

Nanotechnology Design Framework for Healthcare Architecture as a Building Technology Strategy

Mona Hassan Soliman¹, Mohamed Said Meselhy², Mohamed Yasser Qotb³

Professor, Head of Department of Architectural Engineering, Faculty of Engineering, Fayoum University, Fayoum, Egypt¹

Associate Professor, Department of Architectural Engineering, Faculty of Engineering, Fayoum University, Fayoum, Egypt²

Teaching Assistant, Department of Architectural Engineering, Faculty of Engineering, Fayoum University, Fayoum, Egypt³

ABSTRACT: Hospitals and medical facilities are sensitive type of architecture, as this field deals with different types of patients with different diseases, special needs, critical cases and different conditions, so the design process has to be carefully planned. In developing countries the medical sector is deteriorated in the majority of facilities, due to wrong and non-effective architectural designs in the main project. Hospitals are a place where the patient should restore his health, feel comfortable and clean. Healthcare designs also plays a psychological part of treatment for the patient, so the design process has to be well-done to give the patients a positive feeling that will help them to feel better in a well-designed environment that is meant to be designed for them. In the sector of healthcare and therapeutic treatment, the phase of interior design process is one of the most vital phases of the design. Interior finishes are so important aspects of the healthcare facilities environment. Floors, Walls and Ceiling coverings also furniture all of them are major elements in the design process and they all have a vital role in keeping the interior environment of the hospitals and medical facilities health and clean, finishing materials and their different properties are considered to be the most effective factor of the interior design of the medical and healthcare facilities. As discussed in the previous chapter, it showed a different case studies of different types of medical and healthcare facilities around the world and how the nanotechnology played a vital role in rising the efficiency of the facilities through the design, choice of material, flexibility and creativity in the interior designs.

KEYWORDS: Nanotechnology, Nanomaterials, Healthcare Architecture, Interior Design.

I. INTRODUCTION

Human's health is a very important need to keep a healthy community; however, it's common to get infected by different factors even in the therapeutic and medical facilities, that's called healthcare-associated infection (HIAs) infections, this type occurs in medical places where people are receiving treatment. Human's life is surrounded by germs in the air, water soil and their bodies, these germs can be helpful to the body and health and also can be harmful and cause infections and diseases. Otherwise, healthcare design is a new approach that investigates the needs of psychological and social of a human, as a new perspective on healthcare, in addition to concerning conventional biomedical and economic aspects. As part of this design approach, interior design of the healthcare facilities is considered a major vital element in the whole life span of the medical and therapeutic facilities. Interior finishes in the medical architecture is very important to be chosen well during the design process, these finishes include floors, ceiling, walls, furniture and medical equipment. Nanotechnology is the technology of the 21 century and the future, nanotechnology now is included in everything in our life in all the different fields. Nanotechnology in the architecture field witnessed huge developments in the materials industry.

II. RELATED WORK

The research will discuss the design principles for designing an efficient healthcare interior environment with putting the basics for a comprehensive design framework, which will be a design guideline for any architect. This framework

will enable the designer to choose the proper materials for specific spaces in any medical care and healthcare facility, also the furniture and medical equipment. This framework also will help the architectural designer to arrange the priorities of materials choice according to the space function and design.

III. DEFENITION OF NANOTECHNOLOGY

In 1959 the scientist *Richard Philipp Feynman* gave a pioneering speech that was called “there is a plenty of room at the bottom” at Caltech California institute of technology, this lecture was considered to be the spark for a new science to our future, years later in 1974 a new term has entered the English vocabulary this term was “*Nano*”. Nano is derived from the Greek word *Nanos* (latin *nanus*) that means “*dwarf*” this term was first used by *Norio Taniguchi* who coined this term at the Tokyo University of Science in Japan. “*Nano-technology*’ mainly consists of the processing of separation, consolidation, and deformation of materials by one atom or one molecule.”³ (*Norio Taniguchi 1974*)

The term Nano can be used as a prefix for any type of units such as nanosecond, nanometer and other units and it means a *billionth* of this unit; but unlike other unit prefix, Nano is now demonstrating and increase of the news coverage and scientific development, that’s why there is a need to clarify the different definitions and terms in the Nano-Field such as: Nan scale, Nano science, Nanotechnology and Nano materials. Nano scale means objects that have at least one dimension in height, length or depth which measure between 1 to 999 nanometres (nm), but because of some misleading of the term, due to the presence of other technological systems that deal with micrometre (µm) as 1 µm = 1000 nm; so when dealing with the Nano scale objects this means objects that are measured on the range of 1 to 100 nm.

