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Nanotechnology and its role in raising the efficiency of the internal environment in negative patient isolation rooms in Egyptian hospitals- Evidence-Proofs

Mohamed ELSADAT ASSASA[1]*, Khaled KHORSHED[2], Sherief AHMED EBRAHEM[3]

[1]Teaching Assistant, in, Department of Architecture Engineering, manzala academy of Engineering-dakahlia, Egypt
** Corresponding Author Email: mohamedasasa1@gmail.com-- ORCID: 0000-0002-0218-8337*
[2]Professor, of Architecture, Faculty Engineering, Al-Azhar University – Cairo, Egypt
Email: khled_khorshed@hotmail.com -- ORCID: 0000-0002-0068-8475
[3]Associate Professor, of Architecture, Military Technical College, Cairo, Egypt.
Email: sherif_ahmed@mtc.edu.eg-- ORCID: 0000-0002-0268-8457

Research summary:
Despite the development of nanotechnology materials and the discovery of new properties that have contributed to improving various fields, especially the field of architecture, as it has been able to harness some materials to serve the architectural environment, whether internal or external to buildings, and combat the challenges that hinder the harmony of buildings with the natural external environment. Among the most important of these materials are coatings, which of course have an effective role in buildings, especially healthcare buildings, as nanotechnology has been able to produce materials that help support the internal environment of patient isolation rooms to combat the spread of infection and the spread of bacteria and fungi within that environment, which poses a clear danger to the patient and the medical staff responsible for his care. Despite all this, there is controversy over the effectiveness of these materials in that they are useless and similar to their counterparts from traditional materials. Here comes the role of the research to prove through experiments the effectiveness and validity of nanotechnology materials techniques and their role in combating infection in the internal space of patient isolation rooms, and also combating the heat flow through the outer shell to the patient isolation room, which increases the aggravation of bacterial infection particles in the spaces

1- Introduction:

Of course, nano materials are known as materials that can be produced from local materials from the natural environment, for a specific purpose, and when talking about raising the efficiency of the internal environment in negative patient isolation rooms, fighting infection and heat flow must be the focus of the research paper to identify the materials that can achieve this by confronting the factors that may pose a danger to the internal environment and public health

At this time, there is a general trend towards treating and developing coating materials in order to highlight their most important qualities and characteristics that cause a radical change in the internal environments of patient isolation rooms, and among the trends that work to develop materials is nanoscience, where nano materials can be developed with some local and natural additives such as paraffin wax, which works to greatly change the qualities of nano materials, as will be listed in the research paper

Key words:
Sustainability-Energy-Infection control-Indoor environmental quality-Local materials

2- Research methodology:

First: Theoretical study by identifying nano materials and coatings that can be used in the vacuum of negative patient isolation rooms

Second: An experimental study by conducting experiments Which confirms the effectiveness of nano coatings

Third: An analytical study that shows to what extent hospitals support patient isolation rooms in isolation room environments

3- Patient isolation rooms:

3-1- Definitions related to the research:

First, defining patient isolation rooms

A- They are the most effective spaces within the hospital in terms of controlling diseases and preventing the chances of their transmission from patients to ordinary individuals or from ordinary individuals to patients.[1]

B- They are the rooms in which the care and health of patients is focused according to urgent and emergency tasks at a high level of therapeutic care and control compared to ordinary patients.[2]

C- They are a group of independent spaces that are used to isolate patients who suffer from certain diseases in order to protect them and others.[3]

D- They are rooms in which patients are isolated directly so that they can be cared for and treated for diseases and injuries that they may suffer from in isolation from others.[4]

Second: A special definition of nanotechnology

- Nanoscience is the science that deals with the manufacture of matter on the nanoscale, which is an extremely small unit of measurement equal to one billionth of a meter, i.e. ten times less than a hydrogen atom. At this scale, the chemical and physical properties of materials differ greatly from the normal scale. It can be defined by the researcher as: The ability of matter to give new results and new properties as a result of various factors that affected it, leading to its infinitely small and invisible size.
- Nanotechnology improves the architectural and structural properties of building materials and gives them the capabilities of more than one material at the same time. From this perspective, building materials enhanced by nanotechnology are divided into structural and non-structural materials (finishing materials).

3-2 Function of negative patient isolation rooms:

Patient isolation rooms are single-use units to control infectious diseases, in addition to providing therapeutic services in the field of preventive medicine in addition to early detection services for those infected with the epidemic at the level of outpatient clinics and some hospital departments. The following are some of the services they provide.

