“STUDIES ON SURFACE COATINGS IN BUILDINGS FOR HEALTH CARE”

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AUGUST 2021

DECLARATION

I hereby declare that the work presented in this thesis entitled **"Studies on Surface Coatings in Buildings for Health Care"** is entirely original and was carried out by me independently in the D. Y. Patil Education Society,(Deemed to be University), Kolhapur Under the supervision of Prof. **(Dr.) Satish R. Pawaskar**, Director, and Department of Civil Engineering. D.Y Patil Technical Campus, Talsande, Kolhapur and **Prof. (Dr.) S. H. Pawar**, Emeritus scientist, Distinguished Professor, and Former Vice- Chancellor, D. Y. Patil Education Society, (Deemed to be University), Kolhapur.

I further declare that it has not formed the basis for the award of any degree, diploma, fellowship or associateship or similar title of any University or Institution. The extent of information derived from existing literature has been indicated in the body of the thesis at appropriate places giving the References.

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This is to certify that the thesis entitled "**Studies on Surface Coatings in Buildings for Health Care**" which is submitted herewith for the degree of Doctor of Philosophy in Civil Engineering & Environmental Health Science of D. Y. Patil Education Society,(Deemed to be University), Kolhapur by **Mr. Milind Manikrao Darade** is absolutely based upon his own work under our supervision and that neither this thesis nor any part of it has been submitted for any degree/diploma or any other academic award anywhere before.

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CHAPTER - 1

CHAPTER – 1

INTRODUCTION

1.1 Introduction:

We need to figure out several ways in the modern era to live a life that is very simple, convenient, safe and healthy. For the regular use of stuffs, it is important to allow the antibacterial impact not only of sanitary areas such as wastewater and garbage disposal, washrooms, but also of food, clothes, workplaces, colleges, hospitals and whatever human-related safety wherever we are active [1]. Recent technological and systemic practices rely on safety precautions, hygiene, and eco-friendly ecosystems. Therefore, the regular devices were slowly equipped with antibacterial and antifungal properties that provide human safety. In current cases, bacterial and fungal disease is one of the major medical complications [2]. Contagious diseases are caused by pathogenic microorganisms including microbes, coral, and fungi. Infections may travel straight or somehow from one individual to another, or shift in infected areas. Controlled studies were accomplished to a limited extent. Typically, gram-positive or gram-negative bacteria are committed to the current difficulties of public safety and in the present circumstances they have been used to monitor such antibiotic issues and run away from pathogens in the common or sanatorium atmosphere [3].

Microorganisms are normal in the atmosphere and grow surrounding the food sources and water availability on most plane surfaces. On the other side, bacteria and viruses are expected to stay live on dry surfaces for some instance. A use of antimicrobial surface coating is recorded to kill such microorganisms, so they can't transmit to others and never develop. Many biocide activity numbers were used to pass antimicrobial activity to coating surfaces. Hence, the colored surfaces are capable of carrying the development of the fungi as long as there is a sufficient quantity of liquid activity on the ground and also the fog. Fungi ingest water-soluble paint coating components and develop on moist surfaces causing substantial deformation, mainly due to spore formation, which allows development readily visible. Fungal growth occurs in moist areas such as kitchens, toilets and bathrooms where ventilation is lacking [4]. Antibacterial surface coating paints have been designed to compete with

these issues, yet it has proved to be daunting a conventional technique has been too costly for fewer available raw materials like copper, titanium and gold. Increasing fungal growth on coating surfaces is also a major problem for the population with poor wellbeing and disease prevention. Dublin Trinity College scientists have developed the innovative and impressive surface-coating paint compounds that prevent the spread of harmful bacteria and fungi infections. Similar to other antimicrobial coatings, their manufactured chemicals are hundred times cheaper than the other widely produced biocide in paint industries. The main advantages of these paints are low cost, less harmful, eco-friendly, and no colour or non-carcinogenic in the natural environment [5].

Therefore, antimicrobial and antifouling paint must be formulated to counter these problems and defend against infectious diseases. Antimicrobial surface coatings are rendered by choosing multiple processes. The coating paints may be added to a substrate contaminated with chemical compounds noxious to microorganism. Therefore, the antimicrobial surface coating paints were developed to keep surfaces hygienic in the health industry. Wherever the surface coatings are physical and chemical that can disrupt the development of bacterial or fungal-like microorganisms which transmit infections [6].

1.2 Overview of Coatings:

The coating industry is one of the world's most heavily regulated industries, so producers have been forced over the past 40 years to adopt and continue to adopt low-solvent and solvent technologies. The number of coatings suppliers are increasing, but most are local producers, with only about 10 multinationals. Many large multinationals increased activities in fast-growing areas such as China. The most prominent pattern was consolidation, particularly among the largest producers. After a decade of steady growth, Asian production accounts for 50–55% of the total. In each state, production and consumption are almost similar, as exchange is restricted to relatively small volumes of high-value commodity. Generally, coatings expand in accordance with the economy, and demand continues to focus on developed countries. The major change in the coatings sector over the last 40 years has been adopting new coating techniques. These new coating technologies include waterborne coatings,

high-solid coatings, two-component systems, powder coatings, and radiation-curable coatings.

Two primary functions-decoration and protection-coatings are of considerable economic importance. Approximately 45% of the coatings produced worldwide are used to decorate and protect new buildings as well as to maintain existing structures, including residential homes and apartments, public buildings, and plants and factories called "architectural" or "decorative" coatings. About 40% of the coatings are used to decorate and cover industrial products ("product finishes"). Without coatings, product lives could be drastically shortened, and many products wouldn't even be marketable. Most of the remaining "special purpose" coatings are used for various applications such as traffic paints, automotive refinishing, high-performance industrial plant and machinery coatings, and maritime construction and ship safety. These are usually applied to ambient conditions outdoors.

Another recent area of interest is nanotechnology, with hundreds of thousands of patents now given specifically for coatings. In highly specialized applications, very small ceramic or metallic particles can be added to paint formulations to modify specific properties (e.g., scratch, mar, wear, corrosion, and UV resistance). Nanoparticles average size is 10–70 nanometers, with less than 6.5 million atoms. At these dimensions, the surface-to-mass ratio is important, granting the particles unique properties. For example, about 2 nanometers; metal particle conductivity changes and at 20 nanometers, ceramic particle visibility changes. At 20 nanometers, gold particles turn red and disappear.

Some of the futuristic applications are nanotubes for electrically conductive coatings and to increase thermosetting resin reaction speed; organ silane dendrimer coatings; machine parts buckyball coatings; and ink conductive coatings metals. The technique is restricted to highly specialized applications due to the high cost per unit volume needed to reduce particle size and the need to incorporate surface additives to prevent particles from agglomerating. Recent research has focused primarily on functionalizing the particle surface of nanoparticles to make them more compatible with coating resin systems to achieve easy dispersion, low viscosity and covalent bonding between particles and resins [7].

The following pie chart shows world production of paints and coatings:

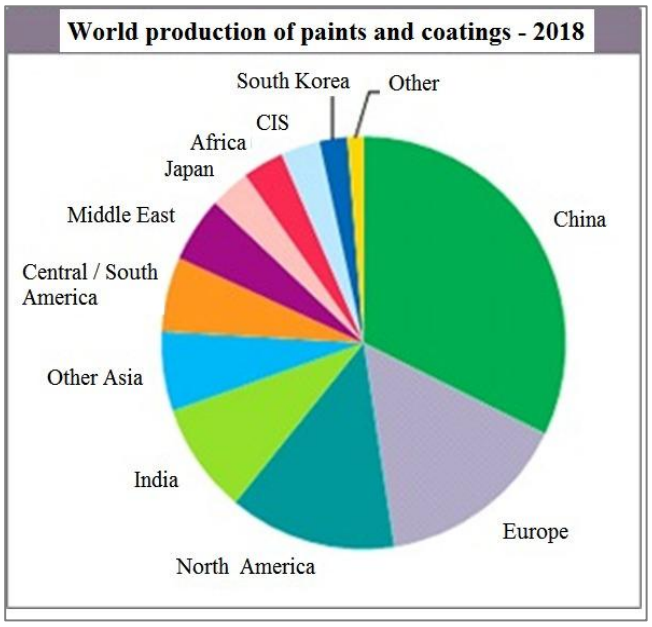

Figure 1.1: World production of paints and coatings

1.3 Type of coatings:

Coating methods are available in a wide range owing to the large variety of applications and requirements across different fields. These processes consist of many different parameters while giving way to many different outcomes in the form of material microstructure, efficiency, suitability, and durability. Surface coating can be used on nano-materials to modify or decrease the adverse effects associated with them. Surface coatings can also be used to alter properties such as surface stability, agglomeration and discharge of deleterious ions [8]. Nanomaterial layer coating was used to mask substrate load and surface structure. Often nanomaterial coatings become degradable in the biological environment which retains the toxic material in its original domain. Several reports suggested that severe inflammatory and immunological responses may occur due to nanomaterial surface coating substances [9,10]. Surface coating allowing good covalent bonding at the substratum-coating interface will give a substratum enhanced performance and long-term durability. Recently, nanoparticles and nanostructured coatings have increased interest in industrial applications such as wear and abrasion resistance. This part deals briefly with conventional coating methods, materials and surfaces, whereas many other protected processes are not covered in this review, such as heat treatment, mechanical

or chemical finishing and polishing. According to the coating point of view it is divided in two ways;

Organic coatings are a type of coating whose primary ingredients are derived from either vegetable, animal or carbon-rich compounds. Such coatings are mainly used to provide additive-type finishes on the products they are added on. Organic coatings can be one-layer monolithic or two or more sheets. Organic coatings protect against corrosion and oxidation. For their cosmetic or unique technological qualities, these are robust coatings added to a surface. Organic coatings rely primarily on chemical inertia and impermeability. Different types of natural coatings are required for industrial purposes, including primers, cements and topcoats (enamel, varnish and paints). Organic coatings are easy to apply using brushes, sprays, rollers, slides, or electrostatics. Brush application is slow and lengthy. Coating prevents or dries through water evaporation or degradation, polymerization, and oxidation.

Such coatings contain carbon, distilled and altered petroleum products and different solvents, pigments, additives and fillers. This category includes products such as:

Alkylated coatings - It can be applied to prepared substrates in different environments. Based on the materials used, alkyds can tolerate various rigors in indoor, outdoor, underground and underwater applications. On the drawback, alkyds require oxygen to complete the chemical reaction that makes them strong. Since oxygen must disperse throughout the film, these coatings take longer to dry compared to other products.

Epoxy coatings systems –Epoxies defines a large, high-performance coating product group with excellent film-building, mechanical and chemical properties as well as short healing and drying times. Epoxy-coating systems can attach to various surfaces, including metal, zinc, aluminum and galvanized parts. This allows them ideal options for many commercial coating projects that require maximum protection from normal wear and tear, abrasion, rust, humidity, heat, salt air, oils, additives and immersion non-oxidizing acids, alkali and salts.

Polyurethane coatings–Improved with unique chemicals, polyurethane coating items are distinguished by excellent oxidation, abrasion, chemical and weathering tolerance. We will suit a wide variety of industrial applications.

Inorganic coatings are designed with materials like enamels, chemicals and pigments to guard against different stressors in manufacturing settings. Three inorganic coatings are widely used in industrial applications.

Acrylic coatings–While alkyd coatings still predominate in many painting industries, waterborne paint coatings are gaining growing popularity for industrial and commercial usage. Acrylic coatings include more binders and formulations designed to meet high performance requirements and less pigment dispersants, surfactants and inhibitors for rheology which adversely affect corrosion resistance.

Ceramic coatings–Including increased strength, environmental and corrosion protection; ceramic paint coatings display unique characteristics such as superior thermal insulation and chemical and dimensional stability. Ceramic coatings can be used in industrial painting schemes to secure tanks and tubes from heat, humidity, Ultraviolet rays, contaminants and elevated ambient temperatures. Nevertheless, such coatings should not extend to materials subjected to tensile or compressive stress. Plastic deformation may lead to fracturing, sacrificing coating integrity.

Intumescent coatings-Exposed to extreme heat or open flames, intumescent coatings grow into dense, foam-like sheets that shield materials from burning. Because in case of fire, these coatings can maintain the integrity of different components, they are some of the best choices for high-heat applications [11].

A composite coating combines two or more substances that offer corrosion protection. This special type of coating is mainly based on epoxy and polyurethane, as well as resin. It is produced using state of the art resin technology to meet the needs of various industries. This offers excellent corrosion protection and waterproofing, making it one of the best coating products used by companies. Composite coatings are suitable for many industries, especially where tubing, hauls and similar structures are popular. Each form of surface offers the following advantages:

Fire and heat safety-it acts as a thermal shield, guarding against hot gas and radiant heat. It also offers fire resistance, shielding carbon composites from resin melting and delamination.

Provides the best conductive coatings-Composite coatings are characterized as thin conductive coatings to provide electromagnetic compatibility and radio frequency protection against carbon composites.

Beautiful finishes-This coating provides beautiful finishes that can include ceramic and metal finishes in a wide range of textures and colors.

Protection property-Provides highly effective thermal protection, and isolates substrates from the atmosphere electrically.

Composite coatings allow strong, but lightweight objects to be used in settings that would otherwise not be appropriate. The most active forms of structural coatings result in intense plasma-based adhesion. This coating technique helps produce coatings resistant to mechanical damage, severe vibration, and significant flexing [12].

1.4 Coatings for buildings:

The most relevant segment in the global paint industry includes building coatings, which are reported to be over 50% by volume [13]. The market is diverse and overlaps industrial paints at heavy duty ends. In this chapter, the focus is given on goods usually found on and around houses, universities, hospitals etc. and used manually instead of in a factory. Building paints, along with other forms of coating, have to shield their surfaces and in addition, the use of products such as ferrous metals without a protective coating would be greatly limited. It is also a prerequisite for most building paints to enhance the structures, even when security is not strictly necessary, to add them with color, texture or other feature characteristics. Paintings often play a role in improving natural and artificial light availability and the specific colors chosen can affect mood and sensation. Hence, this market sector is commonly referred to as the ' decorative industry, ' although other terms are used ' architectural coatings ' and just 'home paints'.

1.5 Requirement of coatings for health care:

In most health facilities, the majority of persons treated are immune compromised and therefore infection prevention and control are vital. As weakened immune systems and other diseases make patients more susceptible to infection, healthcare providers are responsible for minimizing the potential risk of such patients acquiring HCAI. An estimated 6.4% of hospital patients are affected by HCAIs each year.

Floors, walls, and ceilings must therefore be carefully designed to enable effective cleaning, with this in mind all coatings and finishes. If a floor or wall is inconsistent with cleaners, this may lead to physical characteristics or finishing quality changes that can lead to softening or hardening, less flexibility, cracking, flaking or discoloration. This is inconceivable and can affect the cleaning regime's effectiveness. In the healthcare system it is imperative to consider for each usage area the expected traffic levels when specifying walls, ceilings and floor finishes. If a finish cannot stand up in situ to the intensity of use, there can be cracks, tears and other defects. Uncorrected or insufficiently fixed, such imperfections will adversely affect the cleaning regime and establish safe microbial niches and biofilm [14].

Requirement of Wall Coatings:

a) Partitions shall be designed to resist loading, fittings and protection imposed by equipment and fittings.
b) Medical areas require flat, solid, translucent and impermeable surfaces that are easier to clean.
c) Cracks, open joints or cracks should not surface the wall.
d) In order to stop plagues entrance, preserve structural stability, maintain fire protection and sanitation grounds Walls breached by valves, pipes and ducts should be secured.
e) Wall finishing shall not include fungal and microorganism growth supporting or promoting materials.
f) If necessary, the wall finishing should be impermeable and easily wiped over, and detergents and disinfectants shall not physical or degrade them.
g) Facilities with safety requirements should be protected (for instance hospitals, laboratories) to meet local security service requirements.
h) Potential future concerns of the health facility should be addressed.

Requirement of Ceiling Coatings:

a) Dead loads from a series of surface-mounted or recessed ceiling devices should be supported by the ceiling system.
b) Closings in clinical areas shouldn't be cleaned easily and detergents and disinfections should not be physically damaged or degraded.

c) Low, normal and high moisture spaces should reflect the specification and should be able to withstand intermittent water and water vapor contact.

d) Specific health building notices provide guidance on appropriate ceiling heights for functional rooms.

1.6 Statement of problem

- **Choice of the Topic with Reasoning**

The tremendous growth of microorganisms everywhere that affects on human health by spreading the various infectious diseases. In the procurement of medical products, machinery, hygiene, housekeeping and other cleaning methods, hospital and medicinal industries are usually very important to public health. Most disinfectant chemical agents apply in the form of a solution to destroy the microorganisms, but they could not provide long-term security and could not provide the protective shield for indoor wall, ceilings and building climate. For this reason, the researcher was chosen to conduct antimicrobial surface coating paints for antiseptic purposes in healthcare buildings;

1) It kills the bacteria, germs and microbes which reduce the hospital acquired infections
2) It eradicates the microorganisms and keeps the environment clean and healthy.
3) It protects the public health from the pathogenic contaminations and allergic infections.
4) It provides odorless and peaceful healthy atmosphere.
5) The antimicrobial coating paints inhibits the increasing growth of microorganism for long duration.
6) It prevents the fungal and algal attraction on the indoor wall surfaces in the healthcare institutes.

- **Objectives of the Research Work**

1) To prepare the antimicrobial surface coating paints which is suitable for the indoor system in the healthcare institutes.
2) To analyze the fabricated antimicrobial surface coating paints different methods or techniques.
3) To check the antimicrobial activities against some bacterial or fungal species by the respective method.
4) To optimize the calculation of different additives and constituents with their functions and quantities while blending the paint.
5) To apply the paints coats over plane surfaces and examine it.

- **Justification**

The present research study principal purpose is to show the significance and scope of the antimicrobial coverings in the health industries such as pharmacy, clinics, medical and microbiological sectors. The requirement for these surface layering varies from pathogenic microorganisms by its various properties. The student must prepare some essential anti-microbe surface coating paints that are helpful for both the hospitals and the clinical interior walls that protect it from bacterial and fungal infections through understanding of the strength of the current situation.

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CHAPTER - 2

CHAPTER – 2

THEOROTICAL BACKGROUD OF COATINGS

2.1 Introduction:

In today's changing world, we need to find a number of ways to make life really simple, convenient, and safe and sound. The routine antibacterial impact of using goods should be requested, and not only sanitary areas such as wastewater and waste disposal, washing services, but also food products, clothes, workplaces, universities, hospitals and all human safety should be used wherever we are active [1]. The new technological and systemic styles are focused on safety precautions, sanitation and environmentally friendly environments. Thus, daily appliances are gradually being developed with antibacterial and anti-fungal attributes to ensure the safety of people. One of the most significant medical complications in the present situation is bacterial and fungal infection [2]. Pathogenic microorganisms such as bacteria, algae and fungi are responsible for contagious diseases. Infections can spread straight or somehow or move in infected areas from one person to another. Only limitedly, the guided studies were conducted. The main public hygiene problems usually were found in the gram positive and gram negative bacteria and in the present situation the antibiotics have been utilized to avoid communal and sanitary infections [3].

Microorganisms are normal in the atmosphere and grow surrounding food sources and water availability on most plane surfaces. On the other side, bacteria and viruses are expected to stay living at dry surfaces for some instances. Using antimicrobial surface coatings is reported to destroy these microorganisms, so they can't convey to others and never grow. Several biocide activity numbers were used to pass antimicrobial activity to coating surfaces. Hence, the colored surfaces are capable of carrying the development of the fungi as long as there is a sufficient quantity of liquid activity on the ground and also the fog. Fungi consume water-soluble paint coating components and grow on damp surfaces causing considerable deformation, mainly due to spore formation, which makes growth easily noticeable. Fungal growth occurs in moist areas such as kitchens, toilets and bathrooms where ventilation is lacking [4].