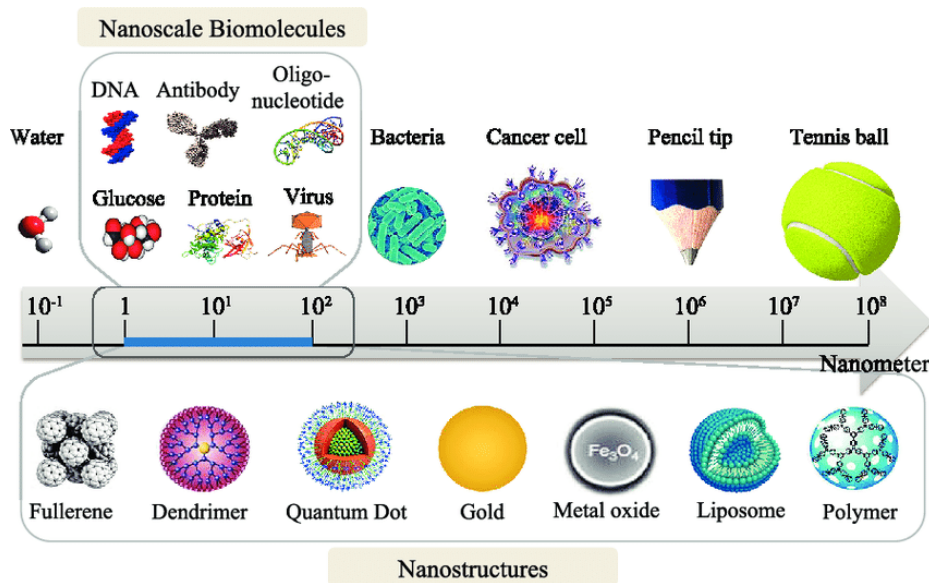


Fig. 1: Nanoscale and Nanostructures

IV. NANOTECHNOLOGY APPLICATIONS AND FUCNTIONS

Nowadays nanotechnology is being applied in most of our daily lives products in all fields that include architecture, construction, energy, environment, and food, industrial, medical and transportation, this chapter will discuss both the daily life applications and the architectural applications of nanotechnology. Nanotechnology plays a vital and major role in many branches and fields, the following examples represent some of these applications: cosmetic industry, transportation field, medical field, environmental technology, warfare and military weaponry, also applied in the field of food and textiles. Nanotechnology is being used widely in the construction and architecture field. The most compelling argument for using nanotechnology in architecture is the greater energy efficiency that provides. Nanotechnology offers a new technological tool to tackle climate change and greenhouse gas emissions in the future. The use of nanotechnology in construction field is linked to the sustainability, energy efficiency and reducing greenhouse gases. The construction industry is a major or the root causes for CO₂ emissions productions. On the other hand, Co₂ emissions across the world must be reduced to halve by 2050, Architects and planners should be concerned about finding innovative ideas and solutions for slowing climate change to combine ambitious architecture with energy

efficiency. The use of materials and surface properties that have now become possible by applying the nanotechnology offer architecture, interior architecture and other fields a means of achieving greater sustainable construction and energy efficiency through innovation and creativity. Nanotechnology provides the maximum use of functions and using it is of lasting value and entirely irrespective of arbitrary fashions.

V. APPLICATIONS OF NANOTECHNOLOGY

A) Nano Coating

Coatings are a thin layer that is used to cover interior and exterior surfaces for protection and decoration, now with the help of nanotechnology there are types of Nano coating layers shown in figure. 2 which work on improving surface characteristics. Nano-coating is considered that coating with Nano structured that applies on surfaces described in table I. These surfaces can be super-hydrophobic or super-hydrophilic. Super-hydrophobic surfaces which means water-repelling surfaces and super-hydrophilic means water-attracting surfaces that lead the surfaces to be easier cleaning. The spray coatings are also created by Nano-structured and applied them to micro-structured previous surfaces. Nano-coating have a several advantages as:

- They give a better surface appearance
- They are easy to clean
- High resistance against chemicals
- They are anti-reflective, anti-fogging, anti-graffiti and anti-bacterial
- Mechanical properties like scratch and abrasion resistance.
- They can be anti-corrosion