• Therapeutic services until the infected person recovers.
• Isolation and control services.
• Personal services such as safety and humanitarian needs.
• Permanent health awareness about the causes that lead to the outbreak of the epidemic and ways to prevent it.
• The presence of patients in patient isolation rooms may lead to a change in behavior, such as reducing contact and other habits that may lead to infection from any disease.

3-3- The main elements of negative isolation rooms:

The following figure shows: (1) The components of the isolation room space, which consists of three adjacent spaces, which are as follows:

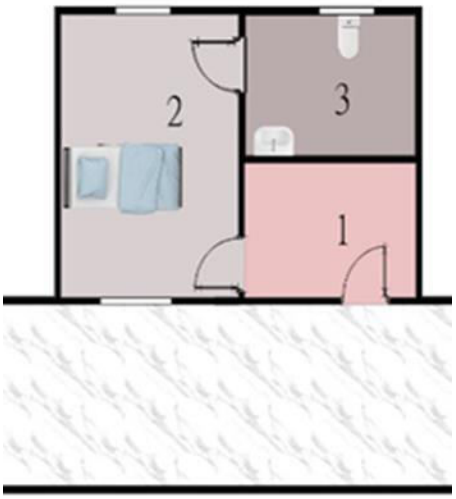
• **(1) The pressure equalization room**, which is a room that separates the isolation room from the external corridors, works as a trap for any leakage of infection from the isolation room when the door is

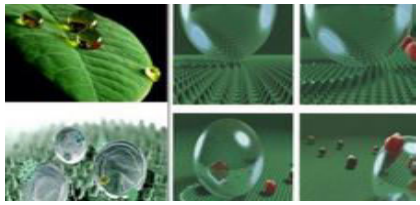
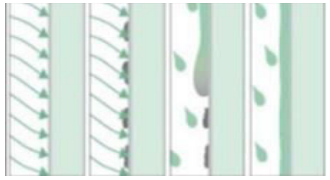
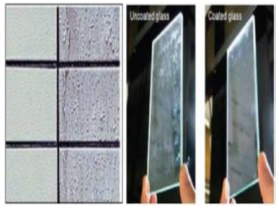
opened, and is equipped with sterilization basins for the medical staff and storage areas for patients' supplies, and is not less than 2.2*2.2 m.

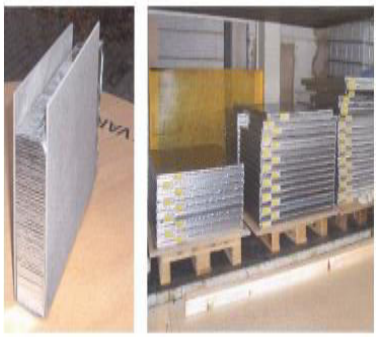
• **(2) Patient room**: According to the latest update of the American code (2021), it is described as a single-occupancy room with a net area of not less than 4.8 * 3.40 m, and the ceiling must be solid and the net height must not be less than 2.7 m, and the air extraction unit is next to the patient's bed, and the air pumping units are distributed at the edges of the room, and the window area represents 20% of the floor area of the room.

• **(3) Bathroom**: The room must contain a separate bathroom designated for the patient alone, and it is provided with a door that opens in the direction of least pressure, and the width of the door is not less than 1.15 cm to allow the patient to enter freely, and the bathroom must be equipped with a shower and a sink, and the dimensions of the bathroom are not less than 2 * 2 m

Figure (1) shows the horizontal projection of the main elements of the negative isolation chamber space, adapted by the researcher.



4- Nano coatings				
Self-cleaning technology coating,(Lotus feature)	Self-cleaning photocatalytic coating	Antibacterial coating	anti-fog coating	Writing and fingerprint resistant coating
This property is due to the lotus leaves having two characteristics: the waxy characteristic and the microscopic protrusions that cover the entire surface of the leaf. It is known that the waxy characteristic alone is capable of making the leaves hydrophobic,repelling water, as the water drops are positioned on the surface coated with this, such that the area of contact with the material is greater than 90 degrees, which causes those drops to form into circular balls, making it easy for them to roll and slide off those surfaces.  Figure (2) shows the self-cleaning feature.	Water repellent surfaces are used to decompose the dust, which floats on the surface and thus the surfaces repel the dust. In this case, ultraviolet rays must be used in addition to the water layer.  Figure (3) shows the operation of photocatalytic cleaning coating.	They are materials that are coated on surfaces to destroy bacteria, especially in healthcare environments, in ways that support hygiene. Antimicrobial and antibacterial nanomaterials were used on all floors and walls of operating rooms in a hospital in the city of Goslar, Germany, in 2009.	The surface is coated with a very thin layer of titanium dioxide that converts water droplets and fog into a thin, invisible layer. This coating is usually used on glass to prevent condensation.  Figure (4) shows the air purifier with silver particles.	It is a coating for surfaces to combat writing and dirt. One of its disadvantages is that the protective coating cannot be easily removed, and thus finishing materials are wasted.  Figure (5) shows the air purifier with silver particles.