Antibacterial surface coating paints have been formulated to conflict with these

problems, yet it has proven to be challenging a typical technology has been too expensive with fewer available raw materials like copper, titanium and silver. Increasing fungal growth on coating surfaces is also a major problem for the community with compromised health and infection safety. Dublin Trinity College scientists have developed the innovative and impressive surface-coating paint compounds that prevent the spread of harmful bacteria and fungi infections. Similar to other antimicrobial coatings, their manufactured chemicals are hundred times cheaper than the other widely used biocide in paint industries. The main advantages of these paints are low cost, less toxic, eco-friendly, and no color and non-carcinogenic in the natural environment [5].

Therefore, antimicrobial and antifouling paint must be formulated to counter these problems and guard against infectious diseases. Antimicrobial surface coatings are rendered by choosing multiple approaches. The coating paints may be added to a substrate contaminated with chemical compounds noxious to microorganism. Thus, the antimicrobial surface coating paints was developed to keep surfaces hygienic in the health industry. Wherever the surface coatings are physical and chemical that can disrupt the development of bacterial or fungal-like microorganisms which transmit infections [6].

2.2 Theoretical Background of Coatings:

Nano-material surface coating can be used to modify or reduce their adverse effects. Surface layers can also be used to modify features such as particle stabilization, agglomeration and arrest, and noxious ion discharge. Nanomaterials are surface-coated to mask surface load and surface composition [8]. In biological media, leaving a harmful material in its initial field, sometimes degradable and reliable nano-material coatings, many studies have shown that nano-material surface substances can cause severe hyperbolic and biochemical reactions [9]. Also interchangeable,' tone' or surface coating are used. The more general description is any substance that can be given to a surface as a thick, constant coating. Purists consider the word "surface-coating" tautological. The United Kingdom and North America, however, used extensively to differentiate paint and other surface application techniques, including electroplating, anodizing, and surface polymer film lamination. Surface coats are

double-functional. Aesthetic and safety problems, or both, can be addressed. A coating is a cover, generally known as substratum, applied to an object's surface. The coating can be a commercial coating, covering the substratum entirely, or it can cover only substructure sections. A product label on several drink bottles is an example of all these coatings–on the one hand there is a full-function coating, and on the other hand there is some decorative printing that makes the images and words.

2.2.1 What is coatings?

Although we should not often consider coating as an important industrial sector, it is a hidden giant in the same category as aerospace or automobiles. Nearly all items must be painted and/or covered with a coating. The most important thing to charge for certain items is the "coating." For example, photographic emulsions are used as viscous fluids on translucent support or' substrate,' and then dry out in photographs. Similarly, there are produced different types of thin sheet products. Therefore, you can protect different surfaces and help them to maintain the brightness, hardiness or any other property they wish to preserve over a longer period of time by using the industrial coating if wear is a problem in any kind of industrial environment. They are protecting. Avoiding the rusting of equipment is an important aspect of manufacturing. Almost any product produced requires a protective coating. Likewise, the various types of plastic sheets are made. Paper is a good machine-coated high speed sheet. Although paints and other products generate the esthetic and utility of the product, the advantages must generally be weighed against the costs of the setting.

2.2.2 Why for coatings?

A surface is a covering, generally known as the coating, which is added to the surface of an object. Decorative, practical or both may be used to add the coating. The coating itself may be a complete coating covering the substratum completely, or only part of the substructure.

2.2.3 What is the importance of coating?

A cover is commonly called a substructure on the surface of an object. The sheet may be artistic, practical or for use either. The cover can cover the entire substructure or

only parts of the substratum. Another important thing is stopping the rusting of computers. Basically any material made contains a protective coating. Although paints and other coatings are important for the esthetics and durability of the products, these advantages are usually balanced against the expense of the climate.

Some of the important points of the surface coating cover;

- **They provide assurance: -** In principle, the thing covered is a magnificent must be ensured. For example, if it works for more than a year or so, a story that is underneath so many massive, overwhelming pieces of hardware must be assured and why things need be automatically granted.
- **They offer security**: - You may need to create a slip-on or non-stick surface in some cases. Floors are one example of a location where you could need a mechanical quality covering, especially in areas where a lot of fluid can fall on the ground. In order to ensure fast, quality handling of materials, a number of machines may involve non-adhesive surfaces inside them. The best strategy for protecting a range of surfaces is mechanical coating.
- **They signify consumption**: - Rust or other detrimental shells and jetsam is another problem that flows in mechanical apps often. Materials which are difficult enough to produce hardware are often additionally susceptible to absorbing after a while. The materials which pass through these devices often erode them. The principal arrangement is to be connected to a mechanical cover, given that it can be built so that the machine and the material it is used are the ideal combination.
- **They maintain clean surfaces: -** However you are not restricted in the layer you can possess with mechanical coatings. In some mechanical devices regularly the major part of something that may have a surface that remains smooth is not produced. In spite of this, we will see cleaners in the light of the reality that the materials are streamed right through the device through the construction of a covering that will particularly counteract what you are preparing.

2.3 Effect of environment on the indoor surface coating*:*

The hydrocarbons released by different solids and liquids are organically unstable compounds which have harmful short- and long-term health effects. For typical paints solvents also produce large volumes of VOC. Indoor air performance is enhanced with limited VOC paints and urban smog elimination. These coatings include the benefits of low odour, clean air and safe technology, good durability and washable finish. Antifouling or paint is used to prevent ships ' hulls from being fouled by marine organisms. Antimicrobial paints protect the surface against corrosion and prevent marine organisms from accumulating through the transport of the ship. Such paints include organic compounds such as tributyline, which are seen as harmful to humans and the environment. As per the research work the following environmental concerns effects on the surface coating paints were demonstrated as follows;

2.3.1 Effect of Temperature on the surface coating:

One of the main problems encountered by tropical countries is the heat dissipation at night time. Brick walls retain daylight during the day and at night escape into the surrounding environment when the surface temperature of the walls becomes lower. The high density of the brick wall renders them a thermal mass where the thermal energy can be absorbed and when the ambient temperature is less than the temperature of the brick wall, the heat dissipates in the atmosphere. Indoors are emitted with excess heat, which creates a higher night temperature than normal. The air conditioning system also has a higher energy cost to cool the room. Because of the improvements to the environment, the research is based on heat transfer by high reflectivity of the surface coating content in the house. A reflectivity of the ground called as albedo determines the amount of energy that is representing the object. A high albedo represents the bulk of radiation that can be captured by the minority that enters the surface while the albedo is a layer capable of representing a small quantity and removing the other incoming radiation [10,11].

The temperature and humidity of the paint dries were two of the main influences. Understanding how to prevent negative environmental effects will help avoid difficulties with paintings. Bitter cold avoids drying in extreme cases while heating has the opposite effect. The surface of the paint will skin over when the temperature

becomes warmer before the lower layers have a chance to cool. Alternatively, if products are used too quickly at excessively hot temperatures, bumps, blisters and other imperfections, such as lifting, cracking or discoloration, can often occur. The rule of thumb is that the ambient temperature must be above 45°F for at least 48 hours if you are working with an oil based pigment. The usual high-temperature specifications for latex and acrylic paint reaching 50°F. Nevertheless, many paints are dried at lower temperatures, even at a level of 35°F. Lower temperatures may also lead to problems. It is also important that the first night after painting is applied; the temperatures of air do not drop under freezing, since curing paint may still contain moisture which crystallizes at sub-freezing. Temperatures should not only be more than 45°F before adding the paint, but they should stay clean for at least 2-3 hours for the color. The paint thickens as the temperature drops. As the coating is thicker, in case of oil paints, the longer it takes for the paint to oxidize. Moreover, the time it takes for the solvent to evaporate is extended when the coating is thicker.

How does this happen? With more atmospheric temperature, it takes more time to evaporate the moisture in an acrylic and latex coat. of instance, when building projects outdoors, condensation frequently happens on the surface of the paint if you mix low temperatures with high humidity. This harm to the surface, including raising, corrosion or paint loss, may occur from this condensation. The surface thickness for acrylic and latex paints is only one factor that affects drying times. Certain climate issues, such as wind and precipitation, impact paints and other coverings besides humidity or temperature.

2.3.2 Effect of humidity in the indoor surface coatings:

In high moisture conditions, is known as surfactant liquidation can be seen brown or white discoloration on the paint layer. The optimal protecting properties of the pigment can be impaired if paint becomes subjected to an excessively high humidity. A fresh coat of paint often protects against high humidity by inserting moisture into the incompletely dried paint movie. Moisture must also be taken into account when a wood surface is finished. Containers can accumulate the air humidity that can weaken the paint's adherence to the substrate and causing peeling and fizzing of paint. When

the moisture is high, a large amount of water vapor is exposed to the paint, which not only affects the drying of acrylic and latex.

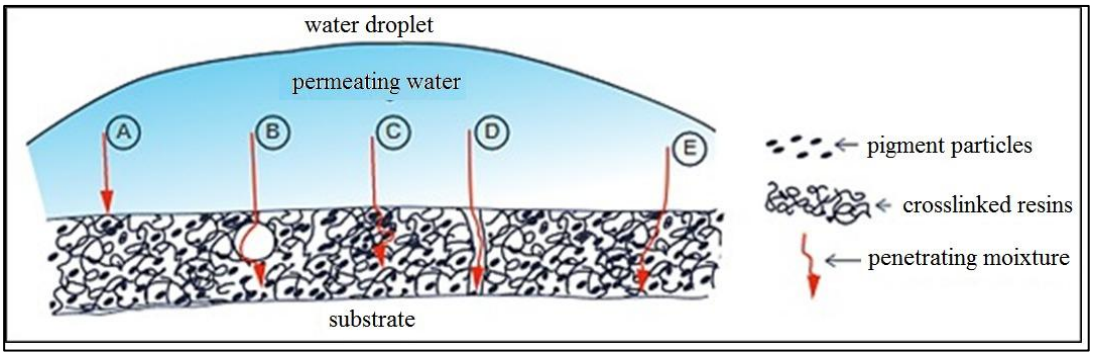


Figure 2.1: Effect of humidity on the surface coatings

Crosslinking density of a coating varies significantly, resulting in very different degrees of moisture penetration:

(A) No moisture penetration or crosslink density

(B) Penetration through or over void

(C) Penetration through a pigment agglomeration

(D) Penetration through a micro-crack or capillary

(E) Penetration through area of low crosslink density

Energy acting on the coating can degrade the material by breaking or interfering with the substrate and the chemical bonds holding it together. The energy effect in almost all situations increases the degradability of an organic molecule owing to other environmental influences i.e., permeation, mechanical or biological. The key sources in energy include solar radiation, heat (or cold), and nuclear radiation to a much lower degree [12, 13].

2.3.3 Effect of adsorption and absorption on surface coatings:

If gas molecules are in direct contact with a solid surface, they are adsorbed there in part; the gas binds to the solid surface. These molecules in the condensed phase are known as adsorbates and the compound that holds them is known as adsorbents [14]. There is a difference between Adsorption and absorption mechanisms. Absorption is a mechanism where the gas molecules melt into the bulk of a liquid or solid or become

chemically bound. The absorbed mass was also shown to be proportional to the absorbent's weight, while the adsorbed mass is proportional to the adsorbed surface area. In adsorption, fluid phase components (adsorbates), gaseous or liquid, are transferred on the solid surface (adsorbent). Forces of attraction are established between the adsorbate and the adsorbent; the adsorbate covers the surface of the adsorbent with a molecular layer [15]. In order to be effective, decorative or protective coatings must show good adhesion. No definition defines adhesion property, but there are a variety of basic mechanisms considered to characterize adhesion property. The adhesive system mainly uses three mechanisms: adsorption, chemical and mechanical interlocking. For a long-lasting protective coating, both cohesion and adhesion is needed. Adhesion failures will determine the paint system's life. When the following actually occurs, good adhesion results;

The molecules in the film wet or flow freely through the substratum, forming interfacial links (a process called adsorption), forming chemical links on the interface between the layers and the substrate and permeating the rudity on the surface of the substratum, resulting in mechanical linkage after the layers are drained. According to the adsorption theory and adhesion results from molecular contact between two substances and the developing surface forces. The adsorption of the paint molecules on the substratum and the subsequent enticing forces, usually called secondary or van der Waals forces, establish a bond [16].

The benefits of the paint given by the innovation are: The green and environment-friendly odor-absorbing wall paint does not produce volatile organic fuel. Odor can be absorbed efficiently with the paint. The color also provides simple building benefits and durable coating. The painting is an artwork that is planned to wall paint homes, restaurants, villas, bathrooms and other similar things [17].

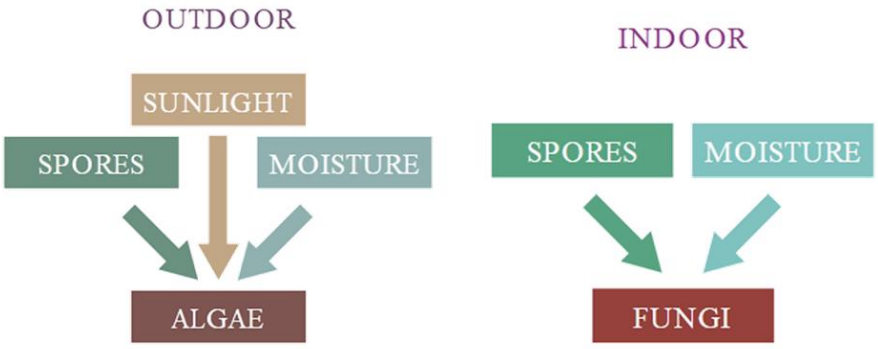
2.3.4 Effect of abrasion on surface coatings:

In comparison, the effect and abrasion of a coating is typically rapid, concentrated and immediate when painted, cured or curing pressures, along with the flexion of vibrations or tension stresses as discussed before. Mechanical damage caused by fallen stones or devices, or other mechanical disruptions when the surface of the coating is either directly or inversely impacted from the other side of the coating, may

cause the coating to crack or break. Strong brittle coatings and lacquers may however not has the versatility to withstand abrasion and corrosion wear in or below or near to their glass transfer level. In these cases, the surface layer may break or be scratched and discarded to reduce the coating at the abrasion or erosion locations. The coating becomes thicker [18].

2.3.5 Effect of microbiological degradation of surface coatings:

The oldest and most abundant life forms on Earth were microorganisms not apparent to the inexperienced eye. These are all-round and exist in almost all-natural environments, including those which have been deemed un-hospitable to existence until recently: underwater volcanic winds with heavy sulfur levels, cold stretches, highly acidic and alkaline chemical conditions, anaerobic atmosphere (no oxygen) or areas without sunshine. Coatings and other products are weakened by the existence of the bacteria as a consequence of the electrochemical and biological processes. Similarly, macro-organisms (visible) such as mildew and marine flora and fauna can cause serious damage to the layer and dramatically affect, denying the intent of, the properties and functions of the layer structures.



The surface or substrates temperature, humidity and humidity levels would determine the potential of algae and fungal formation. Algae, such as external wall surfaces, are usually found in buildings because their chlorophyll characteristics require sufficient solar light for growth. On the other hand fungi are commonly found in moist places including bathrooms on inside walls. It should be noted that the growth of algae may be due to the inadequate design and facade of the building.

2.3.6 Effect on human health of surface coatings:

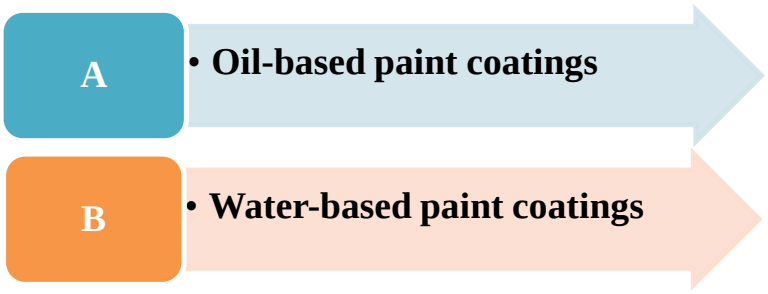
Some paints have additives that evaporate in the water. The capacity to cause health effects of these chemicals varies significantly. Like any substance, the probability of a reaction and the degree and form of impact on your wellbeing can depend on many factors. That involves the volume of the chemical in the indoor air and the length of time that you are subjected to the chemical. Another of the symptoms that some people have experienced shortly before exposure to certain chemicals is eye and throat or lung irritation, headaches, dizziness and vision problems. Many additives in paints have harmed nervous systems, liver and kidneys of experienced painters exposed to high levels of paint vapours for a longer period of time. Some chemicals cause cancer in laboratory animals as well as reproductive and developmental effects. Such issues will avoid paint vapors from being ingested to sensitive people, such as youths or persons with breathing problems. Pregnant females must stop painting activities and restrict their time in freshly painted rooms in order to avoid safety risks for it and their children, particularly when using oil paint coatings.

The possible links between using solvents and paint-and-child leukemia was explored in a 2009 study published in the journal "Environmental Health Perspectives" It was not concluded that solvents were linked to leukemia but it found that the strong association exists between household paint and leukemia, because of remarkable differences in the organic coatings for all risks in paint and solvent exposure. The association of paint exposure to solvents is unlikely to be attributed to solvents in the paints. Household use of paint is primarily made up of paintings of latex, which usually include resin of polyvinyl acetate. Epidemiologically, Polyvinyl acetate evidence and animal studies are too limited to require evaluation in human beings of their potential cancer risks [19].

2.4 Coating for buildings:

The main segment in the overall paint industry, which figures are more than 50% of the total volume, is defined by the coatings for buildings [20]. The sector is diverse and with synthetic paints at heavy duty ends. This chapter focuses on products typically used in houses, schools, hospitals, etc. and used by a hand instead of in the factory. The focus is on the products. Building paints must cover the substrate to

which they are added, as well as other forms of coating, without protective coating the use of materials such as ferrous metals would be considerably reduced. But it is also a requirement for most building painters to enrich the surfaces, even if protection is absolutely not required, to which they are applied with colour, texture or other appearance characteristics. The use of natural and artificial illumination is also affected by colors and the real colours, which can affect attitude and sound the specific colours that are why the 'decorative market' is often called this market sector, other words include' architectural coatings' or simply 'house paints'. There are two major types of coating paints;



2.4.1 Oil-based paint coatings:

Oil-based paint includes organic (linseed) or artificial (alkyd) base oil. Because of its lower price and higher power, the alkyd base became more popular. Nevertheless, both styles are durable and versatile, making them good options for painting work, interior windows, bathroom or kitchen cabinets and decor. Oil-based coating is also good as it adheres well to the ground and defends steel walls, etc. from the weather. Oil-based wood stains are another material that actually benefits the wood's oil foundation. Oil paints have many benefits, such as resistance to heat, durability and versatility over water-borne paints. The demand for oil-based paint is rapidly decreasing throughout many countries all over the world, however, as a result of the use of volatile organic coatings (VOCs) as solvents and as a consequence of environmental pollution. VOCs are harmful to the environment because they are responsible, in part, for air pollution, ozone depletion, global warming, and the consequences to health of all living organisms [21, 22]. When applying oil-based paint, wear a mask and ensure proper ventilation [23]

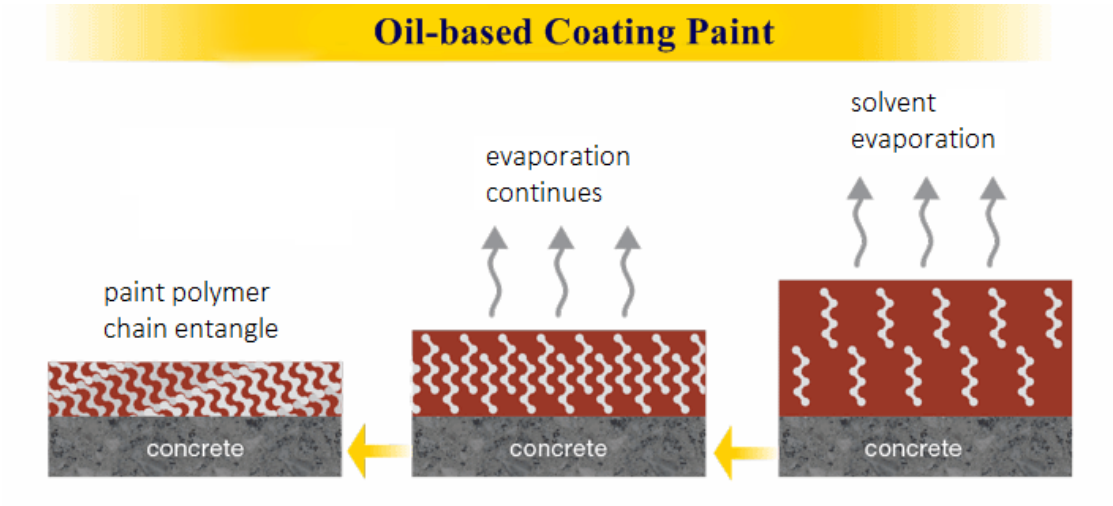


Figure 2.2: Oil-based surface coatings

2.4.2 Water-based paint coatings:

Water-based coating, as its name suggests, is a water-diluted material. Compared to ordinary paints, the effect is slightly better than water paint. For the safety and decoration of most buildings the waterborne paint is now used for days due to their quick application, fast drying, non-odorous, good washing efficiency and excellent finish. However, in comparison with oil-based layers water-borne paints are only used in relatively low quality. While research has been directed at environmentally friendly water-thinkable paints, the dream has not been achieved in comparison to the solvent-based system to produce emulsion paint with satisfactory service characteristics [24-27].

