleaning materials affect the improvement of the human environment?

2 Self-cleaning Materials

Historically, the use of self-cleaning materials in the construction industry is divided into two periods. The first period began in 1280 and lasted up to 1980, during which these materials were not identified properly and people created the new combinations of the materials such as stained glass in the medieval churches or ancient Roman handicrafts by trial and error. During the second period, from 1980 up to now, the self-cleaning materials have been known as a specific field. Now this technology has been studied in different parts of the world[1].

About 400 BC, the Greek philosopher, Democritus, first utilized the term "atom" which means “indivisibility” in Greek language to describe self-cleaning particles. This is a reference number, so, you forgot it to type in superscript. Silver was the first substance known as an antibacterial and microbial agent. Later, the self-cleansing characteristic was discovered in a lotus leaf [1].

Wilhelm Barthlott from University of Bonn in Germany, the discoverer and developer of the lotus effect, propounded a perspective of a self-cleansing city in which rain perfectly cleans windows and walls of skyscrapers like a lotus [11]. The discovery of the lotus effect was initially an attempt to understand the level of self-cleansing ability (Plasticity surfaces with microscopic structures or even nanostructure). Now this extended research has turned into a completely new science in the field of wettability, self-cleaning and disinfectant. The story behind the self-cleaning materials was inspired by the sacred lotus in nature. The lotus is respected due to its cleanliness. The plant grows in muddy water, but its leaves appear a few meters above the surface of water, which causes dirt to stay from it. When rain drops are placed on the leaves of lotus, it is easier to clean them than any other plants. The exceptional cleansing feature of this plant attracted Barthlott’s attention. He noticed that some plants would apparently never need to rinse. Barthlott observed that contamination and dirt were only in contact with the tip of the bulge of the leaf surface on the plant, and rain drops easily cleaned contamination by sliding down from leaf to bottom [11].

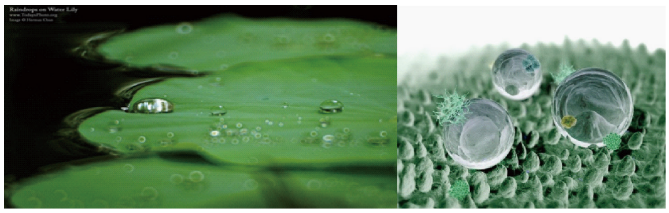

Figure 1. Water on the surface of a lotus leaf [18].

Nanomaterials are defined as materials whose one of its dimensions (length, width, or thickness) is below 100 nm at least. Generally speaking, in a general division, nano products can be expressed in the following ways:

Nano layer thin films mainly utilized for electronic applications, nano coatings to increase corrosion resistance and protection against environmental degradation agents, nanoparticles as a precursor or modifier of chemical and physical phenomena, nanotubes are meant to be a nano-structure or, more clearly, a nanostructure solid with atomic system, the sizes of the constituent crystals and chemical composition spread across a body on a multi-nanometer scale [15].

The physical and chemical properties of nano-materials (in various shapes and forms, including particles, fibers, balls, etc.) differ significantly from microscopic materials. The principal changes that exist is not only small in size, but also in terms of new properties of the nanoscale level. The ultimate goal of the study of nanoscale materials is to find a new class of high-performance building materials, which can be described as multifunctional and multipurpose materials. Multifunctional means the appearance of new and different properties in comparison with the

properties of ordinary materials in a way that the materials can provide various applications [17].

The essence of nanotechnology is the ability to work at the atomic level with the goal of building up and manipulating the formation of atoms or molecules by using materials, devices and systems with new abilities and altering these structures to achieve higher material efficiency. Nanotechnology is the process of manipulating materials in an atomic scale, producing materials and tools by controlling them at the level of atoms and molecules, too. In fact, if infrastructures of all materials and systems are arranged into nanoscale, all the reactions will be faster and more efficient and sustainable development will be achieved [12].

Most of the world's existing resources have been used in the current artificial environment. The restoration and upgrading of existing buildings to reduce environmental impacts is as important as the creation of new structures. In majority of cases where having access to new resources is minimized, methods are discovered with which those buildings built for particular purposes can be also used for other objectives. By changing the materials and applications, nanotechnology will change the space as a result. Nano coatings are the simplest of the nanomaterials that can comprehend or respond to the surrounding environment [15].