5- Thermal insulation		
Thermal Insulation (VIPs)	Aerogel thermal insulation	Nano ceramic paints
It is an insulating material that is highly suitable for providing good thermal insulation with much thinner insulation thickness than usual compared to traditional insulation materials such as polystyrene. This nanotechnology-based material is distinguished by the possibility of achieving maximum thermal resistance with minimum insulation thickness. These insulating layers (VIPs) consist of an outer shell consisting of very thin plastic panels coated with rust-resistant aluminum, and the material inside the plastic panels is a glass powder or porous glass fibers.  Figure (6) shows the nano thermal insulation panels.	Aerogel is a solid material that is difficult to penetrate despite its light weight, as it consists of about 95% air, which increases its ability to resist heat flow through it, and makes it superior to similar traditional insulation methods by about 32 times, and it is called frozen smoke due to its smoky gelatinous shape.  Figure (7) shows the texture of the aerogel.	It consists of very small hollow ceramic balls, so that the ceramic balls work to save energy through thermal insulation. The insulating coating is used on the external and internal walls and its effectiveness increases on the external walls as it prevents the transmission and acquisition of the sun's heat.

- **The researcher concludes from the above that** the most important nanomaterials used in patient isolation rooms are self-cleaning glass, and also paints that are resistant to bacteria and do not stimulate their growth are among the most important paints that can be used in the inner covers of the isolation room. Despite this, there is a difference in the effectiveness of nano coatings and whether they actually fight the growth of bacteria or are just scientific paper research. To resolve the controversy, it was necessary to review the following experiment that confirmed the validity of the hypotheses and the effectiveness of nano-paints, as shown in the following Table (1).

Table (1) shows the experiment to confirm the effectiveness of nano-paint

6- An experiment with existing evidence to prove the effectiveness of nano-paints in resisting bacteria:
The study was conducted in the Microbiology Diagnosis and Infection Control Unit of the Department of Medical Microbiology and Immunology, Faculty of Medicine, Amasya University, Turkey. The study included two samples prepared from nano-paints and another from conventional ones.
6-1 Steps for laboratory testing of antibacterial paints:

• We take a sample of each type of paint using sterile swabs and culture it in blood agar once and nutrient agar once, which are two fertile environments for bacterial growth. They are poured into plastic dishes designated for making bacterial cultures.	 Figure (8) shows the shape of the smears for nano and traditional paint.
• We keep these dishes in an incubator at a temperature of 37 degrees Celsius, as this is an ideal temperature for bacteria to multiply, and the dishes are left for 24 hours.	 Figure (9) shows the shape of the nutrient agar for bacteria.
• We determine the number of isolates that grow in each dish, then a sample of bacterial growth is taken and stained using Gram stain, to determine the type and number of bacteria that multiplied in each dish, and a comparison is made between traditional and nano-paint with the aim of ending the controversy and nominating an effective paint that can be used in patient isolation rooms.	
6-2- Laboratory results	

• Total number of bacteria in conventional paint 100 colonies per 1 mg
• Total number of bacteria in nano-paint 20 colonies per 1 mg

Classification of the types of bacteria that reproduce with each type of paint

Traditional paint	Nano-paint	Type of bacteria
ecoli	80	15
Staphylococcus aureus	12	5
Pseudomomnas aeruginosa	4	0
ecoli	4	0
Total	20 colonies	100 colonies

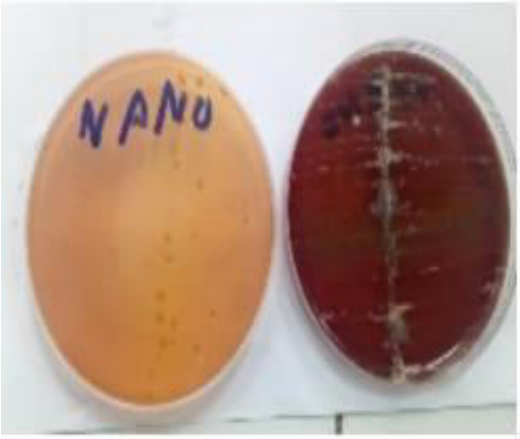


Figure (10) shows the difference in bacterial density in the two containers for nano and traditional paints.