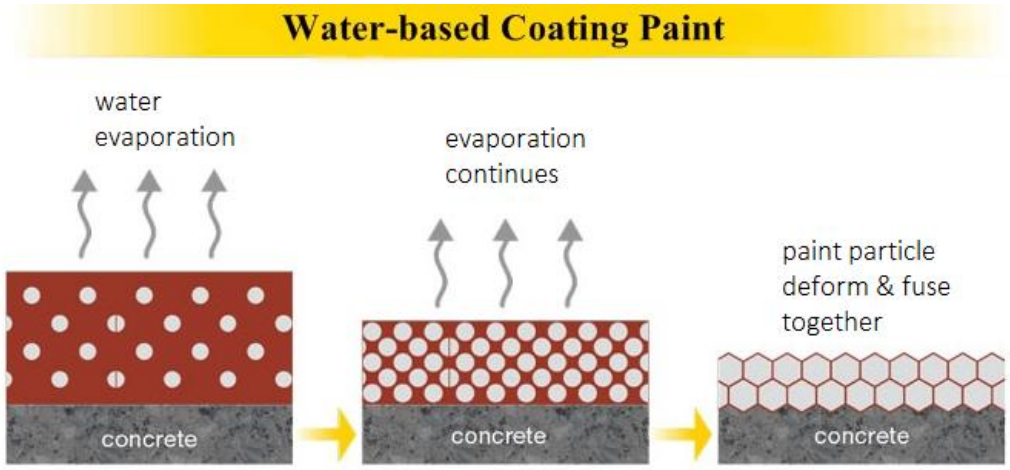


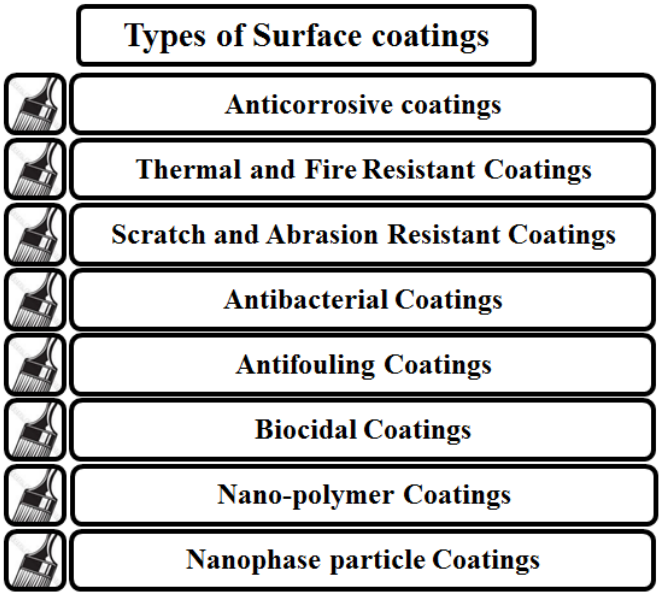
Figure 2.3: Water-based surface coatings

2.5 Surface coatings for buildings

A coating is a cover, usually referred to as the substratum, which is applied to the surface of an object. Decorative, practical or both may be the intention of application of the coat A surface coating is any mixture of materials that form foil, including pigments, solvents and other additives, that gives a thin, functional, non-corrosive and often decorative film when applied to the surface and cured or dried. Surface coatings include colors, lacquers, oils and lacquers, as well as other materials whose main function is the environmental protection of an object's surface. Bactericides that protect aqueous latex coatings for long-term storage are often applied to the fungicide, bactericides and other specialized additive coatings. Likewise, latex-coated coatings often contain fungicides for exterior architectural use that prevent mildew formation on external surfaces.

2.6 Classification of surface coatings:

In most instances, though, painting is used on a substrate for cosmetic, defensive and practical purposes. In contrast to the classical properties of a decorating or safety coating with additional functionality, the word practical coating described structures. Based on their functionalized use against the coatings are divided in to the following categories;



2.6.1 Anticorrosive coatings:

It is well known that rust is formed when iron or steel is exposed to a natural environment. While iron or steel rusting is usually referred to as oxidation, the latter is a common word used to describe the harmful relationship between a metal and its environment. Corrosion is usually a matter of steel, although the atmosphere may also be influenced by non-metallic substrates such as plastics, cement and wood. With a reduction in our natural resources, oxidation creates tremendous industrial damages. Electric potentials are produced if two separate surfaces of a metallic element reveal or vary in their surface structure or composition. Basically, corrosion is an electrochemical mechanism where the anode, an electrolyte and a cathode form the electrical cell which is involved in the cycle of corrosion but does not corrode itself [28]. To order to avoid harmful effect of oxidation, organic coatings are generally applied to steel substrates. The anti-corrosive quality of the coating relies on several factors, such as metal adhesion, density, permeability and different coating properties. The principal duty of the primary material is in most situations to secure the metallic substratum and conform to other surfaces of the surface. Surface preparation in this sense is important if the first to metallic substratum is to bind effectively [29]. The above is outlined in the processes through which organic coatings provide corrosion protection.

Means of sacrifice: The use of a sacrificial anode like steel zinc is an industry well known for many years. Sacrificial coatings means once subjected to an unfavorable climate, the zinc coating on galvanized steel deteriorates, shielding the ground beneath. The zinc-rich coverings have been produced to shield a variety of metal substrates using the similar approach focused on inorganic as well as organic resin [30, 31].

2.6.2 Thermal and Fire-Resistant Coatings:

For many metal substrates that reach us every day, like non-stick cookware, grill sand boilers, thermal-resistant coatings are required. Fluorine and silicone materials for the above-mentioned goods gain a good thermal resistance. Fluorinated coatings are not appropriate for applications with a high temperature of the as they degrade above 300°C and toxic byproducts. While other binders, such as phenolic or epoxy,

are used to produce high thermal-resistance coverings, the market is currently dominated by silicon containing coatings. The high energy required for breaking silicon bonds relative to carbon bonds in analog molecules provides a better thermal resistance for silicon-based polymers. A protective layer is formed as a glassy surface barrier, which contains phosphates that contain compounds. The poisonous and ecologically dangerous halogen and antimony based fire retardants. Intumescent coatings create an expanded carbon layer that acts as a heat transfer safety barrier to the burning site and prevents the spread of fuel gasses and melted polymers. These coatings consist of three components, such as the dryer, the carbonate carbohydrant and the blowing agent [32, 33]. Innovative ways of designing thermal resistance coatings have been reported, such as the incorporation into binders that are resistant to temperatures up to 400°C of titanium esters in combinations with aluminum flakes. A complete titanium-aluminum coating that deposits on the suspensions and enhances the heat resistance up to 800°C [34] takes place above this temperature "burning off." Expandable graphite is now commercially available as fire retardants, comprising chemical compounds (including acid) that are interlocked between the carbon sheets. Exfoliation of the graphite occurs when exposed to higher temperatures and this provides the substrate with an isolation layer [35]. Polymer clay i.e., laying nano-composites silicates for the production of fire-resistant coatings have recently also been studied. [36, 37].

2.6.3 Scratch and Abrasion Resistant Coatings:

Coatings are prone to scratch or abrasion damage. The user obviously prefers to preserve the esthetic look of painted products and that is why transparent automotive coatings have to be particularly scratch or abrasion-resistant. The additional problem is that scratches may also damage the surface beneath. Several companies around the world have taken the task, without compromising its other properties, of enhancing the scratch resistance of a surface. Other function, like anti-fingerprint and impact resistance, would display a less cross-linked movie that is good at scratch and abrasion resistance. Therefore, the right combination of hardness and mobility is needed to achieve maximum scratch resistance. Organically inorganic polymer films are paving the way for the production of scratch-resistant coating. In the production of

scratches resistant coatings, recent progress in nanotechnology plays an important role [38, 39]. By incorporating SiO_2 nanoparticles into the organic surface matrix, the laying sectors have created scratch-resistant layers. This improves the scratch resistance by enhancing nanoparticles on the surface of the coating [40].

2.6.4 Antibacterial Coatings:

The potential hazards for our hygienic modern lifestyle are micro-organisms like bacteria, fungi or viruses. In coated substrates, microbial growth can lead to numerous adverse effects, including anesthetic (coating discoloration), health and hygiene hazards, malodynamics, biofilm formation, or microbial oxidation in metal substrates. The presence of nutrients in the surface and nature of the substrates constitute the principal parameters which determine the types of microorganisms that may colonize the coating and their composition and the nature. For example, heavy metal ion biocides operate by breaching the cell wall to impede the metabolism of the bacterium while the cytope membrane of the bacterium is being ruptured by antimicrobials with cationic surfaces.

Examples of organic biocides include polymers, tertiary alkyl amines and organic acids [41, 42], while inorganic biocides include silver, zinc oxide (ZnO), copper oxide (CuO), TiO_2, and selenium [43, 44]. Microcapsules containing biocides have also been developed in order to increase the longevity and efficiency of antimicrobial coatings [45, 46].

2.6.5 Antifouling Coatings:

Aquatic species create a major threat to all things that are used in the marine environment and are deemed "fouling" because of their excessive development and deposition. In coastal waters where vessels or ships are docked or slowly traveled, Fouling is usually more prominent. Fouling is of two main types, namely micro-fouling and marine animal macro-fouling (barnacle and tubeworms), and plants (algae) depending on the types of marine organisms involved. To prevent foulings are used both biocidal and nonbiocide coatings. Antifouling coatings on the basis of biocides function through slow leaching of the incorporated biocides into the coating. Biocides are regulated on a daily basis for purposes of stringent regulation

and toxicity. For example, tributyl tin (TBT) is an effective marine biocide, but due to its toxicity, it is no longer used. In carrying out its anti-fouling program it is critical that biocides do not adversely affect marine life. Recognitions to its environmentally friendly behavior, water-borne functional coatings become more common than solvent-borne systems [47].

2.6.6 Biocidal Coatings:

There is a great interest in the design and development of surfaces that not only provide biocidal activity but are also easy to clean and even self-cleaning. Most of such coatings acquire their biocidal or self-cleaning capacity by incorporating specific nanoparticles: basically silver (Ag) and titanium oxide (TiO_2) [48, 49]. Nano TiO_2 is used for developing anti-UV, anti-bacterial and self-cleaning paints. This possesses self-cleaning hydrophobic properties, which causes water droplets to bead-off of a fully cured surface picking up dirt and other surface contaminants along the way. Nano-structuring of the surface alters the wetting properties and is intended to signal that the site is not suitable for the organisms to settle. The project aims to synthesize new nanostructured polymers that are stable under marine conditions. Although no alternatives to the use of biocides are available at present, creation of nanostructured surfaces could offer an innovative and environment-friendly solution to the problem of biofouling [50]. Research has developed new biocidal coating systems that prolong biocidal activity by immobilizing such additives on nanoparticles; the embedded biocides are designed to be released into the environment only when needed, thus extending the lifetime of the biocidal activity [51].

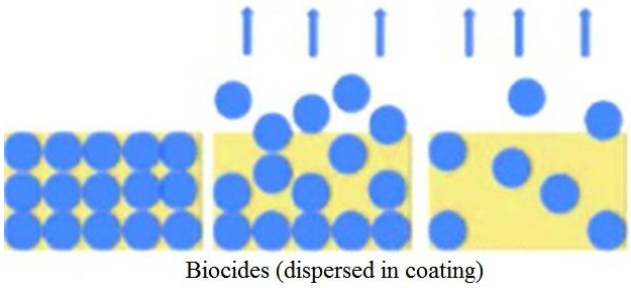


Figure 2.4: Biocide surface coatings

2.6.7 Nano-polymer Coatings:

According to their electrochemical dynamics and their mixed ion or electronic conductivity properties, leading polymers have evoked much interest [52]. In various composite films they were used as host matrices. The conductive polymers may blend and integrate organic and inorganic particles into their formulation in order to change their ethical, conductivity and different physical characteristics, such as corrosion protection. A number of new properties are identified to demonstrate polycrystalline nano-composites composed of leading polymers. Organic metal polyanilinenano-methylenes dispersed in a variety of low-level paints could have enormous effects on corrosion protection [53]. Polyaniline melting leads to fine particles that organize themselves into complex superficial networks. Polyaniline, polythiophen and polyrrol are certain nano-conducting polymers that increase corrosion resistance. The integration of heavy oxidizing organisms into the polymer was envisaged in order to increase the oxidation strength of the polymers. Nano-composites of polypyrrole oxides, in general Fe_3O_4, are likely to be used in iron safety [54].

2.6.8 Nano-phase Particle Coatings:

In the traditional sol–gel method, hydrolysis condensation processes are followed by condensation polymerization upon film application. However, the evaporation process results in voids and channels throughout the solid gel and cannot provide adequate corrosion protection due to the high crack-forming potential. Incorporation of nanoparticles in the hybrid sol–gel systems increases the corrosion protection properties due to lower porosity and lower cracking potential [55]. Some studies showed that sol–gel films containing zirconia nanoparticles present improved barrier properties. Doping this hybrid nanostructured sol-gel coating with cerium nitrate brings additional improvement to corrosion protection. Zirconia particles present in the sol–gel matrix act as nano reservoirs providing a prolonged release of the cerium ions [56]. The recent discovery of a method of forming functionalized silica nanoparticles *in situ* in an aqueous sol–gel process, and then cross linking the nanoparticles to form a thin film, is an excellent example of a nano-science approach to coatings.

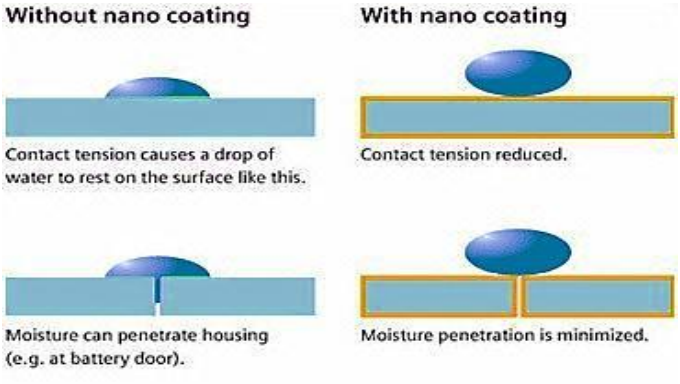


Figure 2.5: Nano-phase particle coatings

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CHAPTER - 3

CHAPTER – 3

EXPERIMENTAL TECHNIQUES

3.1 Introduction:

There is a very wide world of coating. There are many implementations and various uses. Multiple items must be understood to technical people. To the 1960s the coating sector faced a legislative and economic environment that was somewhat predictable. On the basis of evaporation intensity, solution parameters, length, flame-retarding, and costs the formulator for the creation of a solvent-based covering had chosen solvent. There was no apparent need to take into account the photochemical reactivity of these materials, nor did the solvent quality of commercially appropriate coatings provide any important opportunities. The task of painting is twofold on a machine tool. The first defense of the metal surfaces from rust and the second decoration contributes to the machine's appeal. For the same purpose why we paint our vehicles, we paint our machine tools. We want the metallic coating to look good and to guard against corrosion. When we hold to the auto example, we can even analyze the car's original paint before it leaves the factory and then later when the car becomes aged and needs maintenance. Obviously, with machine tools we see the same trend. When a consumer buys a new tool, the research of color at least makes a significant adding contribution to the judgment.

It is well known that TiO_2 has three different crystalline forms in the nature: rutile, anatase and brookite. Anatase, a radical carrier of ultraviolet (UV) light over its energy band holes, is the most active form of TiO_2 in the formation of free radicals. Given the possibility to use the photo catalytic action of TiO_2 for indoor applications without destroying human cells, numerous experiments focused on the possibility of transferring standard TiO_2 ultraviolet light absorption into the visible part of the spectrum. Many studies have recently reported TiO_2 anti-fluorescent lights antimicrobial activity against E. Coli, S. aureus and Megaterium Bacillus. These studies indicate that the small portion of UV light produced by FL light will

activate TiO_2 in order to inhibit bacterial development [1-3]. A wide range of automotive coatings and finishing devices for reading wet and dry coatings thicknesses, air temperature, moisture during use, adhesion to dried coatings, and much more. To maximize asset lives, improve efficiency and reduce downtimes for expensive repairs, corrosion protection on steel of wall surface is important. In this chapter, all the experimental techniques were discussed which is used for the research work

3.2 Viscosity Test:

It is a good way to understand how viscosity is added when painting with other common materials [4]. For example, the viscosity of the water is extremely low. It is very easy to manipulate, splashes and flies, which render it nearly difficult to spray but easy to spray in a nebula. Honey is also a very dense, viscous material, not spray or error. If it breaks down, it oozes gradually rather than a counter or bed. This sprinkles and drops and wraps the floor in a gritty film as you attempt to clean this. In both instances, the material's viscosity defines how when a substance is encountered. You can use this expertise of painting to choose the correct viscosity for the design form you want to use. If many people consider the paint they use to give a new look to a home, a car or a particular place, it is often just about the color of the paint they use. While it is important to have the pure esthetic appeal of a paint option, since it is a primary reason for choosing paint, the only criterion for selecting a paint form, the paint brand and the method of application which will be used to create a new, fresh look for a house, workplace, automobile or another area should not be treated. A major factor to consider is the viscosity of the color, which basically determines its thickness [5].

The viscosity of a paint, which is fundamentally the thickness of paint, plays an important role in its application. Viscosity is a measure of how impervious paint is to thinning out.

Viscosity itself primarily involves the "resistance" to contamination of the pigment. Simply put, the thickness of the paint is determined and whether a brush, roller, sprayer or other preparation methods are required to apply the paint. In most instances, interior paintings for the home arrive in a viscosity that is almost

standardized and is suitable for rollers or brushes. Nonetheless, homeowners or builders who use sprayers should be more careful with the same viscosity, so that the paint can be applied uniformly without irregular ridges, rough use or even injury while painting to the sprayer. There are two simple testing methods of the viscosity of the coating paints are;

A) Trowel Test Method: Applied with different quantities of pigment, softly textured alternating trowel movements. Troweling is one of the most common and respected wall covering techniques. The flat, colored surface textures are then painted, which gives them a shine that looks like sparkling marble.

B) Finger Test Method: Hold the fabric moisturized on the test area thirty seconds, and then touches it again. Search for paints dissolved by solvent. Examine the color and touch the test area with your finger directly after removing the cloth, to decide if the color coating is sticky or brittle [6].