Chrome free and has the best thermal and electrical conductivity

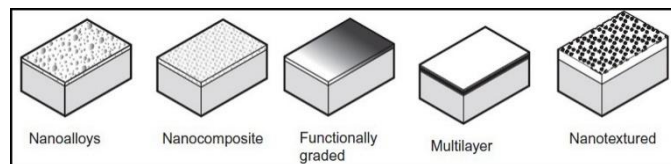


Fig. 2: Nano Coating Layers

Nano-coating			
Product	Properties	Specs	Usage
Self-cleaning (lotus Effect)	Hydrophobic Surfaces	-It was Microscopically rough, not smooth. -It is suitable for surfaces that exposed periodically to sufficient quantities of water	It used for facades to get low maintenance and easy to clean that get the optimal use of facades
Self-Cleaning (Photo catalytic)	Hydrophilic Surfaces	- A water film washes the dirt away - UV light and water are required -Light transmissions for glazing and translucent membranes are improved	It gives the surfaces the ability to reduce dirt adhesion on them
Easy to Clean	Hydrophobic	-Smooth surfaces with reduced surface attraction. -Surfaces have a lower force of surface attraction because of a decrease in their surface energy.	It is common to find in interiors, however, it can be used in outdoors to get the best weather protection
Anti-bacterial	Works on finding bacteria and destroying it	-The use of disinfectants can be reduced -Silver nanoparticles reduce the amount of cleaning time necessary	Supports hygiene methods especially in healthcare environments

Table. 1: Nano Coating Category Classification

Nano-coating is an environmentally friendly and an effective solution for a better protection that lasts for a long time against bacteria, mold and contaminations risk or virus spreading, table II shows the features and benefits of Nano-coating

Nano-coating	
Features	Environmental Benefits
<ul style="list-style-type: none"> - Powered by light - Works with natural UV and Fluorescent 	<ul style="list-style-type: none"> - Improves Indoor Air Quality
<ul style="list-style-type: none"> - High performance - Long-lasting effect 	<ul style="list-style-type: none"> - Reduces using of toxic chemical
<ul style="list-style-type: none"> - Harmless to humans and animals 	<ul style="list-style-type: none"> - Reduces risk of surface bio-contamination.
<ul style="list-style-type: none"> - Decomposition of endotoxin and germ body 	<ul style="list-style-type: none"> - Reduces the time of cleaning and disinfection process.

Table. 2: SELF-SANITIZING OF NANO COATING

Interior design of healthcare and medical facilities has a main issue which is the bacteria inhabiting on different various surfaces, so Nano-coating can be applied to different surfaces that are commonly used in the built environment of medical spaces to enhance their properties, characteristics and their performance against bacteria such as:

- Marble: Nano coating make them very liquid repellent, anti-scratches, anti-stain, and glossy.
- Windows & Facades: Nano coating protects the surface from calcium build-up, hard water, sand, watermarks, and dirt. It gives a self-cleaning property for the surface.
- Wood: It keeps the surface from UV rays and water from damaging, and it is more durability.
- Stainless Steel: Nano coating gives gloss and additional protection by bound it to stainless steel.

Nano-coating is considered the best solution for protecting surfaces against bacteria and contamination according to the tests made by the Institute for Hospital Hygiene and Inflection control, those tests showed up the performance of Nano-coating compared to the performance of conventional paint as shown in figure.3

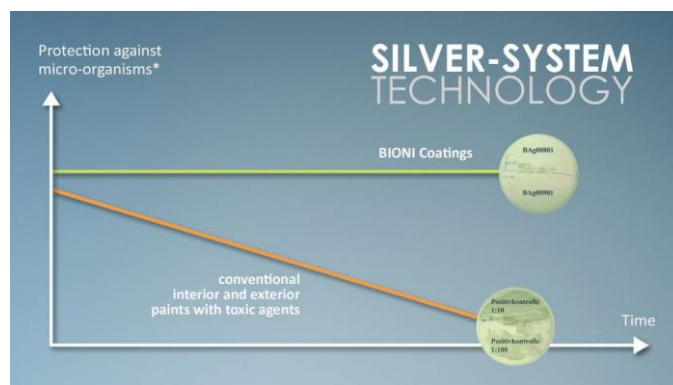


Fig. 3: comparison between Nano-coating and conventional paint

B) Nano Textiles (Nanomaterials in Furniture)

When this coating is applied for any kind of surfaces of a fabric texture, it makes these surfaces resistant to liquids and dirt by wiping them out without leaving any marks or stains as shown in Figure.4. It's a durable product, it lasts for a long period of time. This coating can be heavily washed without losing its Nano-tech properties and it's suitable for all kinds of fabrics and different types of furniture. Nano fabrics embraces



future’s technology today to render protection against harmful surroundings like the UV rays, it also proffer elasticity and have a greater strength beside these main properties these Nano fabrics has other properties like moisture eliminating, bacteria resistance, mosquito repellent, stain free and quick dry. One of the best examples of this technology is the NanoTex powered by Crypton, offers superior spill and stain resistance coupled with remarkable performance & durability. Built into the molecular structure of the fibre, Nanotex permanently protects while maintaining the fabric’s natural hand and breathability. Nanotex uses nanotechnology to transform and permanently bond to the structure of the fibres, creating permanent performance without compromising the hand. The results are fabrics that offer remarkable performance and comfort permanently. They are perfect for:

- Office upholstery (Task & desk chairs - Side chairs & sofas)
- Restaurants (Chairs - Banquettes - Bar stools)
- Healthcare (Lobby chairs & sofas - Cubicle drapery)
- Hotel Rooms (Chairs - Sofas - Headboards - Top-of-bed)

There are number of advantages for applying nanotechnology in textiles:

- To prevent unwanted and uncontrolled reproduction of microbes which can lead to dangerous health problems during using textiles.
- Maintain appropriate moisture and degradation
- Avoidance of unpleasant odors production.
- Prevent stains on textiles because of spilled liquids.
- Prevent dirt or dust.
- Avoid mites in textiles.