7- An experiment confirms the effect of temperature changes in the vacuum of patient isolation rooms on the spread of infection.

Biological studies have confirmed that bacterial respiratory infections cannot grow at an ideal temperature lower or higher than the prevailing, preferred and suitable temperature for their best reproduction in their natural environment, which is known as the thermal coefficient. Temperature is considered one of the

most important factors affecting the physiology of bacteria, and each type of bacteria has three temperatures:

Minimum temp:

It is the lowest temperature at which bacteria cannot grow, so that if the temperature drops below it, the bacteria cannot reproduce.

Optimum temp:

It is the temperature at which bacteria grow in an ideal and best way.

Maximum temp:

It is the highest temperature at which bacteria can grow, so that if the temperature rises above it, growth stops completely. The researcher points out that the purpose of the experiment is to determine the ideal temperature values at which bacteria suspended in the air inside the spaces can grow voraciously, so that we can avoid reaching those temperatures in patient isolation rooms.

7-1- Experiment steps:

Under suitable sterile conditions, 37 samples of young colonies of infectious tuberculosis bacteria were inoculated by respiratory tract in 37 nutrient agars, and each of the previous samples contained 600 colonies per 1 milligram. Each of the previous 37 agars was incubated at different temperatures starting from 6°C to 42°C, for 24 hours.

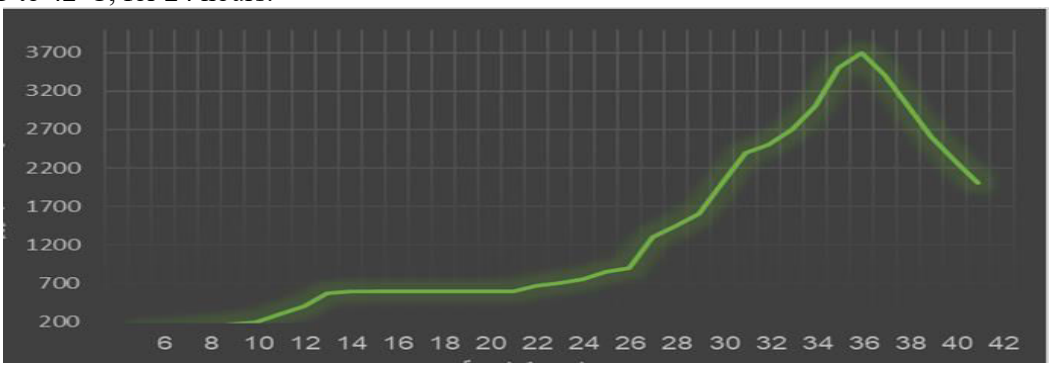


Figure (11) shows the difference in bacterial density in the two containers for nano and traditional paints.

• **Interpretation of the previous curve:**

Starting from a temperature of 10 degrees Celsius, bacterial nodules begin to decrease and colonies decrease, as a result of the effect of the low temperature on the respiration processes of these nodules, which affects the metabolic processes responsible for growth and reproduction.

As for temperatures starting from 13 degrees Celsius to 21 degrees Celsius, bacterial nodules remain alive and in a stable state without an increase or decrease in colonies.

As for starting from a temperature of 22 degrees Celsius to 26 degrees Celsius, bacterial nodules begin to grow slowly to reach approximately 750 bacterial colonies at a temperature of 26 degrees Celsius.

As for temperatures from 26 degrees Celsius to 36 degrees Celsius, colonies grow voraciously, then decrease again at a temperature of 37 degrees Celsius, as a result of the effect of the high temperature on the protein wall of the bacterial cell, which leads to stopping its growth and then killing it.

Figure (11) shows the difference in bacterial density in the two containers for nano and traditional paints.

From the above, it comes to the researcher's mind that it is necessary to maintain an ideal temperature that does not help the growth of bacteria and fungi that are attached and carry infection, especially since it is preferable for patient isolation rooms to be oriented directly south.