2.1 Self-cleaning Foundation:

In practice, cleaning up surfaces of building materials such as glass, tiles and facade surfaces is associated with numerous problems such as high consumption of energy, chemical detergents and, consequently, high costs. In order to understand the process of self-cleaning, we can follow two paths: one is hydrophobic and the other is hydrophilic. Self-cleaning surfaces can be classified into hydrophobic and hydrophilic. Different types of plastics, especially those with a large number of carbon fluorides (such as Teflon) are among the most popular types of hydrophobic surfaces. Well-known hydrophilic surfaces include metal surfaces and ordinary glass [7]. Chemically, the levels can be divided into two active and inactive categories. Hydrophilic surfaces tend to be more likely to bind to absorbent materials, and hydrophobic surfaces are reluctant to produce such a bond. Unfortunately, many suitable technical materials, such as glass and metal, belong to the hydrophilic category [17]. These surfaces easily stain due to their high surface energy. The surface energy of a clean metal easily reaches 1,000 milli-newton per meter (iron surface energy is about 2,500 milli-newton per meter) depending on the degree of cleanliness of the metal in contrast to Teflon surface energy which is only eighteen milli-newton per meter. For this reason, many efforts have been made to reduce surface tensions in various surfaces [7].

The superpower hydrophobic property is known as the lotus flower. This property exists in lotus leaves due to the very tiny bumps on milli-metric bulges. The degree and situation of a surface wettability is determined by the contact angle of that surface with a droplet on that surface. The contact angle of a surface is the tangent line tilt at the point of the contact between the surface and the liquid. Zero-degree contact angle shows that an absolute wettability has occurred. Regarding water, this state is called super hydrophilic or complete wettability. Unlike the said state, there is a contact angle of 180 °. Surfaces with very large contact angles (greater than 150 degrees) are called super hydrophobic. The surface contamination of super hydrophobic surfaces or surfaces having a lotus effect is much lower than surfaces having high surface energy. In addition, the contaminating particles that are loosely linked to these surfaces can be easily wiped off by getting wet for example by rainfall [7].

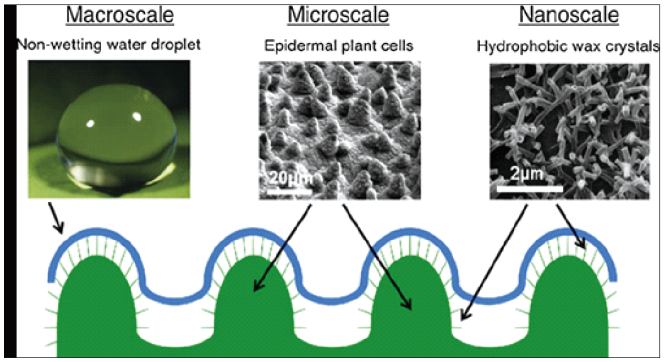

Figure 2. The hierarchical surface structure of the lotus leaf at the micro-and nanoscale are together with the chemical properties of the hydrophobic wax crystals responsible for the macroscopic superhydrophobic phenomenon [26].

The contact angle for hydrophobic surfaces is more than 90 degrees and for hydrophilic surfaces is less than 30 degrees. Water droplets continuously roll on the surface and they clean dirt and contaminants instead of getting absorbed into each other [13]. In 2003, the researchers at Robiner and Cohen Lab at

MIT successfully discovered how a small change in a building could determine whether a super hydrophobic or super hydrophilic has been produced [11]. Some of the fields' applied in these surfaces in the building industry include construction glass, facade materials, bathroom door and walls, swimming pools, saunas, solar panels for energy production and greenhouses [13]. Self-cleaning materials which both are resistant to fire and are energy controller are able to save energy. These materials cause bacteria not to penetrate into office buildings, residential buildings, hospitals, etc. They give them a long life, a bacteria-free environment, bactericidal effect and fatigue nature [18].