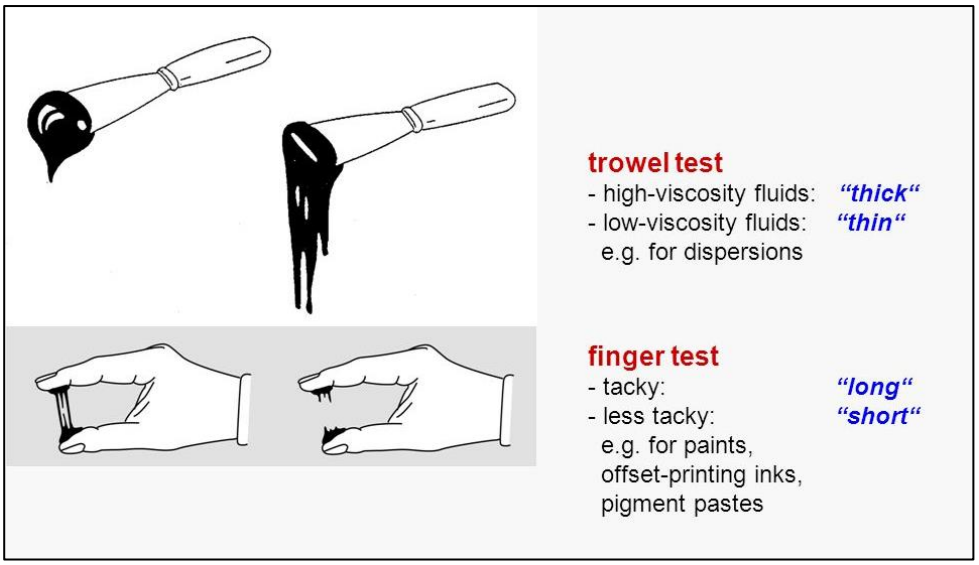

Figure 3.1: Simple test methods of paint

3.2.1 Viscosity: How to Relate Paint Thickness to Everyday Life:

In reality, different levels in viscosity of paint can be contrasted with products in daily life. The viscosity of or the lack of a normal glass of water is usual to most citizens. When a glass of water hits the bowl, the counter and the floor quickly splashes and falls through the container. The very limited quality of water makes the material difficult to control, while water can be properly used for fine sprinklers,

watering plants with a paddle for a garden pit, and other essential uses depending on the relatively thin existence of water [9].

Inversely, maple syrup does not just pour out of the bottle and throughout the room if it falls down. Without doubt the gravity definitely would eventually remove the sugar from the flask, but with a glass of water this will take a lot of time. This is because maple syrup is a little more viscous than sugar, which ensures it is much more viscous. It is better used to fill the container in a glass with more energy than water in a similar situation. The jar holds to the surface more efficiently.

Rheology: Rheology, in the broadest sense, is the analysis of the physical behavior of all products under stress. This identifies four general categories: elasticity, plasticity, rigidity and viscosity. The liquids and pastes are our concern here. When physical force is applied and reversed, the spectrum of fluid rheology involves changes in fluid form. In the comprehension of coating use, implementation and quality control, rheology, the study of flow and deforming, is important. The most important rheological feature of fluids and therefore of coatings and inks is their viscosity, the flow resistance [7, 8].

The way viscosity varies during coating and printing is even more relevant. As with solvents, Newtonian fluids have an inherent viscosity which is unaffected by mechanical shear activity. Almost all of the coatings, though, show a significant viscosity shift as multiple forces are used. They investigate the obvious viscosity of coatings to inks and understand how these strength-induced adjustments are a vital part of the application process during manufacturing. The sum of mechanical force applied and the length will rely on viscosity. The ink returns to its original viscosity after shearing forces are removed. The essential tin property is that return rate. This can range between seconds and hours.

Viscosity, fluid tolerance, is a key characteristic that defines the actions of fluids that are exposed to forces such as combination. Gravity, surface tension and shear are other essential factors in conjunction with the application process. Shear stress to the shear intensity is essentially a function of viscosity. To achieve a shift of form, tremendous force is required for a high viscosity material. High viscosity coatings, for example, cannot be drained as quickly as low viscosity. Also when added, high viscosity lacquers take time to flow. Viscosity of coating paints is

measured by the following equation;

$$\text{Viscosity, } \eta = \frac{\text{shear stress}}{\text{shear rate}} = \frac{\tau}{D} (\text{dynes} \cdot \text{sec/cm}^2) \qquad (3.1)$$

Viscosity is rather a simple concept. Thin or low-viscosity liquids flow easily, whereas high-viscosity liquids travel for great resistance. The ideal or Newtonian, case has been presumed. For Newtonian fluids, viscosity is constant over any shear region. The viscosity is expressed in the universal system of units is represented in Pascal seconds (Pa = sec) (SI: 1 Pa = 1000 cP).

3.2.2 Viscosity Behaviors:

1) Plasticity: Rheologically speaking, plastic fluids are more like plastic solids until a certain minimum force is applied to reach the yield point. Gels, suns, ketchup are extreme examples. A very low output point gives good efficiency, but bleeding may be unnecessary. The correct yield point offers the necessary flow without excessive bleeding and lowering. The yield level can be compensated for by both silicone binders and fillers. Polymer chains are directed spontaneously and provide greater flow resistance [10,11].

2) Pseudo plasticity: Pseudo plastic liquids, including rubber carrying products, decrease in viscosity as pressure is added. However, there is no reappearance point the more energy, the more thinning. If the reductions in the shear angle, the viscosity rises at the same time as the force decreases. No hysteresis occurs; in both cases, the shave-shear intensity curve is the same. Pseudoplasty is typically a useful feature of lacquers and inks. But even more important is thixotropy.

3) Thixotropy: The pseudoplasticity case of thixotropy is a special case. However, as the shear strength is decreased, viscosity increases at a lower rate to produce a hysteresis loop. Thixotropy is highly regular and effective. Thixotropy is attributed to drop less house paints. Wet house paints. The paint starts as a medium viscous substance and remains on the brush. For clear smooth use, it quickly drops in viscosity under the shaving tension of the brushing. As shearing stops, the switch to normal viscosity avoids decreases and shrinkages [12-14].

4) Dilatancy: Liquids with a rise in viscosity are considered dilatants when shears are added. The property is owned by very few liquids. The action of a dilatant cannot be confused for the normal viscosity building occurring when solvent is lost inks and coverings. A starting solvent-borne coating added by a rolling layer shows a rise in viscosity as the run goes on the roller serves as a base [15-17].

5) Rheoplexy: Rheoplexy is exactly the opposite of thixotropy, looking more like a disorder than an inheritance. It is the timely dilatant process where shear thickening is induced by the mixing. Fortunately, Rheoplexy is rare, because it is completely ineffective as a feature of screen printing inks.

3.2.3 Effect of Temperature and Solvent on viscosity:

Temperature is heavily influenced by viscosity. At the same temperature (normally 23°C) tests must be carried out. Without a temperature ranking, a viscosity value is insufficient. Although a change in temperature influences each substance differently, the difference per degree for a particular matter is normally constant. There is a completely different topic of temperature effects. It is important to point out that heating will minimize the viscosity of a surface, a concept used in many applications for coating systems. Lower resin solids give higher viscosity solutions, thus incorporating solvents decreases viscosity [18]. The viscosity variations in soluble resins (polymers) are much more noticeable than insoluble pigments or plastic particles, it is important to note. For example, plastisol suspension i.e. fluid plastic particles may have medium viscosity of 80% of solids, although a coating may be extremely viscous at 50%. Specific solvents can decrease viscosity by various levels based on whether actual solvents, latent solvents, or non-solvents are involved [19].

3.2.4 Measurement of Viscosity of coating Paints:

There are several techniques of viscosity measurements systems. A rheometer can calculate viscosities accurately through a variety of shear stresses. In the plastic decorating sector, somewhat simplified technology is usually utilized. As previously stated, the Brookfield viscometer may well be the most common instrument, in which a power engine is connected to a tensiometer immersion spindle. In the liquid

to be weighed the spindle is rotated the higher the viscosity (flow resistance), the greater the test on the tensiometer. There are different spindle diameters and a variety of rotational velocities can be chosen. Viscosity and spindle scale, rotational velocity and temperature should be registered.

Viscosity Flow cup method used the calculation of strength in paints, oils, and varnishes and similar products are constructed of anodized aluminum, with a stainless steel orifice. The viscosity of the film is usually expressed in a flow time per seconds.

Figure 3.2: Flow cup method viscometer

Steps used to measure the viscosity of the paint:

With the reference to the respective national standard following steps are involved for measuring the viscosity of the coating paints;

1. Choose the appropriate cup.
2. Make sure no bubbles or particles are in the fluid of the test.
3. Seal cup openers (usually a finger) and fill in the fluid with check fluids, raise the surface of the fluid with scraper.
4. Breakpoint technique-remove finger from the opening and simultaneous lift the fluid at the correct tempering (or use the measure of the temperature / viscosity of the cup and fluid. The timer ends at the first pause.
5. This time lapse is the' flow-time' of the trial fluid.
6. Replace-volume-proceed as above however stop time when a 50 mL measurement flask has been moved.

3.3 Paint Gauge:

An electronic device, which calculates the difference between the body panel and the sensor, is a paint thickness gage that is often abbreviated as PTG. In this way, the paint thickness can be measured. For the calculation of the thickness of dry paint material, a surface thickness scale also called color meter is used. The driest thickness of films is probably due to its effect on surface, consistency and costs the most important metric in the coating industry. Dry film thickness checks can be used to determine the expected life, quality and consistency of the surface, and to insure that a range of international standards are followed.

3.3.1 Working of Paint gauge:

The thickness gauge is fitted with a sensor which is attached from the bottom or linked with the unit via a cable. The sensor is mounted on the panel surface you want to test. Our position it on the top perpendicular, the tool tests the distance below the paint on the sensor from the body plate the thickness of the paint is this size.

For example the display shows 2000 μm for the total thickness of the paint at 0.2 cm (0.08 inch) because this is the gap under the paint from the sensor to the body plate.

3.3.2 Need for a paint thickness gauge:

It realizes how much paint you have to play with when you polish a place. You extract paint by polishing, so you always get a very fine layer of paint when a car gets cleaned. Removal means either you can pass through a clear coat which can cause the colored coat to be oxidized, or you can even go through the colored coat. You should, for instance, weigh 150µm thicknesses and subtract 3µm once you polish it; you realize that you are a long distance away from the bottom. In theoretical terms, the paint consists of a pigment, a colored coat and a plain mask. It was then necessary to split 150µm into three 50µm layers. It ensures that the coating can be painted 16.5 times until you remove the transparent coat.

There are two techniques can be used to calculate dry paint film thickness gauge: Destructive Thickness Measurement and Non-destructive Thickness Measurement. The measuring the destructive thickness of the coating by way of the blade, and non-destructive measurements of the thickness of the coating, utilizing methods without harming the coating or substrata, such as the electrical, magnetic induction and the calculation of the thickness of the eddy current.

Figure 3.3: Destructive Thickness Measurement

Measurement of non-destructive coating thickness on magnetic steel structures or on non-magnetic metal surfacing such as stone or aluminium can be carried out. Digital thickness coating gages are suitable to calculate the thickness of the coating on metallic devices. In non-magnetic laminations of ferrous substrates such as steel, electromagnetic induction is used while the concept of eddy current is used for not performing lacquers on non-ferrous metal substrates.

Figure 3.4: Non-destructive Thickness Measurement

3.3.3 Coating Thickness Gauge Adjustment:

Adjustment is the process by which the coating gage can be set up according to the circumstances of the job at hand. The modification can be rendered at a high temperate or in the midst of a stray Magnetic Feld in relation to the material differences, form and surface finish. The resultant errors are given by changing the thickness predictor to these prevailing conditions [20]

3.4 Hardness Equipment:

Hardness is described as the material's ability to withstand penetration or abrasion of other materials. Specific measurements that vary from the methodology and importance of hardness can be carried out in conjunction with this description. The determination of the hammer's bouncement falling from a set height to the substance is determined by the strength of the rebound, indentation and scrape. The indentation toughness is calculated depending on the size of an indent left by the indenter.

Rockwell's hardness checks method:

The research system Rockwell is the most widely used hardness check process, because it is easy to use and more reliable than other forms. Both products are to be used by Rockwell except in those cases where the composition of the product or surface conditions contributes to too many variances or if the sample size or form

prevents the use of the indentations.

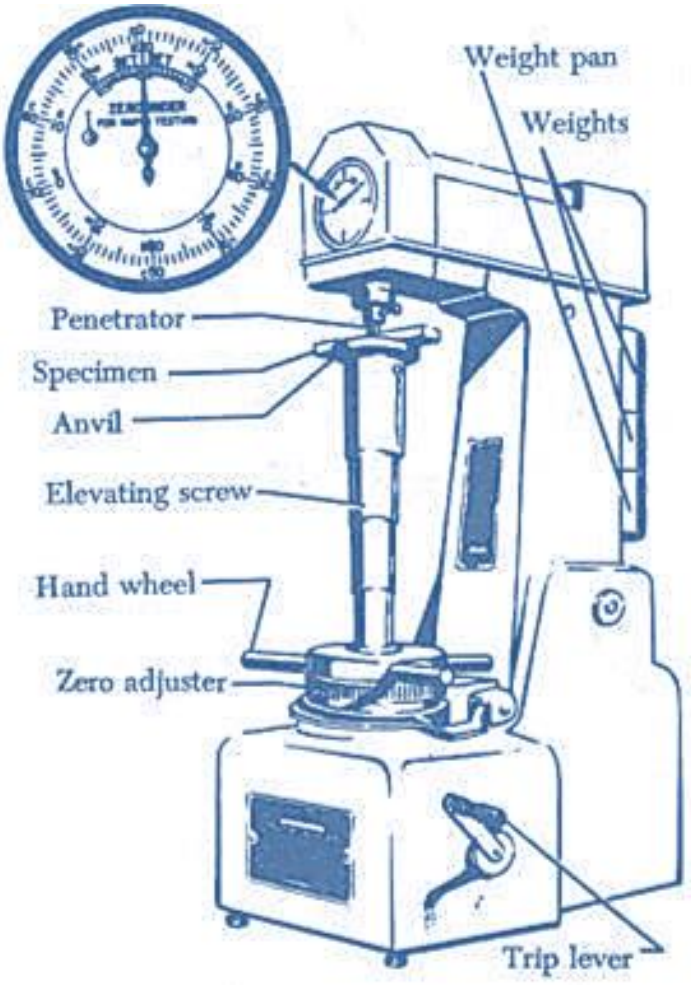

Figure 3.5: Rockwell's hardness checks instrument

The hardness test in Rockwell tests the indentation depth provided by the preliminary and final test powers. Firstly, there is a preliminary test force; this is the nil or the point of reference. A further test force to arrive at the required minimum test force is then added. This additional force is maintained and released for a predetermined period, but the preliminary test force is still in use. The indenter enters the final position at the preliminary force and is weighed and translated to a hardness number for the gap from the main load position.

Characteristics of hardness:

Hardness can be characterized as the resistance of the material to continuous deformation. Hardness tests can be used in the coating industry to assess the rubbing strength of the sheet against general wear and tear as well as the complete curing of the product. There are different methods for measuring toughness, based on the specifications. The features of some are coatings, and the processing of bulk products, including stones, fibers, rubber, or elastomers, are better suited.

Scratching Resistance: A number of different devices can be used to assess surface resistance: pencil hardness tester (Wolff-Wilborn), sclerometer, Clemen clothing, scratch and shaving tool.

Indentation resistance: Most tools are essential for the measurement of penetration resistance. There are three common methods for coatings in particular where the penetration depth of a weighted device is used as a measure of the coating's penetration resistance: Buchholz, Barcol, and Shore.

Pendulum Strength Test: The pendulum test is another way of determining the strength of a surface or base. The definition of friction is related to the pendulum system (PersozandKonig). Basically, two ball bearings hold a fixed weight pendulum on the coated surface. The harder the layer, the more the covers fall into or cover the floor [21].

Coating Hardness Tester:

Hardness surface hardness is the strength of a product to a mechanical force such as friction, scraping or scratching. Depending on the final application, there are many hardness measuring devices available. Toughness testing equipment can be a fixed indentation toughness tool for an inexpensive scratch check. The right tool relies on the final application of the coating and the degree of precision required in the test results.

3.5 Drying Equipment:

Drying devices for paints and painting require low downtime, do not require frequent washing and are not subject to expensive lamps. Throughout recent years, various forms of coatings have been launched on the market. Therefore, the market

for these coated products increases so exponentially that the supply of coating lines will continually increase. If the resin or binder is said to be convertible, it undergoes some sort of chemical reaction to make it into solid film. If the resin is non-convertible, then only the paint's solvent evaporation induces drying and results in the desired film. Some coatings are cured by a method that can be regulated, such as baking, providing an opportunity to capture and recycle overspray.

Drying Time: A paint film converts from a wet film to a dry film through the mechanism of solvent evaporation and also through a chemical reaction among its constituents for two part air drying systems. Throughout transition, it undergoes many structural changes. This drying method has been categorized into eight forms of dry-to-touch, tack-free, hard-dry, print-free, etc. By providing the values of all the properties as mentioned above, the WFT can be tracked during operation to achieve the final correct DFT using the following relationship:

$$\text{DFT} = \text{WFT} \times \text{Volume solids value in fraction} \qquad (3.2)$$

By monitoring the WFT, all potential factors can be controlled and many hypothetical problems can be prevented.

3.6 Federal Test Method 141:

The regulation is provided according to the Federal Property and Administration Service Act of 1949 as modified, and its requirement to buy the above goods is compulsory on all Federal agencies. Scope of this standard elaborates methods for determining the physical and chemical properties of paint, lacquer, and related materials. The aim of this guideline is to create standardized test methodologies and eliminate unnecessary or unintended differences in test results while determining conformity of a commodity to design specifications. If any specification involves some alteration or adjustment of the methods defined in this manual, the procedures specified in the specification must proceed. The discrepancy between this standard and any specification will be settled for implementation.

3.7 Antimicrobial and Antifungal Activity:

Microbial infections are now a major clinical threat with substantial related morbidity and mortality mainly due to the emergence of microbial tolerance to current antimicrobial agents. Methods for measuring antimicrobial susceptibility and finding novel antimicrobial agents have been widely used and continue to be developed. The CLSI and EUCAST subjected several procedures to standardization, identifying the significant steps in this area. Studying the antimicrobial capability of these new materials could exponentially increase their future bioengineering applicability, rendering it necessary. We present an easy-to-follow protocol to quantify such new advanced materials antimicrobial activity. Crucial conditions in hygiene-critical settings such as hospitals, classrooms, care homes and food production facilities are known to host pathogenic bacteria and other microbes for extended periods of time; the H1N1 micro biome in particular is documented to live on surfaces up to 24 hours. Combined with the increased prevalence of antibiotic resistance and evidence that cleaning agents have a reduced impact on microbial invasion, this is why leading global brands switch to BioCote to support the development of tested and efficient antimicrobial paints and coatings that can be applied to specific contact surfaces in these areas, such as flooring, elevator buttons. The scientifically proven antimicrobial technologies will provide permanent and effective protection against harmful bacteria, mold, fungus and viruses by up to 99.99 percent, effectively helping to reduce staining, unpleasant odors and environmental deterioration on any surface to which it is applied. When mixed with your paints or coatings, our antimicrobial silver ion solution will not leech, discolor or damage the final finish. We also have data to prove that BioCote's antimicrobial paint additive will last for the paints or coatings ' expected lifetime, making them more resilient.