8- A practical experiment to prove the effectiveness of nano-paints in reducing the heat flow of patient isolation rooms:

The following experiment aims to prove the validity of nano-paints combating the heat flow through the covers of the internal spaces. In this experiment, a locally sourced, phase-changing natural nano-material will be added, which is paraffin wax, mixed with nano-materials, which has proven effective in increasing the efficiency of traditional paints, if added to it after mixing with nano-materials

8-1- Extracting the nano-paraffin wax powder mixture:

Paraffin wax is a locally manufactured material that melts at a temperature of (58-56) o, and some nano-materials are added that help convert paraffin wax blocks into nano-powder that can be added to traditional paints to change their properties and increase their efficiency to withstand high temperatures. Despite the difficulty of mixing wax blocks with nano-materials, because they are phase-changing materials that hate mixing with any materials that differ from their properties, scientists and researchers have been able to by mixing paraffin wax blocks and converting them into nano-paraffin powder through the processes shown in the following figure (11):

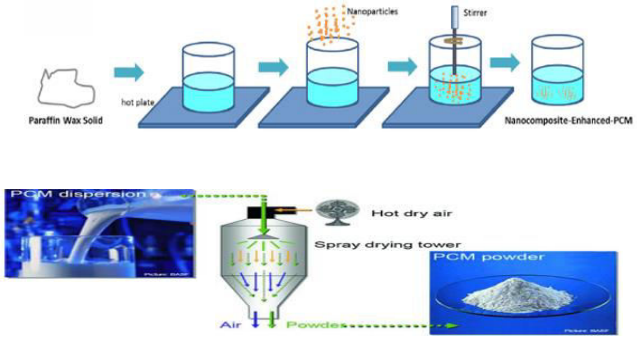


Figure (12) shows the stages of manufacturing nano-paraffin wax.

• Description of the extracted paraffin nano product (pcm):

1- A product with diverse and unique qualities and properties, as it is a heat insulator, moisture insulator, sound insulator, energy saver and also a local product that does not harm health.

• It consists of very small hollow spherical particles that work to insulate heat and prevent water leakage.

• It withstands all harsh weather factors, and is colorfast.

8-2- Experimental steps:

1- The extracted paraffin nano product powder (pcm) is added to traditional paints in different proportions, 20%, 25%, 30%. For each gallon (3.7 liters).

- By analyzing the physical properties of 3 samples of the three gallons to which the nano-paraffin powder emulsion was added in different proportions, 20%, 25%, and 30%, respectively, and analyzing a fourth sample of the gallon containing the imitation paint, it was found that its physical properties are as in the following Table (6-5).

Table (2) shows the characteristics of paints.

Paint Alternatives	Thermal conductivity w/mk	Density kg/m3	Specific heat j/kg.k
Traditional Paint	**0.57**	**1162**	**2863**
20% Nano Paraffinic Paint	**0.15**	**788**	**1724**
25% Nano Paraffinic Paint	**0.2**	**1050**	**1203**
30% Nano Paraffinic Paint	**0.25**	**1250**	**1238**

From the previous table, it can be concluded that it is preferable to nominate the use of the lowest percentage achieved for thermal conductivity, which is the percentage of adding 20% of the paraffin nano-paint emulsion to traditional paint with a weight of 740 milliliters, which is a weight that achieves 20% of the weight of the gallon, which is 3700 milliliters.

2- A room with an area of 6 m^2 was built as a field for testing the results of the paints, facing south and exposed to sunlight from the ceiling as well. Then, internal and external plastering was done for the walls of those rooms.

8-3- Measurement results:

The measurements were made on a room facing south, which is the prevailing direction for patient isolation rooms, with an area of 6 m^2 with dimensions of (2*3) m. The internal and external walls were on the plaster layer. The measurements were made on July 28, 2024 in the city of Manzala, Dakahliya Governorate (the researcher's hometown). Using a thermal thermometer designated for measuring temperatures on flat surfaces, the following measurements were concluded:

- **First**: In the case of painting the external wall of the room with traditional paints once and nano paints another time, the measurement results were as in Figure (12) below