In addition to the method of reducing the surface energy that can be used to induce the inherent property of the stain removal, photocatalyzers can be used to attack contaminated particles absorbed on surfaces and decompose them. Nanoparticles of titanium dioxide can be used in this case. These nanoparticles can produce active oxygen components by absorbing ultraviolet light in the presence of water molecules; these components are capable of effectively eliminating bacterial fields, analyzing organic molecules and contaminants bound to the surface. By coating the walls, sidewalks and roofs of buildings with these particles, the optimal self-cleaning effect can clean up highly adhesive surfaces, like glass surfaces, too. However, these methods are suitable for outdoor applications (such as exteriors); and the reason is that these surfaces are more exposed to ultraviolet rays of the sun. As it mentioned hereinabove, self-cleaning surfaces are activated by UV light and self-cleaning properties are exposed [7].

3 Applications of self-cleaning materials

Due to the fact that this technology is new, the latest applications are introduced in various industries every year. In the case of nanotechnology material applications in the building industry, the following can be summarized: Nano-glasses, nano-coatings, nano-waterproofing [3].

3.1 Nanoglasses

Self-cleaning glass is a reality as well. A transparent coating of hydrophilic and photocatalytic mineral materials is applied during the manufacturing process, enabling the glass to use the power of UV radiation, contained in sunlight, and the rain to efficiently control the dirt that accumulates on the outside of the windows. Exposure to UV radiation triggers the decomposition of organic dirt and makes the glass surface hydrophilic. The rain (or water) forms a layer across the glass and rinses off organic dirt and mineral materials.

Self-cleaning glass, energy-efficient glass and fire protection glass can be mentioned out of Nanotechnology applications in the glass manufacturing industry. Nano Self-Cleaning Glass is a kind of high-to technology glass, whose surface has superhydrophilicity, so that the glass keeps long-term self-cleaning effect without conventional manual wash. In the manufacturing of self-cleaning glass, titanium dioxide nanoparticles are used. These glasses three kinds of glasses have anti-staining and disinfectant properties. Energy control glass reduces the transmission of ultraviolet rays and infrared waves, adjusts the passage of visible light and prevents the energy inside the building from wasting. However, with the introduction of nanotechnology to any sphere, new properties and applications can be expected from that sphere. The glass industry is no exception to this, and it has witnessed significant changes in a variety of products and their functions [7].

Self-cleaning glass with titanium dioxide nanoparticle coating is a member of the large nanoparticle family that has been given special attention since nanotechnology was formed due to self-cleaning properties on surfaces. This type of photocatalysis can be used to make self-cleaning glass and bricks on the facades of buildings. When the coating of titanium dioxide on glass is exposed to UV radiation, which constitutes a large part of the sunlight, it decomposes pollutants such as dust and rain particles, which can cause pollution and poor visibility on the glass over time.

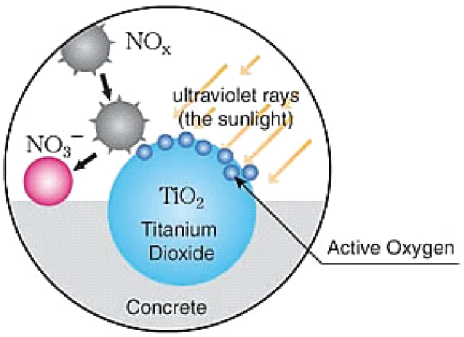

Figure 3. This diagram shows a nitrogen oxide hitting the surface and being converted into a nitrate [25].

The second property that this coating gives to

glass is the hydrophilic property. In this way, the decomposed pollutants of the organic hydrocarbons on glass are washed down due to rainfall or water splashed on the glass [7]. There are some materials for glass coating which are resistant to scratches in addition to water and pollutant repellency. They are also resistant to chemical detergents and mild acids, and has a heat tolerance of up to 250 degrees Celsius. The price of glass with titanium oxide coating is about 10% higher [7].

Figure 4. Super-hydrophilic surface with titanium dioxide, water droplets will easily remove contamination [7].