Nano textiles materials have different applications in interior spaces such as curtains, upholstery, beds and medical uniforms as shown in table III

Nanoparticles	Fiber	Characteristics	Application in interior design
Nanowires silver	Cotton	- Anti-bacteria - UV light resistant - High electrical conductivity - Super hydrophobicity	- Curtains. - Upholstery. - Table Linen.
Nanoparticle Titanium Dioxide	Cotton Wool	- Anti- bacteria - Self-cleaning surfaces - Semi-conductor - Photo catalytic	- Upholstery. - Carpets.
Copper nanoparticles	Nylon	- Anti-microbial - Anti-fungal	- Curtains. - Cushion.
Gold nanoparticles	Wool	- UV light resistant - Stability of color	- Carpets - Upholstery - Bedding
Silver nanoparticles	Cotton Nylon Polyester Silk	- Anti-bacterial - Anti-fungal	- Curtains - Bedding - Carpets
Nanoparticles of Titanium dioxide and silicon oxide	Cotton Polyester	- Thermal stability surfaces - Long life time. - Low toxicity. - UVprotection. - Excellent optical properties.	- Making furniture - Curtains - Carpets
Silver Nanoparticles chitosan	Cotton	- Anti-bacterial - Comfortable	- Application in medical scrubs
Nano Aluminum oxide	polyester	- Water resistant - Super high mechanical strength	- Application in aero-space, automotive, naval, and other industries.
Zinc oxide , Titanium dioxide and Silver Nanoparticles	Cotton wool	- Anti-bacterial	- Medical Textiles application - Textiles and clothing wear application.

Table. 3: Types of Nanomaterials and Nanoparticles used in Textiles Industry



C) Nano Insulations

Nanotechnology promises to make insulation more efficient, less reliant on non-renewable resources, and less toxic, and it is delivering on many of those promises today. Manufacturers estimate that insulating materials derived from nanotechnology are roughly 30 percent more efficient than conventional materials. Nano scale materials offer a great promise as insulators, due to their extremely high surface-to-volume ratio, this give them the ability to trap air within a layer of the material. Nano materials with insulating properties in some designs they are being sandwiched between rigid panels, being applied as thin film or being painted as a coating.

Types of insulation nanomaterials:

- Thermal Insulation: Aerogel
- Vacuum Insulation Panels (VIPs)
- Phase Change Materials (PCMs)
- Thin Film Insulation.
- Nanosulate

Nano-Insulation		
Material	Properties	Features
Aerogel	Hydrophobic Surfaces	<ul style="list-style-type: none"> - It used for windows because of its transparency. - Lightweight. - Very effective insulation.
VIPs	Hydrophilic Surfaces	<ul style="list-style-type: none"> - It has a highly slim profile. - Fits in narrow spaces for novel builds. - High performance for thermal insulation.
PCMs	All Surfaces	<ul style="list-style-type: none"> - Used in all interior spaces parts from floors, windows and walls and ceiling - High performance for thermal insulations - Fits in narrow spaces for novel builds.

Table. 4: Nano Insulation Materials

VI. APPLICATIONS OF NANOTECHNOLOGY IN ARCHITECTURE

Nanotechnology has a variety of applications shows the properties the nanomaterials and their applications on surfaces, such as self-cleaning, air purifying and so on rather than the chemical of physical principles they are based on. Such as photo catalysis, these applications show a variety of different creative and innovative ways to apply in design with real life examples that give a proof that through nanotechnology greater energy efficiency is now possible to achieve. There are number of practical applications applied in architectural field as follows:

- Self-Cleaning: Lotus Effect
- Self-Cleaning: Photo catalysis
- Easy to Clean (ETC)
- Air-Purifying
- Anti-Fogging
- Fragrance Capsules
- Thermal Vacuum insulation (VIPs)
- Aerogel Insulation
- Phase Change Material (PCMs)
- Fire Proof
- Anti-Graffiti
- Anti-Bacterial and Anti-microbial

VII. ADVANCES AND EVOLUTION IN HEALTHCARE FACILITIES

The research of the interior designs in the sector of healthcare developed in the period from 1978 to 1991, then in 1993 was a promotion to a more open to nature designs, during 1995 to 1997 there were some innovators and risk takers, following with the phase of major projects which included connection with nature through the incorporation of oxygen rich varieties, after that some design principles were evolved in the next years and these principles were:

- Providing access to gardens when possible

- Creation of comfortable size rooms
- Increase quantity and size of windows
- Creation of family zones in patient rooms
- Providing decentralized, barrier free nursing stations.