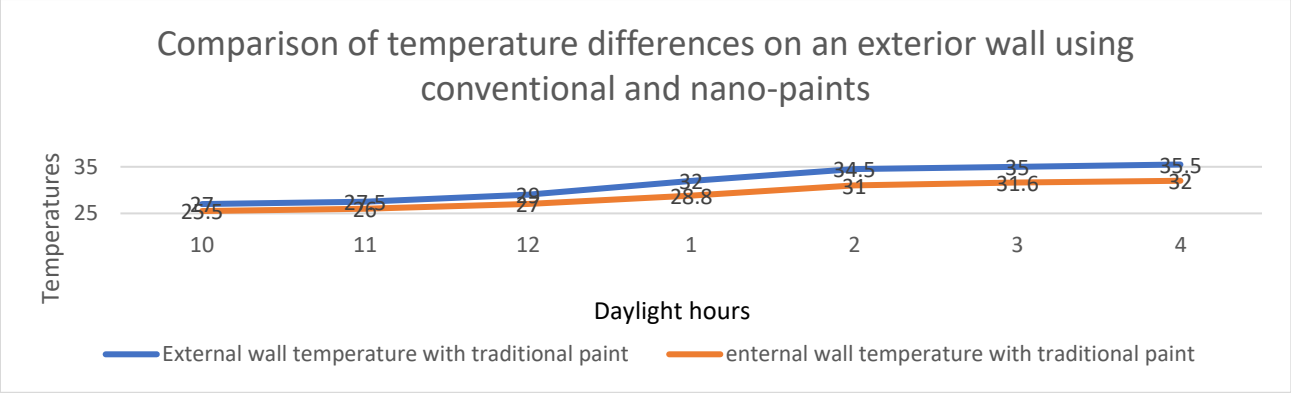


Figure (13) shows the difference in bacterial density in the two containers for nano and traditional paints.

- **Second**: In the case of painting the outer wall of the room with traditional paints and the inner wall with nano-paints in the previous added proportion, the measurement results were as shown in Figure (13) below.

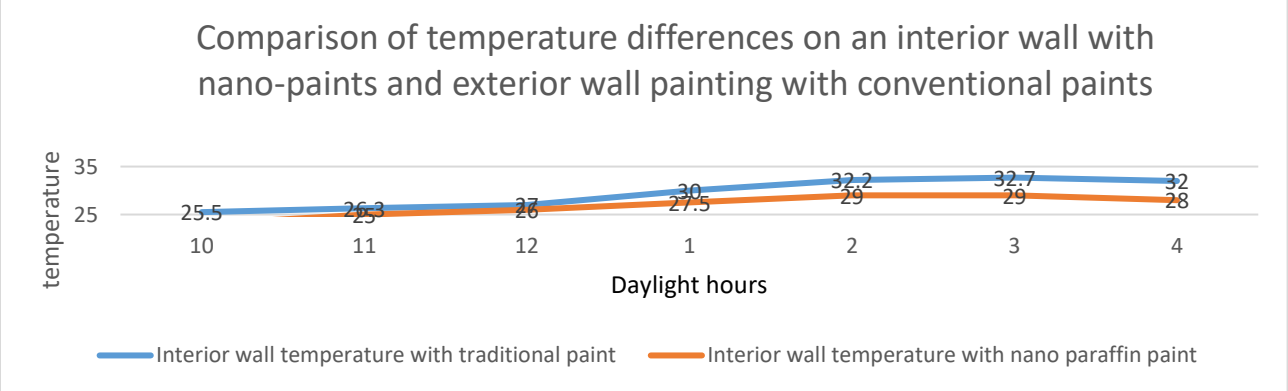


Figure (14) shows the difference in the density of bacteria in the two containers for nano and traditional paints.

Third: In the case of painting the outer wall and the inner wall of the room with nano paints according to the previous added percentage, the measurement results were as in Figure (14) below.

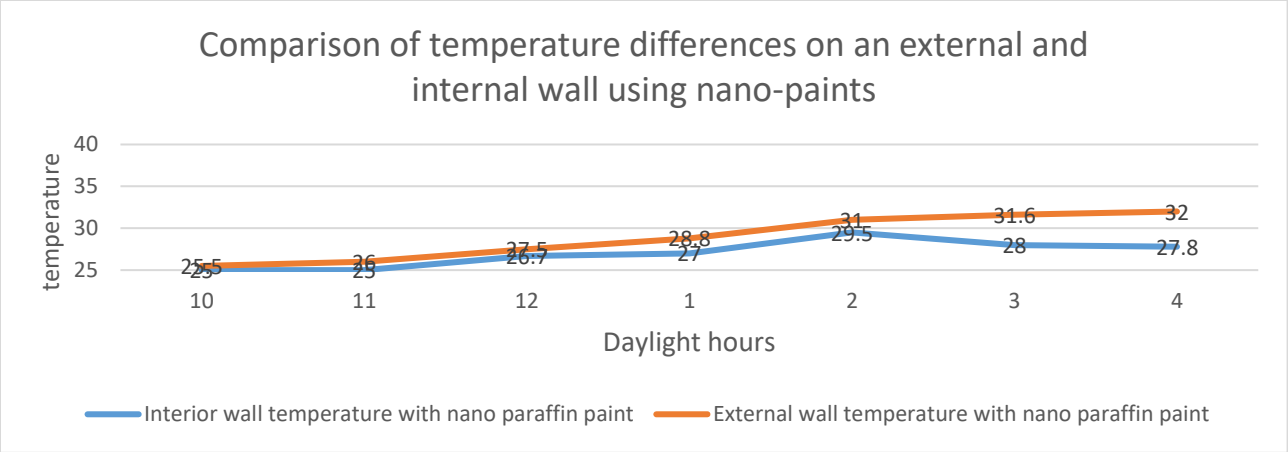


Figure (15) shows the shape of the difference in bacterial density in the two containers for nano and traditional paints.