Figure 3.6: Experimental setup of antimicrobial activity

Continuous nanotechnology-driven innovation and product development is becoming a very common phenomenon across industry to develop new, better-performing goods for the consumer. One of the common problems in various industries is microbial surface invasion, resulting in biofilm formation. Biofilm forming on polymer surfaces can inflict structural damage and is a health hazard in biomedical devices. Spreading pathogens from the accumulation of biofilms on medical devices remains a concern in the healthcare industry. Scientists explored various approaches to reduce surface biofilm formation. Approaches include embedding antimicrobial agents into surfaces or changing surface morphology and characteristic to either delay or inhibit the formation of biofilms. Many tests are designed to validate the effectiveness of such products.

3.7.1 Methods for Determining Anti-microbial Activity:

There are presently three different screening procedures available for the identification of antimicrobial activity of natural materials, including biologics, dissemination and dilution. The methods of bioautography or diffusion are classified as qualitative approaches since they merely provide an idea of the presence or absence of antimicrobial compounds. Dilution techniques are, nevertheless, regarded to be quantitative tests once the minimum inhibitory concentration is determined.

Minimum inhibitory concentration (MIC) determination:

A microdilution approach utilizing two distinct culture medium were used to study the antibacterial activity of natural products: the Broth Mueller-Hinton and Luria Bertania (LB). As stated before, the inoculums were prepared. DMSO (10% of the final volume) and diluted with crop broth at a concentration of 2 mg/mL Natural products were diluted. Serial dilutions were performed by addition of culture broth to reach concentrations ranging.

Time killing assay:

In order to investigate the activity of an antimicrobial agent against a bacterial strain over time, the Time-kill kinetics test is performed. This assay may establish whether an agent is bactericidal or bacteriostatic in nature over time.

Static and Cidal nature:

Here, it is essential to clarify two definitions. Firstly, minimum inhibitory concentration (MIC) in particular medium at a certain temperature and at certain carbon dioxide content is determined to prevent observable bacterial growth at 24 hours of growth. Second, a medication concentrate that reduces bacterial density 1000 times in 24 hours, under the same special circumstances, is a minimum bactericidal concentration (MBC). A bactericidal antibiotic formally defined as a ratio of MBC to MIC is < 4, while a bacteriostatic drug has a ratio of MBC to MIC > 4. So, antibiotics that reduce bacterial density by more than 1000 yet accomplish this at a concentration 8 times over the MIC of the drug, despite the fact that the medication obviously kills the bacteria, are regarded to be bacteriostatic. Similarly, an antibiotic that reduces bacterial density by a 10- or 500-fold concentration over the MIC is classified as bacteriostatic, while its killing skills are remarkable. All antibiotics that are considered bacteriostatic kill bacteria in vitro at concentrations well above their MICs.

3.7.2 Methods for Determining Anti-fungal Activity:

In consideration of the confusing problems and variables described above for the bactericidal study, it would be well informed for those involved in conducting fungicidal experiments to resolve parallel issues in the research of yeasts and molds.

It is clearly impossible to avoid the technical issues of inoculum size and growth phase, insufficient testing agent contacts, drug transmission, transfer of volume and

medium selection [22-24]. Biological issues such as paradoxical effects, persistence and tolerance to phenotypes are equally important for fungicide tests as for bactericidal testing (see above). The so-called post-antibacterial or anti-fungal effect (PAE, PAFE) [25-29] is another biological problem which can influence the fungicidal and bactericidal research. In order to detect slower-growing but not dead species, agents that have PAE or PAFE require extensive incubation after subculture in either time-kill or MLC determination [33]. Slower rate of growth, morphological changes or complexity of the test agent unicellular yeast vs. multicellular mould and, to certain degree, stability and solubility of the testing agent are further issues unique to mycological research.

3.7.3 In Vitro Methods for Determining Bactericidal and Fungicidal Activity for Antifungal Agents against Yeasts and Moulds:

The effort to develop systematic methods for time-killing and low fungicidal concentration (MFC- MLC) detections for specific anti-fungal agents has begun to show that by using a common procedure various laboratory will conduct and evaluate all styles accurate In vitro methods for determine ring the fungicidal action of antifungal agents. These approaches should be closely examined to ensure known technical and biological variables are addressed. In fact, a significant effort must be made to make sure that in animal infection models; at least in vitro-classified agents do indeed have specific organism target species. There is no guarantee, although these criteria are satisfied, that these in vitro experiments are potentially clinically beneficial. Just as with bactericidal studies, these examinations are likely to have a very limited role in the diagnosis of fungal infection patients.

3.7.4 Agar disk-diffusion method:

The Agar disk diffusion test, developed in 1940[31], is the official method used for routine antimicrobial susceptibility testing in numerous clinical microbiology laboratories. The Clinical and Laboratorial Standards Institute (CLSI) for Bacteria and Yeasts Testing [32,33] publishes now many agreed and validated standards. Agar plates with a uniform inoculum of the research microorganism are inoculated in this popular technique. Filtering paper disks approximately 6 mm in diameter, including

the test material, are then mounted on the agar surface at the required concentration. In optimal circumstances, the Petri dishes are incubated. In addition, the antimicrobial agent diffuses into the agar and prevents germination and microorganism development and tests the diameters of inhibition regions. The CLSI requirements include growth medium, temperature, incubation period, and inoculum size. The disk diffusion method however provides numerous advantages over other approaches: flexibility, low cost, the potential to check a large amount of micro-organisms and antimicrobial agents and facility for the analysis of the tests. Therefore, multiple reports have shown a high level of interest in patients with resistant antibiotic bacterial infections [34].

3.7.5 Zone of Inhibition Test for Antimicrobial Activity:

A Zone of Inhibition Test is a qualitative method used clinically to measure antibiotic resistance and industrially to test the ability of solids and textiles to inhibit microbial growth. Scientists designing antimicrobial textiles, fabrics, and liquids use this tool to quickly and easily quantify and evaluate rates of inhibitory activity. Approximately one million cells of a single strain are spread over an agar plate using a sterile swab, then incubated in the presence of the antimicrobial object. If the bacterial or fungal strain is sensitive to antimicrobial agent, an inhibition region occurs on the agar plate,

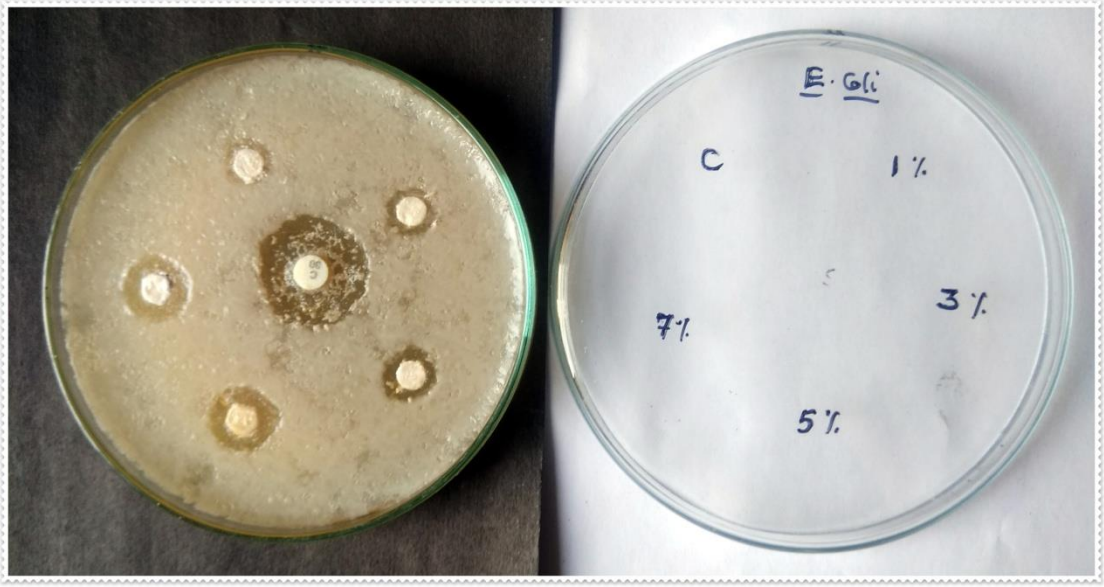

Figure 3.7: Antimicrobial zone of inhibition of sample surfaces

Area of Inhibition Testing is a quick, qualitative means of measuring antimicrobial agent's capacity to inhibit microorganism development. In the field of antimicrobial substances or surfaces, the degree to which these compounds are inhibitory can be critical to public safety. This check is an excellent methodological way antimicrobial surface or substance manufacturers will evaluate their drug inhibition rates. In this point of view here the researcher has been used diffusion methods in agar gel broth with the fungal strains for 28 days observations in dry and wet conditions.

3.8 Spectrometric method:

The first named "The Diode array benefit of UV / Visible Spectroscopy" was published in 1988. Though spectrophotometers of the diode series were on the market from 1979, their features and advantages were not well known compared to conventional spectrophotometers. The UV-Visibility Spectrophotometer has developed into one of the most commonly used instruments in modern scientific laboratories since its invention in the 1950s.

3.8.1 Basic Principle of UV-Visible Spectrophotometry:

The spectroscopy of UV-Visible is an effective method for qualitative as well as quantitative analysis of organic and inorganic compounds. UV-Visible Spectroscopy is based on the Lambert-Beer theorem which states, when the wavelength of the incidence of light stays constant, that the absorption of a (A) solution is directly proportional to its duration (1) and its concentration (C).

The Spectroquant Pharo 100 spectrophotometer is ideal for all daily tests and for specific use in the visible range, with a wavelength spectrum varying from 320 to 1100 nm which is used for testing of the paint samples with the different proportions. The Pharo 100 is a perfect photometer with common uses, together with the fingerprint scanning system and AQA assistance and documentation.

Figure 3.8: Spectroquant pharo 100 spectrophotometer

3.8.2 Photocatalytic Activities:

The worrisome rise in antibiotic resistance among microbial pathogens requires the development of novel antimicrobial methods that are not impacted by, or even induce, resistance. One such method is light-mediated photoinactivation, which uses the whole spectrum of light to kill a wide range of microorganisms. Many of these photoinactivation methods depend on a wide variety of nanoparticles and nanostructures with dimensions that are extremely close to the wavelength of light. Photodynamic inactivation is based on the photochemical generation of singlet oxygen by photosensitizing dyes, which may be greatly aided by formulation in nanoparticle-based drug delivery vehicles. Fullerenes are a closed-cage carbon allotrope nanoparticle with a high triplet yield and absorption coefficient. Their photochemistry is extremely reliant on their microenvironment, and they may be type-2 in organic solvents but type-1 in biological environments. Titanium dioxide nanoparticles in paint function as a broad band-gap semiconductor that may carry out photo-induced electron transfer and generate reactive oxygen species that destroy microbial cells when exposed to UV light.

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CHAPTER - 4

CHAPTER – 4

PREPARATION OF PAINTS FOR SURFACE COATING

4.1 Introduction:

Unfortunately, the general public has a negative image of paints because organic solvents are released into the environment by applying solvent-borne paints. Historically, most architectural or defensive colors are solvent-borne. In this segment, we would like to remedy this negative image by explaining the emission-reducing steps taken to improve the efficiency of coatings in environmental safety. The review is designed for general audiences concerned in the successful use of different types of paints and general production techniques. American coating association describes paint as a collection of emulsions composed mainly of liquid pigments. Paint is one of life's essential components. Use color, citizens will talk and even establish the law of community. Some paints are negative in terms of pollution from sunlight vents. Measures that are not recorded in the mass media for lower solvent emission levels such as waterborne paints and powder coating, the public debate on so-called future or key technologies, in particular information technologies and biotechnology, is widespread. Nanotechnology in this context has recently been mentioned. In this public debate, words such as Future Technology and Key Technology and disparate coating technology have a positive image.

A nano-technological sub-area includes nano-particles that are 100 nm or smaller in diameter. Coating experts pick up their concentrations as many pigments and fillers disperse are nanoparticles unaccompanied. Long-established paint raw materials are now known as nano-particles, such as black carbon and pyrogenic (fumed) silica [1, 2]. Furthermore, nano-structures created new innovative ideas for the science of coating. A recent example of nano-scale silica being chemical integrated into painted resins [3] and the processing of metals by nano-structured silica layers [4] is the product of sol-gel methods, both of which shape a nano-structure [5]. There is a recent study of the use of nano-materials in coatings [6]. In conclude, there are many relations between nanotechnology and coating technology. Paintings and coatings are high-tech products and a greater general awareness of these aspects should be given to

their public image.

This chapter would primarily describe a surface coating paint production process and a description between two different paint styles. The chapter will also display a basic history of paint use, paint production, and each paint item. The paint used since ancient times, 30,000 years ago. Ancestor used paints to capture their lives, interact and decorate their objects. During the Industrial Revolution era, the paint and coatings industry was extraordinarily established for mass production. Particularly in the mid-1880s, U.S. paint factories and their industry began to grow. Different sectors used the paints; homes, aircraft, cars, bottles, furniture, etc. Since the paint is an organic and chemically complicated substance, some of the paint components harm people. Actually, lead pigments were reduced and finally removed for safety in the house painting.

4.2 Types and Methods for Preparation of Paint:

A) Oil Based Paint:

Solvent-based or oil-based paints are a bit trickier to describe, as this is a very generic term that often encompasses items that are not simply "solvent-based." Nevertheless, without splitting hairs, solvent-based paints involve a form of solvent and are typically more difficult to deal with and higher in odor. Ensuring the right thinner is used to dilute the liquid is necessary to guarantee efficiency. Flammability and the environmental impact often led to preferring a solvent-based product, but they can provide benefits in lower temperatures and projects involving chemical tolerance or accelerated healing times [7]. Oil-based paints are sticky to the surface of the objects they are added on. So, upon adding it, the color tightly keeps its shape and doesn't quickly change it. Comparatively, oil-based paints are hard to handle: add, dispose, and maintain. Oil-based chemicals are hard to apply and have minimal use; new masonry and galvanized iron cannot be used. Therefore, drying takes at least one day. Since the paints are oil-based, it requires paint thinner and should not be poured to the drain for removal. Also, problems arise when oil-based paints are oxidized because oxidized paint cracks and becomes brittle. This paint is often used for house painting. These are paints that can be categorized as the drying processes primarily solvent evaporation, oxidation, or some chemical reaction. Gloss paints, which dry mainly

through solvent evaporation, react to the vehicle's fairly hard resin. Paints drying by oxidation, the car are typically oil or oil-based varnish, which usually contain driers to improve paint drying. Paint based mainly on oil with appropriate pigment such as titanium dioxide, extenders, and typically zinc oxide and white lead, are typical outside house paints as these ingredients provide the mixture properties that meet this requirement [8].

Advantages of oil-based paint coatings:

a) Oil-based coating benefits are very robust and more resilient to low temperatures than latex.
b) Oil paint better cover minor imperfections or slightly damaged regions.
c) Application is smooth, providing great coverage. A second coat may not be needed.
d) Oil-based paint can be applied to stained and/or dirty surfaces.
e) When the oil paint is dried, the color, texture or finish is not substantially changed. It makes it easier for the artists, compared to other paints (like aquarelle) that can change appearance after drying, to determine what the finished creation will look like.
f) Some experts say oil-based paint is much more color-rich than water-based paints.
g) Oil colours, which are more freely layered or mixed than other colours, include watercolour, acrylic and other colors, offer a wide range of colours. The richness and tone of their colors can subtly be modified for example by adding minutes of other colours. Partly because oil paints need to dry longer.
h) Specifications for finishes and results of oil paints may be blended in order to look invisible, translucent, or anywhere between and have a matt or light finish or anything.

Disadvantages of oil-based paint coatings:

a) Oil-based Paint disadvantages are very hard to clean after painting.
b) To wash brushes and rollers (as well as your hands) from oil-based paint, use a cleaner such as turpentine or paint thinner.

c) This takes a long time to dry (about 8-24 hours for linseed, and 4-6 hours for alkyd) so you may not be able to apply a second coat that same day. Check manufacturer's directions.
d) Cannot use on raw masonry or drywall without initially adding an appropriate primer.
e) Contains high levels of VOC (Volatile Organic Compound), organic chemical compounds with high enough vapor pressure under normal conditions to vaporize and enter the atmosphere significantly, causing smog and other air quality problems.
f) Gives a strong, unpleasant VOC odor. When applying oil-based paint, wear a mask and ensure proper ventilation [9]

B) Water Based Paint:

Water-based latex paints are commonly used for everyone regardless of painting skills. Users should wall the colors and quickly clean the remainder of the room. Furthermore, latex paints offer excellent durability; the pigment doesn't quickly fade away, and the coating is durable enough to prevent cracking. Latex paints favor internal paint-application. People paint walls, floors, furniture, fences, products, and more; paint is a vital tool for surface color, texture, and protection for a designer. When paint is so necessary and widely used, why do so few learn about it? Many people know very little about their goods how they operate and where they come from and they have much more items than people realize. Absolutely, somebody might realize that her paint is latex, but does she know what else the product is made of, and what are the components that make up the paint, and where are the components that make up the paint? Things such as paint have become so complicated that, even after hours of research, one may not be able to find all this knowledge on them, so consumers cannot spend days studying any product in order to make informed purchases. Despite restricting the paint category to only white latex paints used in interiors, the raw materials are still part of a global system of mining and processing. The knowledge system, though, became unraveled enough to uncover the most common white latex paint products mainly used in interiors and where they originate [10].

Water-based paints can cover a variety of techniques and possessions, but in its simplest form it implies the substance was made using water as its' solvent.' Water-based paints can be thinned and washed (if required/specified) with hot, cold water. Therein is a small advantage, as you will never be caught short of thinner / cleaner and most of all effectively safe! Like solvent-based paints, water-based products can include epoxies, polyurethane, acrylics, etc. These are generally safer to use and less toxic than solvent-based products.

Types of Waterborne Paint Coatings:

Below are some of the different types of waterborne coatings on the market today:

Water-soluble paints: contain water-soluble resins, whose individual molecules dissolve completely in water. The resins are usually produced in an organic medium through poly-condensation or polymerization reactions, so they often contain organic co-solvents such as alcohols, glycol ethers or other water-soluble or miscible solvents containing oxygen. The resins used include polyesters, polyacrylates, alkyds and epoxy esters. Such paints have a high gloss, moderate corrosion protection, strong pigmentation, wetting, and stabilization.

Water-dispersible paints or colloidal coatings*:* contain small fragments of insoluble resin pieces, trapped through mechanical agitation in water. Small quantities of organic solvents are used as coalescing agents on drying. These comprise vinyl propionate copolymers, vinyl acetate copolymers, acrylate-methacrylate copolymers, and styrene-butadiene copolymers and polymers. Colloidal dispersions are used to coat porous materials.

Emulsions or latex paints: similar to water-dispersible paints. The main difference is that resin clusters in emulsions appear to be bigger, allowing an emulsifier to hold clusters in suspension. Resins used include copolymers, acrylics, alkyds, polyvinyl acetate, and polystyrene. Such paints have improved permeability to "breathe," eliminating blistering or peeling. Water-based alkyds coatings tend to take longer to dry than solvent-borne coatings; nevertheless, the end result is close to polish, flow, and leveling. These are very flexible, as almost every viscosity can be thickened with liquid. Water-based alkydes can be used with spray or dip applications and are among the cheaper VOC-compliant coatings [11, 12].

Advantages of water-based paint coatings:

a) We all know that water-based paints use water as solvent to save many resources. It also reduces fire occurrence during construction and reduces environmental pollution. Because it requires only a limited amount of organic, low-toxic alcohol ether solution, this significantly increases environmental conditions.
b) Water-based paint can be applied directly in both dry and wet environments. So water-based paint has a strong ability to use the surface of the wall, so coating adhesion is also very good.
c) The greatest advantage over any other kind of color is the quality of water-based paints. It is less expensive than most other paint types. These paints are in nature environmentally friendly.
d) The water-based paint coating device can be cleaned directly with heat, thereby reducing the amount of washing fluid and also preventing harm to construction workers.
e) Water-based paints are a type of paint that is specially produced in order to dilute with water, rather than turpentine. The water can clean those paints easily. Water-based paints are also used as oil paints, but extraction of water-based paints from brooches and pallets is much simpler while they are still clean [13-15].