VIII. INNOVATIVE TECHNIQUES IN FINISHING MATERIALS IN MEDICAL FACILITIES DESIGN PROCESS

The field of health architecture is at a turning point, as hospital architecture was immediately affected by global economy recession that begun in 2008 until the past three years hospitals were among the institutions suffering from global economic malaise and many are reacting by laying off staff, limiting services or even cancelling the construction projects, also the high cost of construction of renovation prevent private investors from financing. The climatic changes have a direct effect on hospitals building architecture, as the goal of design is carbon neutrality, regenerative strategies on new constructions and preservation and increasing social capital through environmental design. The changing of priorities of our current situation is seeking the trends for the future, so the hospital needs consideration as an idea and as a building type, last but not least the technology is an important and crucial matter in the design process, Nanotechnology, telemedicine, robotics, virtual reality and the role of nature in healing all of these matters will influence the layout and the space, so in a brief hospitals now aren't a place for sickness and sick people, but rather a place for health and recreation. One of the most recent trends in hospitals and healthcare facilities especially in children's hospital design that is linked with technology is including interactive elements in the design. In this way the child would get the feeling of altering the hospital environment and maybe feel more secure by controlling the surroundings. Interactive elements are also positive distractions during the hospital visit or stay. The main aim is to encourage curiosity, wonder, and learning so that the negative feelings are not the dominant ones

IX. HEALTHCARE FACILITIES DESIGN PRINCIPLES

Nowadays the Interior design trends for healthcare facilities are growing and changing along with these new demands. The latest trends for healthcare designs revolve around providing responsive, needs-specific facilities. Special and unique furniture can be made far more functional thanks to innovative design techniques. What you see is what you get, at least that's what the human mind assumes. If the interior design of a healthcare facility looks nice, people are naturally going to assume they are getting a higher level of care. Hence, why good interior design is greatly important in the healthcare industry. It's not just about having good style, but functionality is a big part of the puzzle, as well as knowing what's currently going in the healthcare industry. For designing a successful project the designer must incorporate an eye for details and design, with also a greater knowledge and understanding of the current trends, issues and needs related to the field of healthcare and medical facilities industry. There are a number of challenges face the interior designers when designing spaces for healthcare industry as follows:

- Finding alternative methods that help cut costs—as the rising cost of healthcare is a huge issue
- Incorporating useful amenities to help the growing elderly population
- Increased readiness to handle epidemics or unexpected outbreaks
- Increased access to healthcare for all patients
- “Managed care,” a complicated combination of finances and administration

Healthcare interior design now has a huge advance in finishing materials and design techniques, the latest healthcare facilities are going the extra mile to ensure patients actually enjoy their time there.

DESIGN PRINCIPLES

- Friendly interior design
- Interior design that mimics home
- Make small spaces feel large
- Create bold aesthetics
- Stick to an overall theme
- Color use knowledge
- Balance of form and function



Fig. 5: patient room in the Hartford hospital bone and joint institute

Floors	Anti-bacterial and Self-cleaning	Lights	LED and OLED and anti-bacterial
Wall Paint	Anti-bacterial and Air-purifying	Light Switch	Anti-bacterial
Window and Doors	Self-cleaning Photo catalytic	Chair and Furniture	Anti-bacterial and Dirt repellent
Bedding	Anti-Bacterial	TV	Anti-Reflective
Devices	Anti-bacterial and ETC	Door and window Knobs	Ant-bacterial