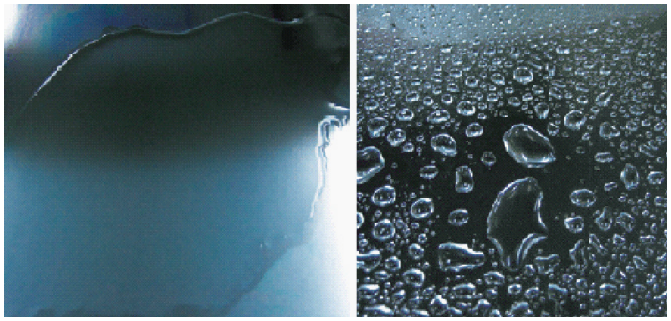

Figure 5. Image of panel with the Eco Clean technology (left), and without the technology (right). The coating is reported to break down pollutants and produce a "super-hydrophilic" surface that washes clean when it rains.

3.2 Nano-coatings:

Typically, the coating is a thin layer that is spread on the material to improve the properties of the surface of the material or give it a better appearance. In the design of architecture, many natural materials that have desirable visual features are used, but they do not have durability and good stability against aggressive agents and require layers and protective coatings on their outer faces. In addition, features such as removing pollutants or self-cleaning on the facade by these coatings are possible. Self-cleaning colored coatings are placed in this range [13].

The construction industry has this ability to utilize nanotechnology to reduce costs of construction and maintenance as well as energy costs. Materials used in building construction should have the maximum strength against the forces entered and keep up their efficiency over time. Meanwhile, it is always desirable that the building cost is reduced simultaneously with the increase in material efficiency. Building safety against earthquakes and energy savings seem very necessary. When competition among manufacturers becomes more intense, nanotechnology can be used to create capabilities such as self-cleaning, controlling and reducing energy waste through insulators, supplying and storing energy, and controlling pollution, preventing corrosion and reducing annoying sound waves… [7].

One of the most important parts of a building unit that plays a significant role in the optimal performance of the building is the roof and shell of the building. The use of superior technologies in this sector is one of the competitive advantages of building contractors. Nanotechnology with the use of aerogels has already had a lot of innovations in this field, and has given this part of the building assistance such as strengthening, thermal and moisture insulation, self-cleaning properties, and the elimination of pollution. Today, a lot of clay manufacturers have made clay self-cleaning building materials for roofs. When they are utilized on roofs, their particles of soil, fat, soot, algae and moss are killed and easily cleaned with the first rain by using photo catalyst and with the help of sunlight nanoparticles. Photovoltaic coatings as building roofs, and titanium dioxide is a usual material for photovoltaic coatings. This substance is a non-special light diffuser and an ultraviolet light absorber. The first feature makes the titanium dioxide a very good material for white color, and the second feature creates a self-cleaning characteristic and protects the roof against ultraviolet light [7].

3.3 Waterproof nano-coatings:

Water absorption causes unprotected buildings to sustain numerous and irreparable damage. This damage includes superficial and structural damage to building such as scurf, blow out wall and flake of colors, creating mold, absorption of pollution and dirty, creation gap between the wall & the ceiling and premature fatigue, reducing the strength of concrete and corrosion in cast iron. Waterproof coatings are a good way to prevent damages caused by water penetration into the building. Waterproof coating

materials made of nanoparticles, provide long-term protection for surfaces if they are properly penetrated in the materials. Waterproof coating materials can be utilized in new buildings, old buildings, reinforced concrete and cement parts, tiles and stones. It is noteworthy that waterproofing the building is possible in different areas such as foundations and columns, internal walls, walls and external coatings, sanitary facilities, built-in wiring and ducts, groundwater reservoirs and above ground water storage tanks, and roofs [3].

New types of products based on chemical nanotechnology are also being used to protect the surfaces of construction materials, for example to prevent damage caused by water penetration or to protect outside walls from mildew, moss, algae and dirt. Also, protective "anti-graffiti" coatings make it easy to remove undesirable "art", as spray paints do not adhere to them. Even chewing gum can be removed more easily from surfaces coated in this way. Unlike the coatings which used to be applied for these purposes, the new silane-based products do not seal the surface, hence moisture can escape10. The protection provided is usually permanent and is retained even after repeated cleaning. Steel and glass are popular materials in architecture. However their appearance can be spoiled by, for example, fingermarks which have lipophilic characteristics. New types of "anti-fingerprint" nano-coatings counteract this as they are fat-repellent and modify the light refraction so that the marks remain invisible [41].