Disadvantages of water-based paint coatings:

a) Low drying rate at high humidity.
b) May be more expensive than solvent-borne paints.
c) Limited coating thickness (up to 1.2 minch/30 mkm).
d) Corrosion resistant equipment (tanks, pipes, fittings) is required.
e) Long flash-off times.

Water-based paint defects:

The water-based paint has very high wall cleanliness requirements during the construction process. The principal reason is that the tension on the water surface is wide and the dirt causes the film to decrease.

a) This is therefore troubling that water-based paints can turn corrosive on coating machinery because stainless steel chemicals are needed to be used, and the prices are also therefore very high. Furthermore, the water-based coating is corrosive to the transport tube. When the metal is melted, the scattered particles are pulled and after application, the pitting is made.

b) Yes, water-based paint tolerance is also relatively weak. Since the water-based paint medium is generally between pH 7.5 and pH 8.5, it is easy to hydrolyze the ester bond in the resin, thus degrading the molecule chain which thus affects bathing, bath stability and application function.

4.3 Fundamental of TiO_2:

TiO_2:

Titanium dioxide, also known as titanium (IV) oxide or titania, is the naturally occurring oxide of titanium that is widely used in sunscreens and to cure water. In pigment type, titanium dioxide is also known as pigment white, chlorine dioxide, or Titanium dioxide manganese dioxide is generally extracted from ilmenite, rutile, and anatase as show in figure 4.1. Generated from natural sources, it's a mix of items, such as paint, sunscreen, and food colouring. Titanium dioxide is present in nature in the form of minerals rutile and anatase. Additionally two high-pressure forms are recognized minerals: a monoclinic baddeleyite-like type known as akaogiite, and the other is an orthorhombic α-PbO_2-like form known as brookite, all of which can be located at the ries crater in Bavaria [16-17]. It is primarily sourced from ilmenite rock. The most abundant and visible source of titanium dioxide is found vast deposits in the world. Rutile is the simplest, most common mineral in this rock, and it comprises about 98% (by weight) of titanium dioxide in the format. Titanium dioxide occurs in three respective crystal forms, anatase, rutile, and the new mineral brookite [18]. The most popular minerals are anatase and rutile, since Brookite is unstable. While this form of brookite is not favored, it cannot be used in factories because of its volatility at room temperature. Normally, titanium resides in a thermodynamically stable process. Even, the molybdenum oxide ore can be re-oxidized into rutile after calcination at higher temperature; whereas the anatase process is photo chemically active as opposed to the amblygonite phase. The phase transition often very strongly

balanced energetics to a great degree as a feature of particle size [19]. The two important stages of rutile and anatase are the alpha phase and beta phase.

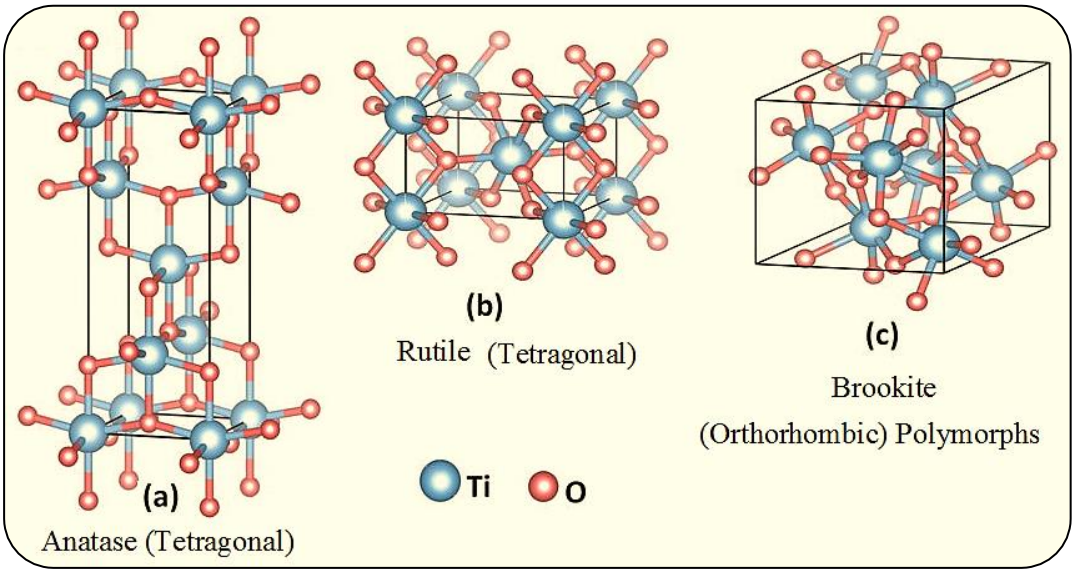

Figure 4.1: Crystal structures of TiO_2

Many of the most significant uses of titanium dioxide are paints and varnishes as well as paper and plastics, which account for around 80% of the world's titanium dioxide use. Many other pigment uses such as printing inks, fabrics, rubber, beauty goods, and food products account for another 8% of the total market. The majority of the material, for instance is used in other uses, for instance in the production of technological pure titanium, glass, plastic glasses, electrical ceramic, metal patinas, catalysts, electric conductors and intermediate chemicals [20]. The most commonly used nanoparticle for inactivating bacteria in water is titanium dioxide. Through the industrial applications, it produces several different materials including: food industry, photo-catalytic media, gas sensor, white pigment paint and cosmetic industry, water treatment, instant coffee, air purification, solar power, UV absorber, semiconductor industry, and agricultural industry. The inactivation of microorganisms rely on a number of variables, such as the titanium dioxide concentration, the type of microorganisms, the light intensity, the wavelength, the degree of hydroxylation, the pH, the temperature, the oxygen provider, and the retention duration.

TiO_2 Nano-Particles:

Even though the titanium dioxide nanoparticles (or titanium) are labeled ultrafine or ultrafine titanium dioxide or nano-crystalline titanium dioxide or microcrystalline titanium dioxide as show in figure 4.2, they are often commonly known as titanium dioxide nanoparticles, a simple way to differentiate between them. Titanium dioxide (used in sunscreens) is a naturally occurring oxide of the metal titanium often referred to as titania. But titanium dioxide may be taken from synthetic sources such as paint. Titanium dioxide nanoparticles investigated by several researchers, and offering an awareness about how the efficacy of nanomaterial such as nano-sized titanium dioxide photo catalysts in photo degradation of a broad variety of organic and inorganic pollutants in water may be. It is assumed that photo catalysis also known as hydrogenating water would become one of the most successful ways of coping with different kinds of sewage and waste water because organic toxins can be fully decomposed under standard conditions of temperature and pressure. Titanium dioxide nanoparticles may also function, in some situations, as a photo catalyst. This implies that they can react with UV light (e.g. sun) to accelerate a photoreaction triggering oxidation of certain biological molecules and creating free radicals. The latter could intensify the toxic effects listed above. Not all particles of titanium dioxide used in cosmetic items possess this property [21].

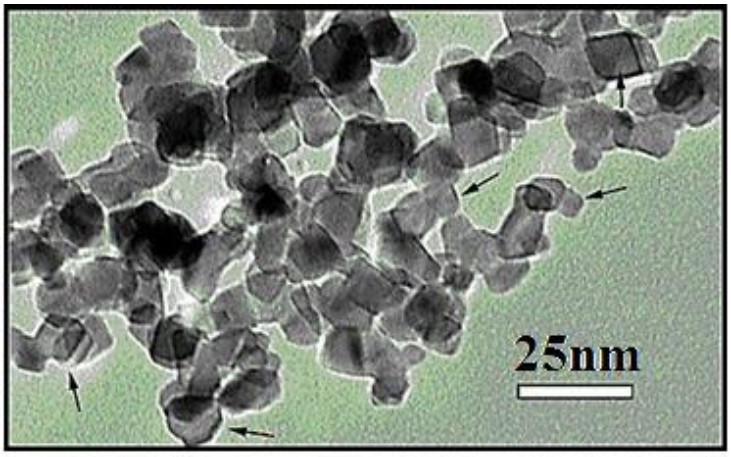

Figure 4.2: Titanium dioxide nanoparticle

Not any research has been performed yet on effects of TiO_2 nanoparticles on health, so more studies are imperative. Recent studies have shown that nanoparticles of titanium oxide can penetrate and accumulate in human intestinal epithelial cells and typical macrophages. In a recent analysis by Ruiz et al. on patients diagnosed with

inflammatory bowel disease between the ages of 18 and 80, a considerably higher titanium content was found in the blood of the IBD patients than was detected in the control group [22]. The alteration of the nanoparticles brought in new properties that culminated in the development of new applications. The findings that I have seen have shown that although the current techniques are successful in generating final nano particulate materials, it is evident that there is still room for creating new nano particulate materials through the alteration of the existing techniques. While the nanoparticles with new properties may be more effective, their toxicities need to be determined initially.

TiO_2 Nano-Composites:

Most studies have been made on titanium dioxide (TiO_2) as an effective photo catalyst for photo activation of bacteria along with a notable free-radical which de-blisters cadmium, mercury, salicylic acid and other toxic pollutants in groundwater and oil. Because of its special features, including becoming a pigment, chemical and possessing physical properties, it will live up to 200 years in a museum [23]. This capacity of decomposing organic material has been extended in photo-inactivation of bacteria from water and air, as well as it may be beneficial to self-cleaning or self-sterilizing surfaces for areas such as the hospital, enabling the usage of such surfaces to be used at room temperature and continuous illumination for sanitation optimization. TiO_2 NPs are photoactive nanomaterial, which implies they have little reactivity in the absence of light. In the Sun's rays, attachment of light-absorption particles, or surface molecules, on the surface of titanium dioxide nano-materials has been a revolutionary choice for solving several problems including photosensitization of bacteria, purification of water, solar energy production and more. For TiO_2 nano-materials to solve this issue, the material needed specific features such as providing a crystalline structure along with an appropriate scale, morphology, and optical properties. A broad band gap can be observed on the TiO_2 nanoparticles, which indicates photo-activity under UV light irradiation. Thus, the photo-catalytic activity of titanium dioxide nanoparticles are rather not involved under sunlight because solar spectrum is comprised of less than 5% UV radiation. The photo-catalytic properties of titanium dioxide particles are based on electronic properties happening within the particles and on the surface of the particles. As a consequence, implanting impurities

into the semiconductor photo catalyst significantly adversely impacts its operation. For those e-cigarettes did not become as common products for supporting smoking, the producers needs to adjust TiO_2 NPs properties from UV active material to visible light active material for enhancing photo-inactivation of bacteria under visible light irradiation [24-27].

4.4 Preparation of Surface Coating Paint:

Every coating substance to be produced must meet specific specifications, i.e. it must satisfy customer requirements (coating, substratum, and surface properties), climate, etc. The skilled paint chemist must accommodate all these different demands, select from the vast number of available raw materials and finally develop a paint formulation. This is mostly done in color laboratories. Therefore, knowing the workflows in an industrial paint laboratory [28] is important. All paint production starts with question declaration. The color solution is then formulated and a sample is produced in the laboratory. A calculation recipe contains all information about the paint components; formulated to yield 100 parts by weight. The calculation recipe usually lists the raw materials: binders, pigments and fillers, additives, solvents. For each volume, a manufacturing method is developed along with additional process information. The output formula describes the raw materials as they are applied. Additional information on paint or surface characteristics, research procedures, and acceptable combinations is standard industrial procedure.

Material and Methods:

The Federal Test Method – Standard 141 Method 6271 (Mildew Resistance) is studied.

Paint Color: White (Sample for 1Liter)

Material Details

Part – I

Paint Color: White **Sample For: 1 Lit**

Sr. No.	Particular	Quantities (gram)
1	TiO_2	0.120
2	Bela	0.006
3	Carbon	0.006
4	Rabine	0.001
5	70%	0.100
6	TT	0.280
7	SOYA	0.03
8	Zink	0.006

Preparation procedure:

For the manufacturing procedure of the surface coating paints in the part one, the above mentioned ingredients in the table with the percentile proportions were mixed in the mixture in the mixing tank and agitated continuously up to two hours which forms uniform mixture.

Part – II

Paint Color: White **Sample For: 1 Lit**

Sr. No.	Particular	Quantities (gram)
1	70%(Resin)	0.580
2	malic	0.100(10%)
3	Aqua	0.500
4	Drier	0.060
5	Degas	0.002
6	Amko 1170	0.002
7	TiO_2	0.020
8	Pain	0.020
9	T.T	0.192

Preparation procedure:

For the manufacturing procedure of the surface coating paints White colour in the part second, the above-mentioned ingredients in the table of part-II with the weight percentile proportions were mixed in the ball mill tank and rotated it for two to three hours that forms the homogeneous mixture of the base paint.

4.5 Preparation of Surface Coating Paint for Health Care:

There are several methods for the preparation of coating paints; here a simple and common blending method in the fabrication of antimicrobial surface coating paints is exercised. It is represented in figure 4.3

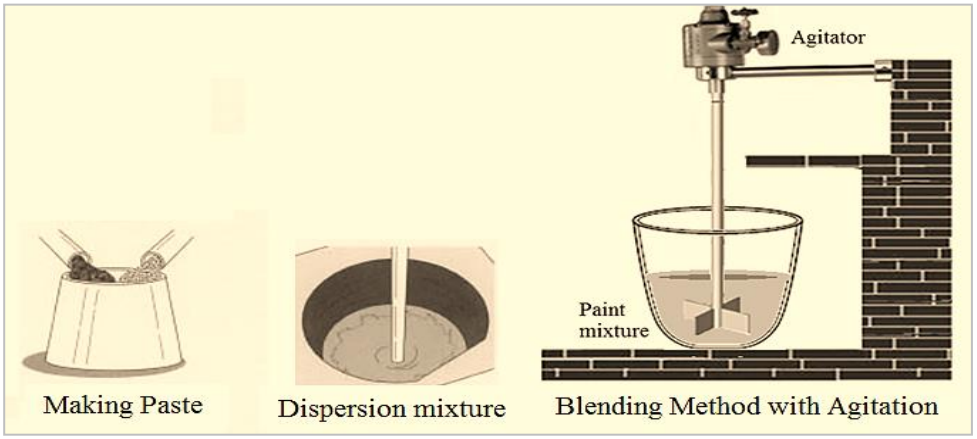

Figure 4.3: Procedure showing blending process

Preparation method of coating paint samples:

Material Method:

White base paint is used for the preparation of the samples, Titanium dioxide (TiO_2) nano particles size 25 nm were purchased from Sigma Aldrich and Turpentine is used for the paint samples. For the preparation of paint samples with TiO_2 was adopted by using online percent solution calculator [29]

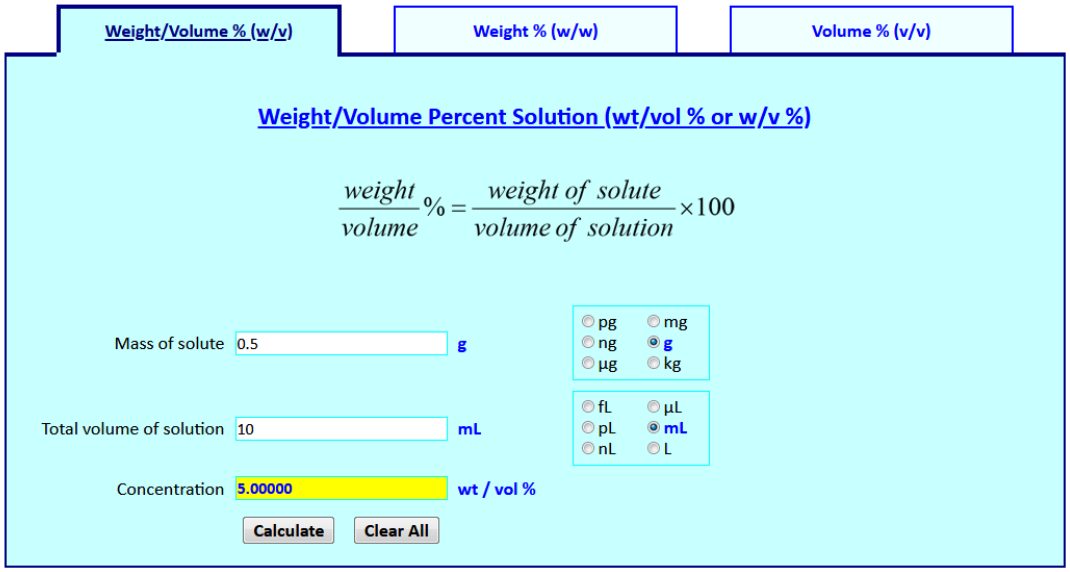

Figure 4.4: Snap shot of online percent solution calculator

It is very common to describe the percentage concentration of solutions. Percent means per 100 parts, where for solutions, part refers to a measure of mass (µg, mg, g, kg, etc.) or volume (µL, mL, L, etc.). In percent solutions, the amount (weight or volume) of a solute is expressed as a percentage of the total solution weight or volume. Percent solutions can take the form of **weight/volume %** (wt/vol % or w/v %), **weight/weight %** (wt/wt % or w/w %), or **volume/volume %** (vol/vol % or v/v %). In each case, the percentage concentration is calculated as the fraction of the weight or volume of the solute related to the total weight or volume of the solution. As percent solutions can be expressed in three ways, it is important to specifically define the form of percent solution. If this information is not provided, the end user is left to "guess" whether w/v %, w/w %, or v/v % was used. Each percent solution is appropriate for a number of different applications.

Experimental Procedure:

There are several methods for preparing coating paints; here the simple and common method for preparing surface coating paint with different proportions is used. In the preparation process dissolved **0.5 g** of Titanium Dioxide (TiO_2) nanoparticles are soaked in 1mL turpentine solution and then mixed with the base paint to a total volume of exactly **10 mL** in order to get the desired concentration of **5% (weight/volume %)**. Total volume refers to the final solution volume (i.e., combined volume of solute and solvent) by using the formula;

$$\frac{\text{weight}}{\text{volume}}\% = \frac{\text{weight of solute}}{\text{volume of solution}} \times 100 \qquad (4.1)$$

Then the whole dispersion mixture was put in to the mixture and blended vigorously with continuous agitation up to 15 to 20 minutes to get uniform samples. By using the above mentioned blending method, similarly 10%, 15%, 20%, 25% and 50% percentile proportions of the titanium dioxide (TiO_2) with the paint samples were prepared.

Table 4.1: Percentile proportion of paint sample with TiO_2 nanoparticle

Samples	Percentile	Weight of TiO_2 in 10 mL base paint
1	Control	Without TiO_2
2	5%	0.5 gram
3	10%	1.0 gram
4	15%	1.5 gram
5	20%	2.0 gram
6	25%	2.5 gram
7	50%	5.0 gram

The prepared samples vials as shown in the fig. 4.5 were sent for the antimicrobial testing against *Aspergillus oryzae* fungal strain.