Table. 5: Finishing material table for a patient room

SPACE TYPE	SPACE NAME	NANO CHARACTERISTICS	NANO PRODUCT FEATURES AND REQUIRMENT IN MEDICAL INTERIOR									
			Walls	Ceiling	Floors	Furniture	Insulation					
Highly Sensitive Spaces	Operating Theatres	SET-E-CLEANING LOTUS EFFECT - HYDROPHOBIC SURFACES SET-E-CLEANING PHOTOCATALYTIC - HYDROPHILIC SURFACES EASY TO CLEAN (ETC) - HYDROPHOBIC SURFACES ANTI-BACTERIAL AND ANTI-MICROBIAL EFFECT	- Hygienic Spaces.	- Protection against Settlement of Germs and bacteria.	- Durability.	- Contamination proof.	- Removal of dirt, bacteria and odorants.	- Enhanced scratch resistance.	- Different types of Nano coatings applied to textiles including cotton, wool, nylon, polyester, silk and leather	- Coating should contain Nano silver, copper and gold nanoparticles or titanium dioxide.	- Wall, floor and ceiling insulation with VIPs and PCMs features : - High slim profile and tiny thickness - Fits in very narrow and small spaces.	
	Intensive Care units		- Hygienic Spaces	- Resistant to Bacteria	- Resilient to Regular Cleaning process	- Mechanically loadable	- Control of indoor climate.	- Enhanced of UV resistance.	- Blocking of IR (Infrared)	- Repellant against water and dirt	- Prevention of unwanted and uncontrolled reproduction of microbes which can lead to dangerous health problems during using textiles.	- Has a very high performance for thermal insulation. - Can be applied in different parts of the space.
	Emergency Ward		- Hygienic Spaces	- Resistant to Bacteria	- Resilient to Regular Cleaning process	- Mechanically loadable	- Control of indoor climate.	- Enhanced of UV resistance.	- Blocking of IR (Infrared)	- Repellant against water and dirt	- Prevention of unwanted and uncontrolled reproduction of microbes which can lead to dangerous health problems during using textiles.	- Aerogel is a perfect material to be used in windows due to its transparency and it is lightweight and very effective on hydrophobic surfaces
	Surgical Washrooms		- Hygienic Spaces	- Resistant to Bacteria	- Resilient to Regular Cleaning process	- Mechanically loadable	- Control of indoor climate.	- Enhanced of UV resistance.	- Blocking of IR (Infrared)	- Repellant against water and dirt	- Prevention of unwanted and uncontrolled reproduction of microbes which can lead to dangerous health problems during using textiles.	- No discoloration and decrease in degradation.
	Aseptic Rooms		- Hygienic Spaces	- Resistant to Bacteria	- Resilient to Regular Cleaning process	- Mechanically loadable	- Control of indoor climate.	- Enhanced of UV resistance.	- Blocking of IR (Infrared)	- Repellant against water and dirt	- Prevention of unwanted and uncontrolled reproduction of microbes which can lead to dangerous health problems during using textiles.	- Reduce the risks of potential health.
Sensitive Spaces	Trauma Rooms		- Hygienic Spaces	- Resistant to Bacteria	- Resilient to Regular Cleaning process	- Mechanically loadable	- Control of indoor climate.	- Enhanced of UV resistance.	- Blocking of IR (Infrared)	- Repellant against water and dirt	- Prevention of unwanted and uncontrolled reproduction of microbes which can lead to dangerous health problems during using textiles.	- Prevent stains on textiles because of spilled liquids.
	Pre-Operative Spaces		- Hygienic Spaces	- Resistant to Bacteria	- Resilient to Regular Cleaning process	- Mechanically loadable	- Control of indoor climate.	- Enhanced of UV resistance.	- Blocking of IR (Infrared)	- Repellant against water and dirt	- Prevention of unwanted and uncontrolled reproduction of microbes which can lead to dangerous health problems during using textiles.	- Avoidance of unpleasant odor production.
	Recovery Rooms		- Hygienic Spaces	- Resistant to Bacteria	- Resilient to Regular Cleaning process	- Mechanically loadable	- Control of indoor climate.	- Enhanced of UV resistance.	- Blocking of IR (Infrared)	- Repellant against water and dirt	- Prevention of unwanted and uncontrolled reproduction of microbes which can lead to dangerous health problems during using textiles.	- Prevent dirt or dust.
	Sterilizing Rooms		- Hygienic Spaces	- Resistant to Bacteria	- Resilient to Regular Cleaning process	- Mechanically loadable	- Control of indoor climate.	- Enhanced of UV resistance.	- Blocking of IR (Infrared)	- Repellant against water and dirt	- Prevention of unwanted and uncontrolled reproduction of microbes which can lead to dangerous health problems during using textiles.	- Avoid mites in textiles.
	Laboratories		- Hygienic Spaces	- Resistant to Bacteria	- Resilient to Regular Cleaning process	- Mechanically loadable	- Control of indoor climate.	- Enhanced of UV resistance.	- Blocking of IR (Infrared)	- Repellant against water and dirt	- Prevention of unwanted and uncontrolled reproduction of microbes which can lead to dangerous health problems during using textiles.	- Anti-bacteria