4 Restrictions on self-cleaning materials

• The construction of a lotus leaf structure is a hard and costly process, and there are few low-cost processes for large-scale construction.

• These coatings are sensitive to mechanical stresses and lose their properties by applying any mechanical force such as scratches. Also, unlike the lotus leaf, which is self-healing meaning that it repairs itself in the event of bludge loss, self-cleaning coatings do not have such a feature. In other words, self-cleaning coatings have a lifespan and do not retain their properties forever.

• Application of these coatings is only possible in places exposed to rain and water. Self-cleaning also requires running water, rain for example, hence surface structures with these properties are not practicable for use in most interiors. Water plays an important role in the self-cleaning process [41].

• Environmental factors such as acid rain or chemicals such as detergents destroy these coatings.

• Due to the use of nanoparticles in these coatings and the gradual entrance of nanoparticles into the environment, there is a risk of environmental pollution [6].

4.1 The role of values in discussing issues of water

Valuing water means recognizing and considering all the diverse benefits and risks provided by water and encompassing its economic, social, and ecological dimensions as well as its diverse cultural meanings. With time, the perception of the world towards architecture has changed and with that, has defined new roles for water.

Water, the most abundant and freely available liquid system with optimal density as well as polarity, is being used as an essential medium to remove different types of contaminations on surfaces. In Nature, many ingenious designs exist which combine surface properties and water energetics to scour material surfaces. As mentioned, lotus leaves, one of the earliest discovered and investigated self-cleaning bio surfaces [43, 44], uses a specific water–surface interaction to clean the surface of leaves.

While water-assisted self-cleaning is an efficient pathway for surface cleaning, under some special conditions where water is not readily accessible, such strategies can fail. For example, in outer space and in cold areas where the temperature is below 0°C, surfaces cannot access abundant amounts of liquid water or the free movement of water will be hindered. Such conditions may limit the usages of water-assisted self-cleaning surfaces. Thus, there is an urgent need to develop advanced technology for surface decontamination in such unique extreme environments.

5 Nanotechnology in the facade of buildings and urban landscape

The elements of aesthetics have been of human interest in the construction of houses and towns since ancient times. Facades are the interface between the interior and exterior of a building. They are the most striking and visible parts of a building, they protect it from external agents and are one of the main contributors to creating comfortable environments since it is where thermal gains and losses occur. Just

like our skin, an extremely versatile organ of our body, it should be natural for it to be the part of the building which bears technology capable of becoming adaptable to the environmental conditions of the place where it is located. Building façades not only play an important role in users' perception of buildings and urban spaces, but they also have a significant impact on visual qualities in this domain. Today, due to the development of different types of facades, a lot of costs are spent on these. Because of the ever-expanding population on Earth and the consequent rapid growth of pollution and its consequences, such as acid rain, air dust, facades and their appearances will gradually be eliminated or degraded. Researchers have been attempting through preventive strategies to prevent the spread of these contaminants [4].

Self-cleaning or easy to clean surfaces can reduce the amount of cleaning required. In the case of industrial cleaning in particular it can reduce labor costs and extend a material's durability. Lower energy costs and less use of cleaning detergents are expected to be the primary environmental benefits [41]. Self-cleaning coatings have recently become very much considered in business applications and researches, especially in health facilities as one of the most important urban areas. These coatings are widely used in various fields of construction including: exteriors, roofs, floors, ceramics, doors and windows, anti-corrosion coatings, anti-freeze coatings... [6].

According to the estimations done, construction equipment generates an annual income of one thousand million dollar. The construction industry is one of the industries, in which nanotechnology and nanomaterials can be widely used. Nanotechnology is currently used in some products and construction equipment such as self-cleaning windows and flexible solar panels for façade buildings [10].