From the above, it can be concluded that nano paints have proven their effectiveness in combating heat flow through the walls. Through the previous measurements and combat, the specifications of the achieved model can be extracted (Table 6-6) for those satisfactory and acceptable measurements that enhance the sustainability of patient isolation rooms and work to improve the thermal performance of their internal environment, which is positively reflected on the state in saving energy.

table (3) shows the type and properties of the outer shell that achieves the previous results.

Wall layers Previous experiment field	Thickness m	Thermal conductivity w/mk	Density kg/m^3	Specific heat j/kg.k
Nano paraffin paint	0.003	0.15	788	1724
Splashing and cement plaster	0.02	0.6	1858	837
Thickness wall	0.25	0.72	1850	829
Splashing and cement plaster	0.02	0.6	1858	837
Nano paraffin paint	0.003	0.15	788	1724

9- Analytical study of the use of nano materials in global and local patients' spinning rooms:

The following is an analytical study of various isolation rooms for patients, some local and some international, in order to identify the extent of the reach, spread and application of these technologies in isolation rooms in hospitals and treatment centers, and on the other hand, to benefit from Western countries in applying these materials that work to sustain and ensure the safety of the internal environment in patient isolation rooms. The following table (5) shows a sample of local and international hospitals.

9-1- Analysis of nanomaterials used in the isolation room at Charité Hospital in Germany:	
Location	Berlin Germany
Operation	1994
Last Renovation	2017
Floors	Self-cleaning nano-treated vinyl flooring
Walls	Normal matte plastic paint with antibacterial nano-based coating

Figure (16) shows the shape of floors treated with antibacterial nanomaterials.

Ceilings	Normal gypsum ceilings with anti-fog coating
Openings	Self-cleaning glass doors and windows
Nano Textiles	Water-repellent textiles used in curtains and bed linen

Figure (17) shows the shape of the interior ceiling of the room coated with nanomaterial.

Evaluation of the use of nano elements in the isolation room of the Chartier Hospital in Germany with nano materials

	Glass							Nano coatings					Insulation			Nano lighting	
Antibacterial wood	Self-cleaning	Reflective	UV protection	Nanoplastics	Textiles and Fabrics	Air Purification	Energy	Self-cleaning (Lotus feature)	Self-cleaning by photocatalyst	Writing and fingerprint resistant	Anti-fog	Anti-bacteria	Aerogel	VIPs	Nano Ceramic	OLED lighting	LED lighting
✓	✓				✓			✓			✓	✓					

Table (4) shows the analysis of nano materials used in isolation rooms at the Charité Hospital in Germany, adapted by the researcher.

9-2- Analysis of nanomaterials used in the isolation room at Pennsylvania Hospital in the United States of America:

Location	USA
Operation	2002
Last Renovation	2017
Floors	Self-cleaning ceramics
Walls	Self-cleaning and antibacterial paints
Ceilings	No nano-processing
Openings	All doors are coated with antibacterial nano-coating, window glass is coated with self-cleaning and anti-fog nano-coating
Supplementary items	Patient bed made of easy-to-clean, antibacterial nano-plastic

Figure (18) shows the shape of the walls with nano paint.

Figure (19) shows the shape of doors with added nanomaterials.

Figure (20) shows the shape of the bed made of nanoplastic.

Evaluation of the Use of Nano Elements in the Pennsylvania Hospital Isolation Room with Nano Materials

Glass								Nano coatings					Insulation			Nano lighting	
Antibacterial wood	Self-cleaning	Reflective	UV protection	Nanoplastics	Textiles and Fabrics	Air Purification	Energy	Self-cleaning (Lotus feature)	Self-cleaning by photocatalyst	Writing and fingerprint resistant	Anti-fog	Anti-bacteria	Aerogel	VIPs (Insulation)	Nano Ceramic	OLED lighting	LED lighting
✓	✓			✓				✓			✓	✓					

Table (5) shows the analysis of nanomaterials used in isolation rooms at Pennsylvania Hospital in the United States of America, adapted by the researcher.