Moist Rooms	Treatment Rooms		- Washable	- Hygienic spaces	- Insensitive	- Repellant against dirt and water	- Removal and resistance against bacteria	- Suitable for easy cleaning	- Fireproof Aspects	- Mechanical Loading	- Enhanced UV protection	- Long life time
	Public Washrooms		- Washable	- Hygienic spaces	- Insensitive	- Repellant against dirt and water	- Removal and resistance against bacteria	- Suitable for easy cleaning	- Fireproof Aspects	- Mechanical Loading	- Enhanced UV protection	- Low Toxicity
	Bathrooms		- Washable	- Hygienic spaces	- Insensitive	- Repellant against dirt and water	- Removal and resistance against bacteria	- Suitable for easy cleaning	- Fireproof Aspects	- Mechanical Loading	- Enhanced UV protection	- Anti-fungal and anti-microbial.
Kitchen Spaces	Laundry		- Washable	- Hygienic spaces	- Insensitive	- Repellant against dirt and water	- Removal and resistance against bacteria	- Suitable for easy cleaning	- Fireproof Aspects	- Mechanical Loading	- Enhanced UV protection	- Long life time
	Kitchens and Food Preparation Spaces		- Washable	- Hygienic spaces	- Insensitive	- Repellant against dirt and water	- Removal and resistance against bacteria	- Suitable for easy cleaning	- Fireproof Aspects	- Mechanical Loading	- Enhanced UV protection	- Long life time
	Catering Spaces	- Washable	- Hygienic spaces	- Insensitive	- Repellant against dirt and water	- Removal and resistance against bacteria	- Suitable for easy cleaning	- Fireproof Aspects	- Mechanical Loading	- Enhanced UV protection	- Long life time	
	Cold Stores	- Washable	- Hygienic spaces	- Insensitive	- Repellant against dirt and water	- Removal and resistance against bacteria	- Suitable for easy cleaning	- Fireproof Aspects	- Mechanical Loading	- Enhanced UV protection	- Long life time	
Common and public Spaces	Store Rooms	- Washable	- Hygienic spaces	- Insensitive	- Repellant against dirt and water	- Removal and resistance against bacteria	- Suitable for easy cleaning	- Fireproof Aspects	- Mechanical Loading	- Enhanced UV protection	- Long life time	
	Reception Area	- Washable	- Hygienic spaces	- Insensitive	- Repellant against dirt and water	- Removal and resistance against bacteria	- Suitable for easy cleaning	- Fireproof Aspects	- Mechanical Loading	- Enhanced UV protection	- Long life time	
	Waiting Rooms	- Washable	- Hygienic spaces	- Insensitive	- Repellant against dirt and water	- Removal and resistance against bacteria	- Suitable for easy cleaning	- Fireproof Aspects	- Mechanical Loading	- Enhanced UV protection	- Long life time	
	Care Rooms	- Washable	- Hygienic spaces	- Insensitive	- Repellant against dirt and water	- Removal and resistance against bacteria	- Suitable for easy cleaning	- Fireproof Aspects	- Mechanical Loading	- Enhanced UV protection	- Long life time	
Staff, Administration, Technical and Store Spaces	Wards	- Washable	- Hygienic spaces	- Insensitive	- Repellant against dirt and water	- Removal and resistance against bacteria	- Suitable for easy cleaning	- Fireproof Aspects	- Mechanical Loading	- Enhanced UV protection	- Long life time	
	Reception Rooms	- Washable	- Hygienic spaces	- Insensitive	- Repellant against dirt and water	- Removal and resistance against bacteria	- Suitable for easy cleaning	- Fireproof Aspects	- Mechanical Loading	- Enhanced UV protection	- Long life time	
	Staff Private Rooms	- Washable	- Hygienic spaces	- Insensitive	- Repellant against dirt and water	- Removal and resistance against bacteria	- Suitable for easy cleaning	- Fireproof Aspects	- Mechanical Loading	- Enhanced UV protection	- Long life time	
	Corridors	- Washable	- Hygienic spaces	- Insensitive	- Repellant against dirt and water	- Removal and resistance against bacteria	- Suitable for easy cleaning	- Fireproof Aspects	- Mechanical Loading	- Enhanced UV protection	- Long life time	
	Admin Offices	- Washable	- Hygienic spaces	- Insensitive	- Repellant against dirt and water	- Removal and resistance against bacteria	- Suitable for easy cleaning	- Fireproof Aspects	- Mechanical Loading	- Enhanced UV protection	- Long life time	
Staff, Administration, Technical and Store Spaces	Staircases and Stairwells	- Washable	- Hygienic spaces	- Insensitive	- Repellant against dirt and water	- Removal and resistance against bacteria	- Suitable for easy cleaning	- Fireproof Aspects	- Mechanical Loading	- Enhanced UV protection	- Long life time	
	Technical Rooms	- Washable	- Hygienic spaces	- Insensitive	- Repellant against dirt and water	- Removal and resistance against bacteria	- Suitable for easy cleaning	- Fireproof Aspects	- Mechanical Loading	- Enhanced UV protection	- Long life time	
	Storage	- Washable	- Hygienic spaces	- Insensitive	- Repellant against dirt and water	- Removal and resistance against bacteria	- Suitable for easy cleaning	- Fireproof Aspects	- Mechanical Loading	- Enhanced UV protection	- Long life time	