Now, there are many self-cleaning products available commercially. Some of the companies which produce these kinds of products are: The Pilkington Group which was the first company commercializing its self-cleaning glass [27], the German Lotusan Company producing self-cleaning paints [28], Cardinal Glass Industry in Europe [29], Saint Gobain [30], PPG industry [31], Fletcher Steel Company which has dedicated itself to providing the best solutions by Self-cleaning roofing [32], Paneltek which is a leading manufacturer of high quality terracotta products in China [33], Lapitec Company creating a ceramic based product with unsurpassed technical properties and design appeal [34] and Breinco Company producing air-clean manufacturers of precast concrete pavements with decontaminating effect to reduces air pollution [35].

Moisture has destructive effects on building materials. Due to the porous structure of many building materials and their capillary nature, water molecules enter the structure of these materials and cause various damages to these materials. Scurf, flake of colors, molds, and dirt as external damage reduce the strength of building materials, especially concrete. These nanoparticles prevent concrete, bricks, and other salt-rich materials from creating nitrate [21].

Super-hydrophobic nano-coatings are resistant to dirt, ink and also paint to prevent graffiti and such destruction. These coatings have been chemically combined with the minerals of the ancient buildings, and are resistant to scratches and bad weather conditions. These materials are also resistant to harmful sunrays, and do not allow paint and dust particles to be stuck to the surface of building.

According to what is said above, the best cover for urban space is self-cleaning cover because it allows sunlight to decompose urban pollution existing on these walls. Also due to the hydrophobicity of these coatings, rain, water and mud cannot be absorbed, and this will significantly assist urban aesthetics. Contrary to popular belief, the application of these coatings varies depending on the type of coatings and surface types. Generally, these coatings can be placed on surfaces when constructed. Also after the completion of the manufacturing process, and even after the installation of these surfaces, the coatings can be sprayed on the surfaces easily. By using this method, in addition to urban walls, important historical buildings as well as commercial buildings with expensive facades can be preserved. The other advantages of using these coatings in facades of buildings and urban walls are to prevent dirt and contamination of surfaces, reduce environmental contamination, and maintain the appearance of buildings against environmental conditions, anti-scurf and anti-mold. Also, these coatings can have a long lifespan and finally no apparent changes [21]. For example, sodium lamps that diffuse yellow light are used to illuminate most tunnels and streets, but due to air pollution, the external surfaces of the lamps become dirty and the light is dimmed. Sodium lamps

diffuse visible spectrum, but they also diffuse around 3mW/cm^2 ultraviolet light. This property is applied so that these lamps can be used for a longer time. This is because the coating of titanium dioxide (Tio2) on the outside of the lamp and the photocatalytic effect of Tio2 create self-cleaning effect on these kinds of lamps. Large trees surrounding buildings have their effect on the surfaces of the buildings because the facade of buildings absorb the green color of the trees over time, and a strong pressure cleaner should be used to clean them. However, this makes it possible to cause more adhesion on the building surfaces after a few months, and this also makes it faster and easier to absorb dirt. In such cases, the use of nano-coatings of stone and wood seems essential [2].

Figure 6. Smart Glass Façade: Smart window with a pencil-like engraved nanostructure onto the glass [45].

5.1 Effects of self-cleaning materials on construction costs:

Traditional treatments for polluted facades showed to be waste of effort, money and time. The proposed method could be considered as a sustainable economic treatment for pollution control in humid areas in the developing countries [42]. Given the rapid growth of the scientific and practical research of nanotechnology in all sciences and industries, little attention has been paid to the applications of this phenomenon in the construction industry in general. Yet, with regard to nano reinforcement and hardening agents in construction materials in the recent years, a new wave of growth has been accelerated in the construction industry.

Nanotechnology and self-cleaning materials with more selectivity and efficiency can have tremendous impact on production and energy efficiency, reducing pollution, producing chemicals and special medications, development and health of the global economy; therefore, researches and development in the field of self-cleaning materials will have a profound impact on society and quality lifestyle. In fact, according to studies, energy and environment are key applications that expand researches in the area of self-cleaning materials in the world. Development of self-cleaning materials through new, better and cheaper products not only affects societies directly, but also it will have a greater impact in future [16].

The move towards the development of nanotechnology is regarded as the 21st century economic and industrial development strategy. Developing countries need the presence and development of this type of pervasive technology to achieve competitive ground and expand entrepreneurial activities that are competitive with the rest of the world. Since nanotechnology is expected to have profound impact on the global economy, market volume is a good indicator for evaluation of its economic significance. If nanotechnology succeeds, this technology will significantly improve the performance of many products, or produce completely new products [5].