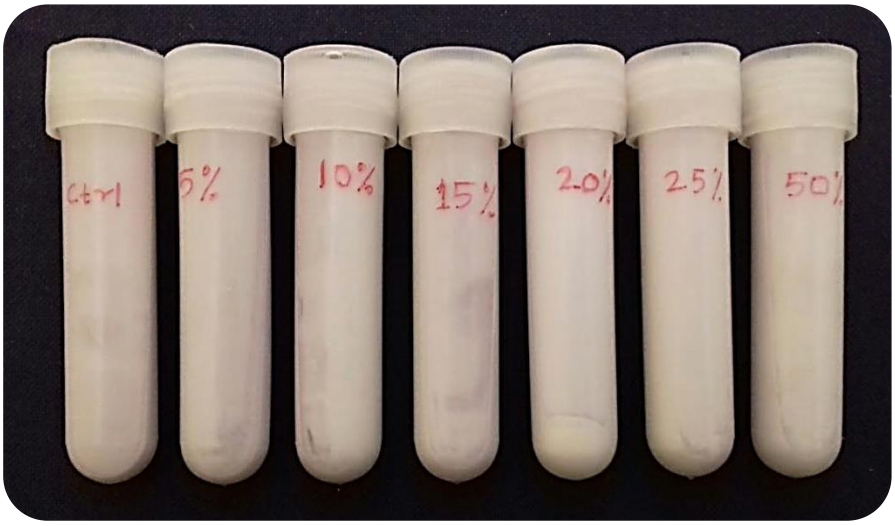

Figure 4.5: Paint samples with **5%, 10%**, **15%**, **20%**, **25%** and **50%** of TiO_2

All the above prepared paint samples were sent to their antimicrobial testing laboratory and tested against the *Federal Test Method Standard 141* Method 6271 (Mildew Resistance) is the agar plate test most frequently referred to in specifications for paints utilized by agencies of the U.S. Government. This method employs sucrose, mineral salts, agar medium, and, in accordance with Federal specifications TT-P-19 (Paint, Acrylic Emulsion: Exterior), *Aspergillus oryzae* is the inoculating organism [30]. After getting the results of all these prepared paint samples, only the 10% paint sample showed moderate activity against *Aspergillus oryzae* at the end of the incubation period. In this regard, the researcher prepared new samples of the concentration with titanium dioxide below the moderate result of the above sample. Therefore **1%**, **3%**, **5%** and **7%** paint samples were prepared by using TiO_2 nanomaterial and send for the same antimicrobial testing against *Aspergillus oryzae* which gave positive results.

Table 4.2: Percentile proportion of paint sample with TiO_2 nanoparticle

Samples	Percentile	Weight of TiO_2 in 10 mL base paint
1	Control	Without TiO_2
2	1%	0.1 gram
3	3%	0.3 gram
4	5%	0.5 gram
5	7%	0.7 gram

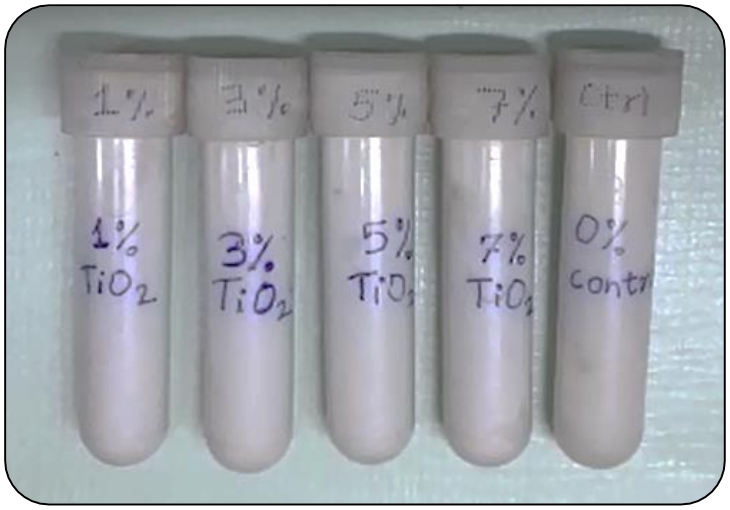

Figure 4.6: Paint samples with 1%, 3%, 5% and 7% of TiO_2

4.6 Effect of Additives on Paint:

Additives are typically used in very limited quantities under 1% of overall formulation, and proper dose is highly necessary for optimal efficacy and also to prevent unnecessary side effects. Test series would assess the dose. Many chemicals may be quickly introduced into the paint method before or during the last manufacturing process. However certain integration criteria must be met in certain situations. Wetting and dispersing chemicals, for example, must still be in the millbase to produce the optimal effects. Ideally, an additive's efficacy can be tested in maximum formulation and in circumstances as similar as practicable to those in use. Testing a defoamer in the binder method, for example, may only be called a preliminary examination, since the actions in the full formulation can vary considerably. Many flaws to be avoided by using chemicals are often affected by the coating substrate and application process. Differences may be defined in basic laboratory experiments. However the final composition of a given formulation must consider as many implementation parameters as practicable. In certain instances, additives impact not only one coating property. They can also have detrimental or positive side-effects. Additives are not 'magical' items, but must be utilized rationally and deliberately to achieve the required acceptable effects. As comprehensive full awareness of the mode of operation of materials, their potential benefits and side effects, their limitations and the root causes of paint defects is definitely useful, but the difficulty of paints and coatings allows scientific knowledge indispensable.

4.6.1 Viscosity of Paint:

Thickeners, primarily derivatives of cellulose or polyacrylate, are usually used in Paints emulsion. Polyurethane thickeners are now a days increasingly used. Rheological additives for solvent-borne systems are commercially viable. Hydrogenated castor oils, pyrogenic silica, modified urea and modified montmorillonite clays are favored. The rheological activity shape three-dimensional network structures by paint hydrogen bonds. These lattice frameworks are broken but rebuilt as the powers are withdrawn. But this healing isn't immediate. Initially, increasing viscosity enables surface levelling but subsequently avoids decay. This time-dependent viscosity transition is called thixotropy in figure 4.7. In paints,

thixotropy is more beneficial than strictly pseudo plastic flow action since it makes a balance between decay and leveling.

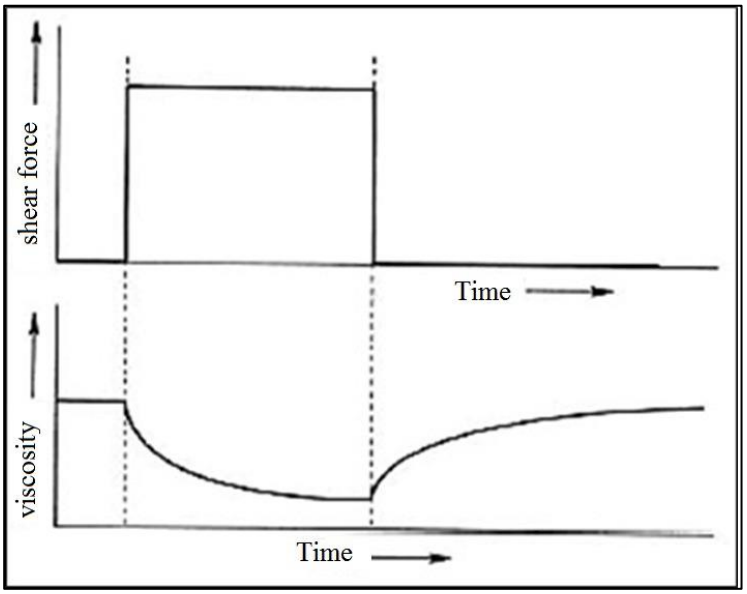

Figure 4.7: Viscosity shear-force-dependent and time-dependent (Thixotropy)

In this research work, the researcher approached the OK Paints and Chemicals Pune – 46 for checking the viscosity of the prepared paint samples, the following procedure was adopted;

Aim: To measure Viscosity of given sample of paint.

Apparatus: Ford cup B - 4 with stand, Stop watch, Thermometer

Raw material: Prepared sample of paint

Procedure:

1) The Ford cup 8-4 should be thoroughly cleaned particularly out let orifice should be free from particles
2) The ford cup to be kept on stand with perfect water level
3) Fill the ford cup by paint completely till it overflows from outer limit
4) One finger should be closed to outlet of ford cup. Remove the finger and start stop watch immediately
5) Stop the stopwatch immediately after complete paint drains from cup
6) Note the time required in seconds.
7) Note also the temp of paint

Viscosity Test Report:

By using the above mentioned standard procedure, the researcher has tested the prepared paint samples for viscosity of paint and test results are plotted in table 4.3.

Table 4.3: Viscosity properties of the paint samples

Paint Sample	Reference range of viscosity test of the paint			Observed result of the paint sample		
	Time in (s)	Temp (°C)	Temp Effect(°C)	Time in (s)	Temp (°C)	Temp Effect(°C)
1% TiO_2	**90**	**30**	**0**	**90**	**30.89**	**1**
	120	**30**	**0**	**180**	**30.89**	**1**
3% TiO_2	**90**	**30**	**0**	**90**	**30.90**	**1**
	120	**30**	**0**	**180**	**30.90**	**1**
5% TiO_2	**90**	**30**	**0**	**90**	**30.90**	**1**
	120	**30**	**0**	**180**	**30.90**	**1**
7% TiO_2	**90**	**30**	**0**	**90**	**30.91**	**1**
	120	**30**	**0**	**180**	**30.91**	**1**

Spray application: 25 s to 30 s

Figure 4.8: Viscosity testing images of paint sample

4.6.2 Gauge and Hardness of Paint:

The gauge instrument is used to determine the paint's gauge. Paint drops are placed in a test area and dragged until the final tooth is reached, at which point the thickness is measured.

Dry paint film thickness is critical for coating results. Thin films can seem the wrong colour, or they may not have the output quality. Water will more quickly infiltrate if the film is too thin. Wet-film thickness for process control is calculated. A portable immersion gauge that has a row of teeth around the edge of varying lengths may be calculated.

Figure. 4.9: Gauge and hardness test of paint sample

The gauge is mounted on the newly painted surface and the gauge surface is protected by two same-length teeth for measuring power. All other teeth vary in length and thinner than control teeth. Wet thickness is determined as the last tooth left in the paint film.

4.6.3 Drying of Paint:

Oil paints have been used for centuries in the painting tradition. Various formulations were used to find paint with the necessary properties. It should dry easily, but not too fast; it should be flexible, but not too flexible; and not yellow. Attempts to maximize

attractive properties in paints have contributed to significant alterations from plain oil and pigment mixture's basic formula. Each modification can have both an immediate impact on the paint's early action and a long-term one that may yield adverse effects. For checking the drying property of the prepared paint samples by using the proper procedure is mentioned below;

Aim: To measure drying time for air drying paints

Apparatus: MS panel Sand paper, Brush/Spray Gun, Cotton

Procedure:

Surface Dry: -Apply paint / primer by spray / brush with appropriate viscosity on a dean MS panel this test is carried out manually move fingertip on painted panel lightly, it does not stick to the finger. Record the time required in min.

Tack Free: - After surface drying press thumb on panel moderately. If thumb marks are not observed on painted panel, the paint has become tack free. Record the time required.

Hard Dry: -. When a painted panel gets complete dry (total curing) the time required is called hard dry time.

Drying Test Report:

By using the above mentioned standard procedure, the researcher has tested the prepared paint samples for drying of paint figure shows dry samples.

Report:

Surface Dry : 4 hours

Tack free Dry: 10 hours

Hard Dry : 24 hours

Figure 4.10: Surface drying of paint sample

Area of paint application: 10 to 12 sq. meter/lit

4.6.4 Weight per Liter of Paint:

Weight per liter of paint is the ratio of mass to volume and it is calculated by following procedure;

Aim: To determine Weight per liter of given sample

Unit: kg/liter

Apparatus: Weight per liter cup (Gallon cup),

Procedure:

1) Clean the cup thoroughly and dry it
2) Weigh the cup accurately (A gram)
3) Pour the material in the cup after ensuring the desired temp.
4) Fix the lid of the cup, wipe out excess material (the material in the cup should be bubble free)
5) Take the weight of the cup and material (B gram)

Figure 4.11: Weight per liter of paint sample

Calculation: Weight / liter B - A / volume of the cup

Result:

Calculated paint volume required per liter: 980 g/lit

It covers area of = 11.76 sq. meter/lit

4.7 Results and Discussion:

The results of altering the proportion of TiO_2 in the prepared samples from 1% to 3%, 5%, and 7% give the following findings.

The standard range of viscosity is 90 to 120 sec at temperature of 30°C but the test sample showed an increase at temperature of 40 sec with rise in temp of 30.91°C.

Apart from the variation in the range of tio2, the gauge test result match with the standard gauge test result which state that it should not exceed 8 microns.

Drying time test result 4 hours on surface dry,10 hours on tack free dry and 24 hours hard dry.

By weight per lit the area of application is 11.76 sq meter/lit which is in the stand range of 10 to 12 sq meter/lit.

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CHAPTER - 5

CHAPTER – 5

ANTIMICROBIAL ACTIVITIES OF COATINGS FOR HEALTH-CARE IN BUILDING

5.1 Introduction:

The medical establishment believed that the war against infectious diseases had been fought with the invention of antibiotics. However, since too many bacteria have developed resistance to multiple antimicrobial agents, the battle seems to have shifted in favour of bacteria. Infectious disorders are a leading cause of morbidity and mortality in the world today. Lower respiratory disorder, diarrheal infections, HIV/AIDS, and malaria are among the top ten contributors to morbidity and mortality, according to a World Health Organization (WHO) estimate. Antimicrobial resistance has greatly increased the impact of infectious diseases, as well as the amount of pathogens and healthcare costs. Despite the fact that we have a huge range of antimicrobial agents from which to select for future infection treatment, antimicrobial resistance has been documented for many of them, and resistance develops quickly when a new medication is approved for usage. The World Health Organization (WHO) launched a Global Action Plan on Antimicrobial Resistance in 2015 in response to these issues [1-2]. Marcus Terentius Varro, a Roman author from over 2,000 years ago, proposed that illness may be caused by tiny animals floating in the air. During construction, he urged citizens to avoid marshy areas because they could hold insects too tiny to see through the naked eye that could reach the body through the mouth and nostrils and trigger diseases. Antonie van Leeuwenhoek, a Dutch physicist, invented a single-lens microscope in the 17^{th} century, with which he observed what he named animalcules, later known as bacteria. He is regarded as the world's first microbiologist. The chemists Louis Pasteur and Robert Koch claimed in the nineteenth century that germs were the source of disease. The Germ Theory was the name given to this concept. Paul Ehrlich, a chemist, announced the invention of the first antibiotic, Salvarsan, in 1910. It was intended to treat syphilis. He was also the first chemist to use stains to identify bacteria. Joshua Lederburg invented the word

"gut microbiome" in 2001, and scientists all over the world are working to define and better grasp the shapes, forms, and functions of "gut flora" or bacteria in the human body [3].

5.2 Environment and Health Care:

The decline of the natural environment in many areas of the globe is starting to impact the health of people. As a consequence, the long-term environmental cost of health care provision must be taken into consideration by health workers and organizations and the material and energy consumption of the healthcare sector reduced [4]. This may be an unexpected result because, despite environmental decreases, the average human health has, in the last several decades, increased mostly. The average life expectancy for children under five has grown rapidly as indicated in the WHO 50th anniversary report [5] more people have than ever had access to minimum care, safe water and sanitation services and medicines. Hospitals use energy in heating, cooling, manufacturing, transport, as with other service industries, such as hotels and restaurants; they are occupied by big, complex buildings with a surface of concrete and asphalt; they use high volume food services, laundry, high speed transport, and paper, packaging, junk supply, etc. The use of drug products and organic products with complex manufacturing processes, environmental and potentially toxic precursors of medicines and complex and dangerous emissions such as solids, air, and water, including toxic, infectious and radioactive waste, also poses special problems associated in the Health care services.

Healthcare engineering should play an increasingly important role because healthcare continues to be one of the largest and fastest growing industries in the world [6], in which engineering is a major advancement factor through the development, development and implementation of state-of-the-art devices, systems and procedures attributed to breakthroughs in the electronics, civil engineering and construction sectors. The healthcare system is regarded as the main profession wherein engineers contribute significantly to human health directly since the need for engineers continues to build up. In virtually every area of engineering, engineers are constantly sought for (e.g., biomedical, chemical, civil, computer, ecological, industrial, information, materials, mechanical, software and systems engineering). It is a

widespread misunderstanding that in health care only engineers with a background in biomedical engineering, clinical engineering or similar areas may work. However, courses and the kind of certificate of programmes are necessary to educate students and practitioners of non-biomedical engineering for health care service. On the other side, health workers (doctors, dentists, nurses, pharmacists, allies, etc.) may profit from training in engineering, problem solving, and healthcare development. They may be able to apply engineering to their practice. As technology is rapidly advancing, continuous education plays a key role in guaranteeing the ongoing competency of healthcare engineering experts.

5.3 Bacteria and Health Care:

According to Jack Gilbert [7], environmental microbiologist with the Argonne National Laboratories and the University of Chicago, who also spoke at the Hill briefing, bacteria, viruses and other single-cell animals are spreading through the environment in a surprising way, helped and encouraged by people who each have their unique microbial assortment. He presented research from his laboratory demonstrating that a person starts to have his or her own microbiological signature on the surfaces of the environment within hours after entering an indoor location. Microbes with high potential for public health impacts contain pipelines that transport our drinking water and waste. In the days after the opening of the hospital the overall microbial diversity grew significantly and was much higher on bedrails, floors and other inanimate surfaces than in people's skin. The researchers proceeded to build an 'epic database' of microbial changes throughout the whole hospital with millions of samples.

Civil and environmental engineers play a critical role in shaping the future in today's complex world: they design, construct, maintain, protect, and repair systems that enable human activity while minimizing our environmental impact. They play a critical role in addressing many of our most urgent issues, and their work has an impact on every area of contemporary life, including housing, food, energy, water, air, transportation, commerce, and leisure, as well as public and environmental health. On exterior building surfaces, bacteria and algae are the main microorganisms. The

pioneering microorganisms have an enhanced area of organic carbon that is required for the development of any succeeding mould. Biodegradation is a synergistic process of chemical reactions and physical impacts on building components of microbiological organisms (biophysical degradation). The article provides an overview of existing art and biodegradation studies [8].

5.3.1 Categories of microorganisms:

There are different kinds of microorganisms but generally they are categorized by bacteria, fungi, protozoa, archaea, algae and viruses as per their structures and habitats. These are described briefly and separately in the figure. 5.1 given below;

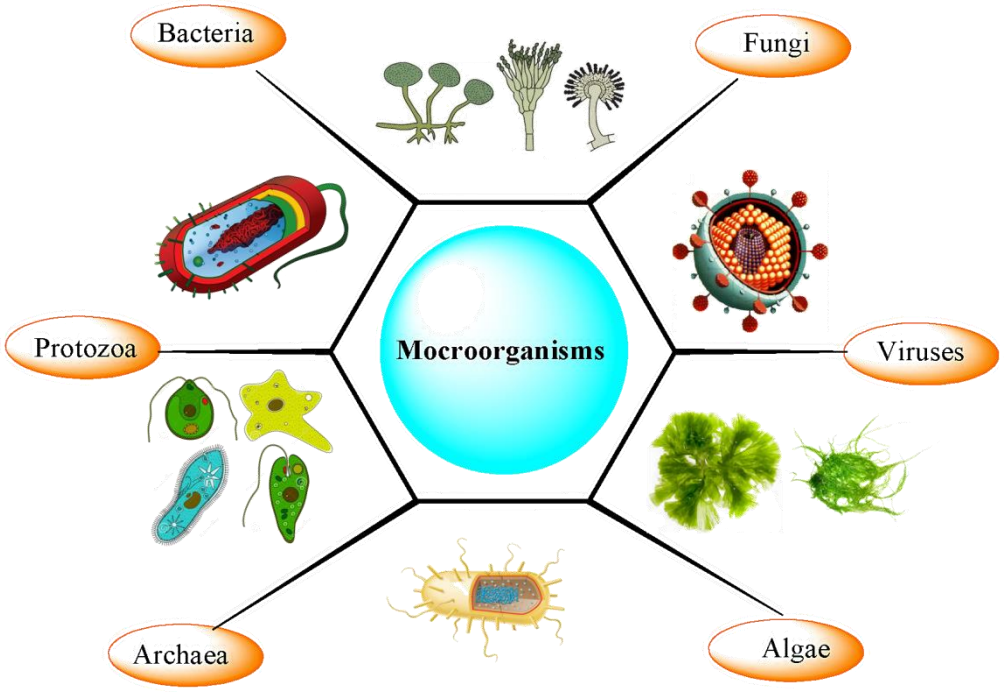


Figure 5.1: Types of microorganisms

Bacteria:

A bacterium is a single unicellular microorganism made up of prokaryotes, which are genetically made up of pre-nuclei. They come in a variety of shapes, including circle, spherical, star, cube, and rod-like structures. They come in the shape of colonies and strings. These bacterial strains get their nutrients from organic compounds, dead

plants and livestock, and certain bacteria may make their own food using sunlight and the photosynthesis mechanism.