Fig. 6: Design Framework for Medical Spaces

XII. CONCLUSION

- The nanotechnology is producing hygienic products without harming human health or the environment. In addition, it is considered the solution for environmental problems especially that related to building problems. The study focused on discussing the impacts of nanotechnology applications in the interior and exterior environment of the building. With applying nanotechnology it can increase the lifespan of healthcare buildings and keeping them in the best quality and efficiency through application of nanomaterials that make the building more sustainable, environmental friendly and protected from damage for long time periods.
- Nanotechnology applications is considered a revival and upgrade process for the building to protect it from different tearing, bacterial, and damage factors that affect the building's performance whether in interior or exterior and the cost of maintenance is reduced due to the properties of these materials.
- Applying nanotechnology techniques in Egypt in the construction industry and healthcare and medical facilities designs is a must because it contributes in improving healthcare buildings efficiency as in all the developed countries. The research argues the architects and designers to apply the latest techniques of the nanotechnology materials and its applications in the finishing materials selection phase especially in healthcare and medical facilities and buildings to keep it protected over time as possible without any defects appearance and damage.

- We are living in the age of technology, so all architects, designers and Authors in the construction and architecture field should find and explore more new ideas and new nanotechnology materials to apply in order to raise the efficiency of the medical buildings. It is recommended for the architects, and interior designers to be aware of the benefits of using these materials and its impact on the human health and surrounding environment for applying them.

REFERENCES

- [1] Leydecker, Sylvia, *Nanomaterials in Architecture, Interior Architecture and Design*, BirkhauserVerlag AG.(2008)
- [2] Ashby, M., Ferreira, P. &Schodek, D. *Nanomaterials, Nanotechnologies and Design: an introduction for engineers and architects*, Butterworth-Heinmann,(2008).
- [3] Dr.George Elvin. *Nanotechnology for Green Building*, UK, (2007).
- [4] FaniVavili, Artemis kyrkou, *Innovative Materials in Children’s Hospital Design*, pp.2-20 (Aug. 2014).
- [5] Lavy, S. and Dixit, M. K. (2012). Wall finish selection in hospital design: a survey of facility managers. *HERD: Health Environments Research & Design Journal*, 5 (2):8098.
- [6] Nitin Sharma, Pranav Arora, M.Arch (HCA). *The advances in interior design technology in hospitals* pp. 5-9.(2019)
- [7] Ge, Z., &Gao, Z. (2008). Applications of nanotechnology and nanomaterials in construction. *First Inter. Confer. Construc. Develop. Countries*, 235-240. M. Young, *the Technical Writers Handbook*. Mill Valley, CA: University Science, 1989.
- [8] M.C. Roco, S. Williams, and P. Alivisatos, *Nanotechnology research directions: vision for nanotechnology in the next decade*, IWGN Workshop Report, U.S. National Science and Technology Council, Washington, DC, 1999.
- [9] DeutschesLackinstitut (2012): Brandschutz-Beschichtungen 40 MinutenknnenLebenretten. Lack imGesprch, InformationsdienstDeutschesLackinstitut Nr. 112, Seite 5.
- [10] Silver-System-Technology, <http://www.bioni.de/en/silver-systemtechnology.html>.
- [11] Melchor-Alemn, M. A., Mesta-Torres, L., & Martel-Estrada, S. A. *APPLICATIONS OF NANOPARTICLES IN TEXTILES FOR INTERIOR DESIGN*.
- [12] Berger, Michael, “Anti-fogging windshields through nanotechnology,” *Nanowerk News*, <http://www.nanowerk.com/news/newsid=1157.php>, Dec 15, 2006.
- [13] FaniVavili, Artemis kyrkou, *Innovative Materials in Children’s Hospital Design* (Aug. 2014).
- [14] Nitin Sharma, Pranav Arora, M.Arch (HCA). *The advances in interior design technology in healthcare facilities from: healthcaredesignsmagazine.com*
- [15] InasHosny Ibrahim Anous, “Nanomaterials and their applications in interior design”, *American International Journal of Research in Humanities, Arts and Social Sciences*, vol (7), pp. 19-27(2014).
- [16] Shinn, Eric; Hübler, Alfred; Lyon, Dave; Perdekamp, Matthias Grosse; Bezryadin, Alexey; Belkin, Andrey, *Nuclear energy conversion with stacks of graphenenanocapacitors*, *Complexity*, vol. 18, issue 3, pp. 24-27, (2013).
- [17] Hartford Hospital bone and joint Institute, Perkins and Will Architects, Source: <https://perkinswill.com/project/hartford-hospital-bone-joint-institute/> (2019).