Because there is a need for development in the field of construction in general, we must develop appropriate equipment and made it available to the community of researches [16]. Today, buildings are a kind of technology. They adapt themselves to technology and take advantage of it. Buildings as structures will become intelligent as soon as they can be equipped with computers. An intelligent building is a building that enhances the efficiency of its inhabitants and provides effective management based on specific requirements and at the lowest cost [14]. For the façade, the main benefit is maintenance, as the idea is to halve the need for cleaning, reducing the cost of scaffolding, cranes, or all the dangerous operation that involves cleaning façades of tall buildings. It is important to note that, despite the technological advances concerning facades, many gains in terms of sustainability can be made through conscious design and by choosing materials that are suited to the climate and the environment. The combination of both traditional and intelligent systems and materials can enhance the comfort and efficiency of a building.

Considering all the above mentioned, the reason for the spread of the use of self-cleaning materials is some of the characteristics of these materials which are listed below:

- They are economical.

• They are non-toxic and Eco-friendly.

• They convert widespread types of pollution into water and carbon dioxide.

• They are activated by the sunlight and require no specific chemical reactions.

• They combine with the facade of buildings (glossy appearance).

• The self-cleaning glass and purifies air.

• They have proper shelf life to increase lifespan of buildings.

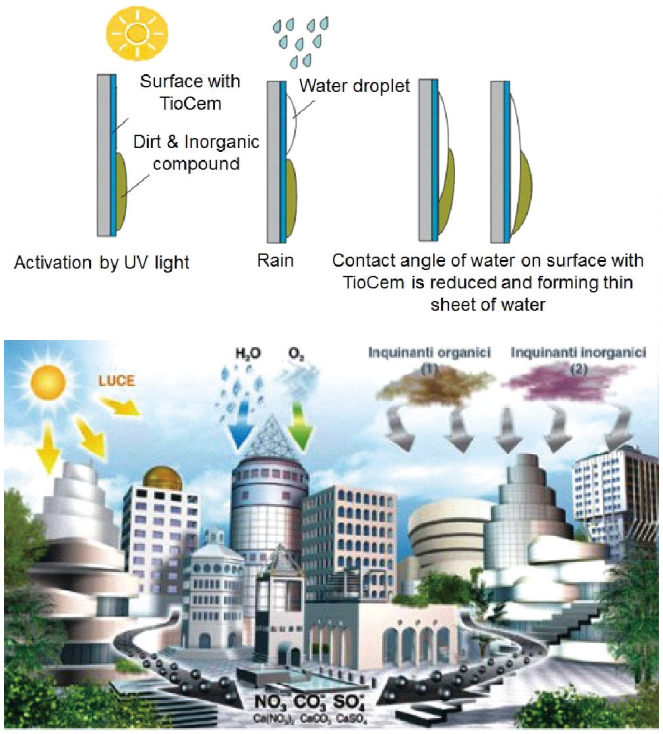

Figure 7. Coverage of buildings with self-cleaning materials, environmental pollution purification [39] [36].

5.2 Bratislava Mall Project

Details: Location: Slovacchia, Bratislava.

Date of Completion: August 2017

5.2.1 More about this product and project

Technology rises to power. When it comes to design choices, architecture firms often look for materials that combine elegance with the latest technical features; for this reason, Lapitec was the focus for the application of the exterior wall cladding on this grand Bratislava building, its sintered stone is made in Italy and dedicated to exterior design applications. The Urban finish completely covers the building, giving it a dash of elegance and purity in this corner of the Slovak capital dedicated to business.

Lapitec is the ideal external architectural panel because it guarantees complete resistance to atmospheric agents, UV rays, frost and "urban" issues, such as smog or graffiti while preserving its unique aesthetic and technical features. The Sika polyurethane glue system is used for the fixing of this ventilated facade in Lapitec.