9-3- Analysis of nano materials used in the isolation room at Al-Azhar Hospital in New Damietta:

Location	New Damietta Egypt
Operation	2000
Floors	Normal ceramic floors
Walls	Paints containing self-cleaning and antibacterial materials
Ceilings	No nano treatments
Openings	Doors are made of ordinary wood covered with a layer of plastic mica similar to nano-plastic, and windows are of the transparent type, 2 mm thick
Supplementary items	Patient bed is made of nano-plastic, easy to clean and antibacterial

Figure (21) shows the shape of regular ceramic floors.

Figure (22) shows the shape of the bed made of nanoplastic..

Evaluation of the use of nano elements in the isolation room at Al-Azhar Hospital in New Damietta with nano materials

	Glass							Nano coatings					Insulation			Nano lighting	
Antibacterial wood	Self-cleaning	Reflective	UV protection	Nanoplastics	Textiles and Fabrics	Air Purification	Energy	Self-cleaning (Lotus feature)	Self-cleaning by photocatalyst	Writing and fingerprint resistant	Anti-fog	Anti-bacteria	Aerogel	VIPs (Insulation)	Nano Ceramic	OLED lighting	LED lighting
✓				✓				✓				✓					

Table (6) shows the analysis of nano materials used in isolation rooms at Al-Azhar Hospital in New Damietta, adapted by the researcher.

9-4- Analysis of nano materials used in the isolation room at Mansoura Chest Hospital:

Location	Mansoura,Dakahliya
Operation	1985
Renovation	2021 Following the Corona events, some finishes were removed and changed appropriately
Floors	Vinyl without joints and welded to the ministry in a circular shape
Walls	Antibacterial plastic paint
Ceilings	It was made of gypsum board panels and coated with nano-water and bacteria-resistant materials
Openings	The doors are made of antibacterial materials and coated with nano-plastic, while the windows are of the frosted type that blocks vision
Supplementary items	The bed is made of antibacterial nano-plastic

Figure (23) shows the shape of traditional vinyl flooring.

Figure (24) shows the shape of the white nano paint on the walls, and the bed is made of nano plastic..

Evaluation of the use of nanomaterials in the isolation room of Mansoura Chest Hospital

Glass								Nano coatings					Insulation			Nano lighting	
Antibacterial wood	Self-cleaning	Reflective	UV protection	Nanoplastics	Textiles and Fabrics	Air Purification	Energy	Self-cleaning (Lotus feature)	Self-cleaning by photocatalyst	Writing and fingerprint resistant	Anti-fog	Anti-bacteria	Aerogel	VIPs (Insulation)	Nano Ceramic	OLED lighting	LED lighting
✓	✓			✓				✓				✓					

Table (7) shows the analysis of nano materials used in isolation rooms at Mansoura Chest Hospital, adapted by the researcher.

11- Results and recommendations:

First results:

- Antibacterial paints have proven their effectiveness through previous experience.
- Nano-paints that combat heat flow through the outer coverages of buildings have proven their effectiveness and credibility.
- Nanotechnology is one of the most important applications that have affected all fields, especially architecture.
- Nanotechnology can serve humanity and provide quality of life for people.
- Operating and maintenance costs of nanomaterials achieve a lower rate than traditional materials
- Nanotechnology emphasizes the concepts of sustainability in architecture from several angles, including the use of local materials and combating the challenges of the natural environment such as energy saving
- Nanotechnology still needs to be widely spread so that people can learn about this huge revolution in serving humanity
- Nanotechnology contributes fundamentally to the safety of the internal environments of patient isolation rooms
- Negative patient isolation rooms are among the hospital spaces most in need of the application of nanomaterials
- With the advancement of technology, it becomes clear from time to time that the profession of architecture is linked to various scientific fields.

Secondly, recommendations:

- It is necessary to increase awareness and publicize nanoscience and the tremendous development in discovering new properties of materials.
- It is necessary to integrate nanotechnology into the quality standards of health care in hospitals.
- It is necessary to update the Egyptian code for hospitals to keep pace with the development taking place in the world.
- It is necessary to prepare an Egyptian code for patient isolation rooms, clarifying the necessary standards for finishing.
- It is necessary for the Egyptian state to unite to establish factories that support the manufacture of nanoscience materials.
- The Egyptian state must apply nanotechnology in all new hospitals and even when renovating existing buildings.
- It is necessary to urge researchers to conduct experiments that confirm the effectiveness of other materials from nanotechnology

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