The coatings of ventilated facades are perfect for the use of unique colors and for emphasizing the quality and stability of buildings, as in this case. The difference is the performance: here in addition to the aesthetic impact, this facade is a future investment for minimum necessary maintenance (it is self-cleaning) and for material compactness [36].

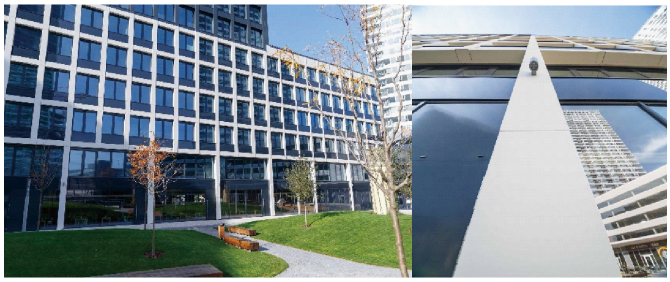

Figure 8. Exterior Cladding in Shopping Center [38].

5.3 Glass Coating:

Details: Location: Germany, central Hamburg

Date of Completion: Refurbishment completed in 2011

5.3.1 More about this product

With the latest technology, this dream of self-cleaning glass is entirely possible. Nano glass Coating is a transparent shield that is applied to any glass or ceramic surface, giving it a hard and durable water repellent and “self-cleaning” surface. Dirt and other deposits cannot cling to the treated glass surface and either wash away easily or can be simply cleaned with water and a cloth.

What happens is that our glass coating makes the glass water repellent and the water can’t get into the pits and valleys of the glass. In fact the water will sit high on the surface and the droplets will tend to curl up and quickly roll away. Dirt, grime, slime, calcium and other deposits will not be able to embed or cling strongly to the surface and will wash away easily. This is why it is known as self-cleaning glass - it does

practically clean itself.

Figure 9. Façade of the EMPORIO complex [38].

7 Conclusion

Pollution in cities is not only a risk to our health but it also has a damaging effect on buildings, external cladding, monuments and infrastructures. The main cause of damage to buildings is the buildup of organic matter which deposits on the surface.

By introducing these new materials into building technology, disadvantages such as chemical corrosiveness in them will not be conceptualized. Therefore, phenomena such as acid rain, chemical mechanisms during execution and construction of a building, and weather temperatures will not be considered as destructive or limiting factors anymore. Each new technological paradigm, like the digital world, is an opportunity to redefine our world and our cities. The challenge of cities is no longer their digitalization, but how this shift could make them more ecological and human.

The great challenge for humans is to transform cities into bio-cities. We have to design and build cities that function more like forests, like self-sufficient ecosystems that produce the resources they need to thrive, and that promote life. This issue, especially regarding exposed surfaces like the facade of the building, is particularly important. The cost and manpower that are used for skyscrapers and large buildings like stadiums and hospitals are significantly large.

In order to reduce the cost of maintaining and cleaning the building surfaces, as well as reducing the repetition of this process, technology professionals have used this new technology to create building surfaces with the objective of self-cleaning and easy cleaning which dramatically has been welcomed by designers, builders and building owners. The technology of self-cleaning surfaces is now very much taken into consideration in order to increase durability, and reduce costs and the time required for maintenance of equipment. These surfaces are divided into two groups of super hydrophobic and super hydrophilic with relatively similar mechanisms. They are used as coatings on different surfaces in order to prevent the sediment contamination. Many uses of self-cleaning surfaces have caused them to be utilized in a variety of fields such as the textile, car manufacturing, aerospace and optical industries. Many commercial products have been produced by using this technology. The construction industry has seen a lot of recent developments on the nanotechnology front. Many nanomaterials have made an impact on the construction industry.

The results of this study show that not only the application of nanotechnology in different industrial and economic fields should be developed, but also its positive and negative effects should be taken into consideration. To this end, along with the development of positive externalities that directly and indirectly play a role in the environment, it is necessary to pay attention to controlling and directing negative external effects by using scientific methods and proper policies. This will make the industrial and scientific innovations in the field of nano becomes sensitive to negative external influences and, as a result, devises practical solutions in this field. Finally, these materials are the perfect choice for locations where you have to guarantee a high standard of cleanliness and hygiene with anti-polluting and self-cleaning properties.

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