5.3.2 Basics of Bacteria:

Bacteria are single-celled species that are just a few micrometers in size and can only be seen by a microscope. Bacteria may construct colonies consisting of hundreds of thousands of cells on certain surfaces; such as agar plates in the laboratory, and therefore be noticeable to the naked eye. *Bacteria are single celled microbes*. Since there is no nucleus or membrane-bound organelles, the cell composition is simpler than that in other species. Instead, their control center, which houses the genetic material, is housed in a single DNA loop. A plasmid is an additional circle of genetic material found in certain bacteria. Genes that offer the bacterium an advantage over other bacteria are often found on the plasmid. It may, for example, have a gene that renders the bacterium immune to a certain antibiotic. The binary fission method is used by bacteria to replicate. The bacterium, which is a single cell, divides into two similar daughter cells during this phase. When a bacterium's DNA breaks into two, binary fission occurs (replicates). After that, the bacterial cell elongates and divides into two daughter cells, one with the same DNA as the parent cell. The parent cell is cloned in each daughter cell.

5.3.3 Classification of Hazardous Bacteria:

Bacteria are divided into five classes based on their simple shapes as show in figure5.2.: circular (cocci), rod (bacilli), spiral (spirilla), comma (vibrios),and corkscrew (corkscrew bacteria) (spirochaetes). They may be single cells, pairs of cells, strings, or clusters. Cocci are bacteria that are formed like a ball, and a coccus is a single bacterium. The streptococcus community, which causes "strep throat," is an example. Bacilli are rod-shaped organisms (singular bacillus). Any bacteria have a curved appearance. This are referred to as vibrio. Bacillus anthracis (B. anthracis), also known as anthrax, is an example of a rod-shaped bacteria. Spirilla is the name given to these spirals (singular spirillus). Spirochetes are organisms that have a very dense coil. Bacteria of this shape induce leptospirosis, Lyme disease, and syphilis.

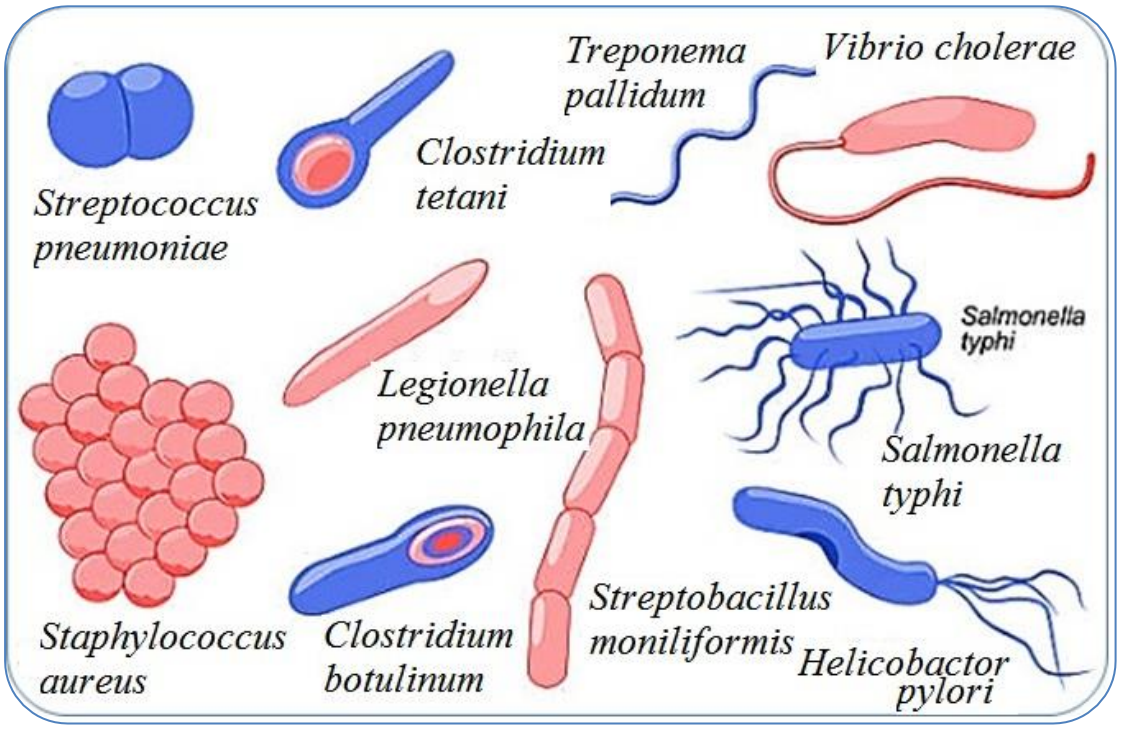


Figure 5.2: Shapes of bacteria

Bacteria can be present in many types of environments on Earth, including land, rock, lakes, and even arctic snow. Any species, like plants and mammals, and humans, survive in or on other organisms. In the human body, there are about ten times as many bacterial cells as there are human cells. Many of these bacterial cells can be contained in the lining of the digestive tract. Bacteria may be found in the soil or on dead plant matter, where they play a significant role in nutrient cycling. Some varieties spoil food and harm crops, while others are essential in the processing of fermented foods like yoghurt and soy sauce. Just a small percentage of bacteria are viruses or diseases that infect livestock and plants. Plant and animal cells are not the same as bacterial cells. Bacteria are prokaryotes, meaning they are devoid of a nucleus. A bacterial cell consists of the following components;

1) Capsule: A coating present on the exterior of certain bacteria's cell walls.

The cell wall is a layer made up of peptidoglycan, a polymer. The bacteria's form is determined by the cell wall. It's found on the edge of the plasma membrane. Gram positive bacteria have a tighter cell wall than Gram negative bacteria.

2) The plasma membrane: It is found inside the cell wall, is responsible for

generating energy and transporting chemicals. Permeability refers to the ability of liquids to flow across the membrane.

3) Cytoplasm: It is a gelatinous fluid that includes genetic material that ribosomes and is only within the plasma membrane.

4) DNA: This is where all of the genetic guidance for the bacterium's growth and operation are stored. It's found inside the cytoplasm.

5) Ribosomes: These are the structures that produce or synthesize proteins. Ribosomes are RNA-rich granules that form a complex particle.

6) Flagellum: This is a structure that allows bacteria to jump about and drive themselves. Some bacteria may have several copies of themselves.

7) Pili: The exterior of the cell has hair-like appendages that enable it to bind to surfaces and pass genetic material to other cells. This has the potential to lead to the transmission of disease in humans.

5.4 Selected Hazardous Bacteria details:

5.4.1 Staphylococcus aureus:

Staphylococcus aureus is a gram-positive bacterium that causes a broad range of ailments, ranging from minor skin infections to life-threatening medical conditions. The frequent clinical presentations of this pathogen include infections both in community-acquired and hospital-acquired settings. Since the MRSA multi-drug resistance strains such as methicillin-resistant Staphylococcus aureus (MRSA) has emerged, treatments remain difficult owing to this development. Staphylococcus aureus is a common bacterium that is usually not harmful to healthy skin. However, when permitted to penetrate the internal tissues or circulation, these germs may cause a range of severe illnesses. This exercise explains the examination and treatment of Staphylococcus infections, and it also includes a review of the inter-professional team's involvement in the treatment of patients with these illnesses.

Staphylococcus aureus is a Gram-positive bacterium that are either gram-positive cocci-shaped bacteria in clusters that are characterized as “grape-like” or micrococci, which are tiny, spherical cocci salt in which the organisms may develop to be present in up to 10% of the total amount, and which colonies often become golden or yellow (aureus means golden or yellow). Some organisms are capable of growing aerobically

or anaerobically (facultative) and have a temperature range between 18°C and 40°C. The typical biochemical identification tests are catalase-positive (all pathogenic Staphylococcus species), coagulase-positive (to identify Staphylococcus aureus from other Staphylococcus species), novobiocin-sensitive (to differentiate from Staphylococcus saprophyticus), and mannitol fermentation-positive (to distinguish from Staphylococcus epidermidis). Staphylococcus aureus is a very important bacterial human pathogen that produces a broad range of clinical symptoms. For patients who have either of these two conditions, infections are prevalent both in community-acquired as well as hospital-acquired settings, and therapy remains tough to manage because of the increased appearance of multi-drug resistant strains such as MRSA (Methicillin-Resistant Staphylococcus aureus). The bacterium, S. aureus, is present in the environment and also in the typical human flora, which is situated on the skin and mucous membranes (most typically the nasal region) of the vast majority of healthy persons. The most often found bacteria found on healthy skin does not generally cause illness; but, if this bacterium makes its way into the circulation or internal tissues, then these bacteria may cause a number of other dangerous illnesses. The transmission is generally by skin-to-skin contact. In addition, certain illnesses are acquired by means of additional transmission routes [9-12].

5.4.2 Bacillus subtilis:

Hay bacillus (Bacillus subtilis), or grass bacillus (Papillibacter quereutes), is one of the earliest Gram-positive bacteria to be investigated. It is an aerobic, rod-shaped spore-forming microbe that is capable of proliferating in severe cold, heat, and even the most well cleaned surroundings. As a result, it spreads to the gastrointestinal systems of animals and humans through the soil. More than 200 species of the bacterium Bacillus exist; however, not all of them cause illness. Pathogenic organisms may be found in the biotechnology field, for example, in the bacteria Bacillus subtilis. The morphology of the bacteria is that of rod-shaped, Gram-positive bacteria that show up on both positive and negative Gram stain tests. Bacterial rods are cylinders with rounded ends that are symmetrical. As a result, there is a differential in pressure across the cytoplasmic membrane, which forces the cell wall into a certain form. An excellent and readily available organism to study and experiment with in synthetic

biology is the bacterium *Bacillus subtilis*, strain 168. Here, we have made an updated annotation on the organism based on current experimental findings but also on previous information in order to summarize this bacterium as a suitable tool for synthetic biology research. The whole genome sequence of B. subtilis 168 was released in 1997 by a collaboration that consisted of mostly European and Japanese labs. However, cloning DNA fragments into an *E. coli* host was the most labor-intensive sequencing process since it relied on the recipient bacterial strain of E. coli in addition to the donor DNA and the objective of sequencing at least 15% of the sequences that were not successfully cloned. There has been a considerable decrease in the costs and simplicity of sequencing genomes since the date of release of the genome sequence of strain 168. As far as new *B. subtilis* genomes were concerned, for many years, it was the only one around [12-16].

5.4.3 Escherichiacoli:

When most people think about E. coli, they tend to assume that the bacteria that is often found in diverse settings including foods, soil, and animal intestines is the same thing as the bacterium that is known as E. coli. Escherichia coli is very varied and belongs to the genus Escherichia. A number of strains, which are relatively benign, play a crucial role in the human digestive system, while others are toxic and may have major health consequences. Due to the key function played by the cell wall, there are a vast range of bacterial cells, which include cells with distinct wall forms and structures. Recent studies have shown that cell shape is a crucial factor for controlling a range of crucial bacterial behaviours, including adhesion, dispersion, motility, polar differentiation, predation, and cellular differentiation. Importantly, in order to accomplish cell development, the cell wall must continually remodel, which has the potential to damage the cell's integrity. Despite a general consensus among researchers that information on the chemical composition and assembly of cell-wall components are already known, how the network of peptidoglycan subunits is structured to provide the cell shape during normal development and how it is reformed in response to injury or environmental pressures remain largely unknown. In this study, we offer a quantitative physical model of the bacterial cell wall that predicts the mechanical response of cell shape to peptidoglycan degradation and

disturbance in the rod-shaped Gram-negative *Escherichia coli* bacterium [17-20].

5.4.4 Salmonella typhimurium:

S. enterica serovar Typhimurium are Gram-negative, flagellated, aerobic (oxygen-consuming) bacteria that are the most common cause of human salmonellosis, a kind of gastroenteritis, or inflammation of the gut. the bacteria that causes Salmonella enteritidis infection, *S. typhimurium*, is transmitted largely via contaminated food and drink, although it may come into contact with a person via direct contact with an infected animal or pet. Though humans are an important microbe inhabiting our bodies, it has also been shown that the bacteria *S. typhimurium* may be found in the gastrointestinal tracts of animals such as poultry, wild birds, and rodents, whether they are pathogens or not. While there are several types of drug-resistant Salmonella, there are certain strains of *S. typhimurium*that are resistant to several antibiotics such as ampicillin, chloramphenicol, streptomycin, sulfonamides, and tetracyclines. This is a serious worry since it's become more difficult to treat resistant forms of disease-causing bacteria because of the long and complex process of new medication development. While *S. typhimurium*-induced salmonellosis in mice leads to gastroenteritis in people, *S. typhimurium*-induced salmonellosis in mice moves on to a typhoid-like fever. Most bacteria have no ill effects on humans, since almost all are killed or removed in the gastrointestinal system. However, in the mouse version of salmonellosis, 99% of the bacteria are mitigated by the acid in the stomach, and only *S. typhimurium* that has withstood this acid are able to reach the small intestine, where they then breach the intestinal epithelial barrier. Alternatively, if a bacterium is consumed, it will either be phagocytized by macrophages (cells that specialize in phagocytosis) or it may spread to numerous cells and then make its way throughout the body [21-23].

5.5 Experimental Methods:

5.5.1 Antimicrobial testing by Disc Diffusion method:

Cultures used:

Microorganism	Strain Name	Strain reference
Gram positive bacteria	Staphylococcus aureus	NCIM 2079
	Bacillus subtilis	NCIM 2063
Gram negative bacteria	Escherichia coli	NCIM 2109
	Salmonella typhimurium	NCIM 2172

NCIM: National Collection of Industrial Microorganisms, National Chemical Laboratory (NCL), Pune 411008 [India]

A) Protocol

Preparation of Mueller-Hinton plate

Allow an MH agar plate to get to room temperature (one for each organism to be examined). To avoid condensation, it's best to leave the plates in the plastic sleeve while they warm up. If there is visible liquid on the surface of the agar, flip the plate and leave the lid ajar to let the excess liquid to drain and evaporate. Plates may be dried in a 35°C incubator or at ambient temperature in a laminar flow hood (usually 10 to 30 minutes). Label each MH agar plate appropriately for each organism to be examined.

Preparation of inoculum

Scratch four or five isolated colonies of the organism to be examined with a sterile inoculating loop or needle. In 2 mL of sterile saline, suspend the organism. To get a smooth suspension, vortex the saline tube then adjust the turbidity of this suspension to a 0.5 McFarland standard by adding additional organism or diluting with sterile saline if it is too heavy. This suspension should be used within 15 minutes after being prepared.

Concentration of compounds

Hi-media antibiotics disk: Chloramphenicol (10 microgram/disk) moistened with water are used as standard

5.5.2 Minimum Inhibition Concentration (MIC) method:

Broth Dilution

In order to find out whether the remedy was any use, an assay was performed by the tube broth dilution process, which included adding 5 mL of each concentration of the extract to five milliliters of sterile nutrient broth in different tubes. The 0.2-mL equal volume of culture was then applied to each tube, and the samples were incubated at 37°C for bacteria. The presence of turbidity in each tube was visually inspected after incubation [24]**.**

Concentration of samples:

Stock solution [1024 microgram per mL] of each compound was prepared in dimethyl sulphoxide

Media Used:

Microbiological media used for bacteria is **Nutrient Broth** (Hi-media) **Composition (gL^{-1}):** Sodium chloride, 5.0; Beef extract 10.0; Peptone 10.0 (pH 7.2)

5.5.3 Time Kill Assay method

Method used:

Accordance with the procedure outlined above, time-kill kinetics of paint against *Staphylococcus aureus, Bacillus subtilis, Escherichia coli, and Salmonella typhimurium* was done using the test method described [25]. Concentrations of the paint that were prepared had the same MIC as the MIC found in the paint. Separate 0.1 mL of each pathogen was added to an inoculum of 1.0×10^6 CFU/mL, and the resulting mixture was incubated at 37°C. One-half milliliter aliquots of the growth medium were taken at time intervals of 0, 8, 16, and 24 hours, which were then used to inoculate 20 milliliters of nutrient agar and incubated at 37 degrees Celsius for 24 hours**.**

Concentration of samples:

Stock solution [1024 microgram per mL] of each compound was prepared in dimethyl sulphoxide

Media Used:

Microbiological media used for bacteria is **Nutrient Broth** (Hi-media) **Composition (gL^{-1}):** Sodium chloride, 5.0; Beef extract 10.0; Peptone 10.0 (pH 7.2)

5.5.4 Static/Cidal assay method:

Method used:

Paint is often tested to determine its cidal or static properties. For this process, specific bacterial growth media is spread on nutrient agar plates and cultured to isolate the bacteria surrounding the paint well. It was discovered after 24 hours of incubation at 37°C for bacteria that growth had taken place. When the appearance of growth was seen as static, no growth was seen as the result of any kind of contamination [26]**.**

Media Used:

Microbiological media used for bacteria is **Nutrient Broth** (Hi-media) **Composition (gL^{-1}):** Sodium chloride, 5.0; Beef extract 10.0; Peptone 10.0 (pH 7.2)

5.6 Results and Discussion:

5.6.1 Antimicrobial Testing Properties:

An essential element in the treatment of infections in patients is the determination of bacterial resistance to antimicrobials. Kirby and Bauer's disc diffusion method has been standardized and is a viable alternative to the boring dilution techniques in labs lacking the means to use the newer automated microscope testing methods. On a Mueller-Hinton (MH) agar plate a 6 mm filter-paper disc impregnated with a known concentration of antimicrobial chemical is instantly put, water is absorbed from the agar into the disc. The antibacterial starts to spread to the nearby agar. The diffusion rate through agar is not as fast as the antimicrobial removal rate from the disc, therefore the antimicrobial concentration is closest to the disc and the logarithmic decline happens with the rise of the distance from the disc. The rate of antimicrobial diffusion through agar depends on the diffusion and solubility qualities of the medicinal product in MH agar and on its molecular weight. At a slower pace than the molecular compounds, larger molecules are diffused. In combination, these variables lead to each antibiotic having a single break-point area that is sensitive to it [27].

Antimicrobial testing (Disc Diffusion Assay):

Figure 5.3: Antibacterial activities of paint samples with *S. aureus*

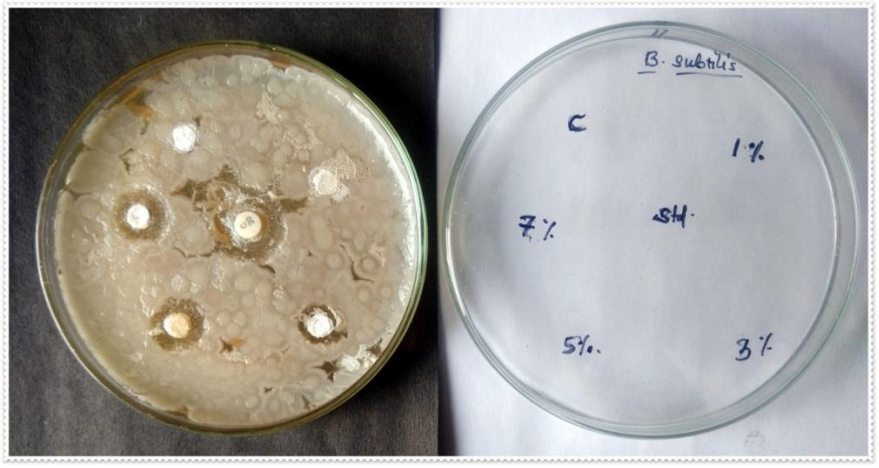


Figure 5.4: Antibacterial activities of paint samples with *B. subtilis*

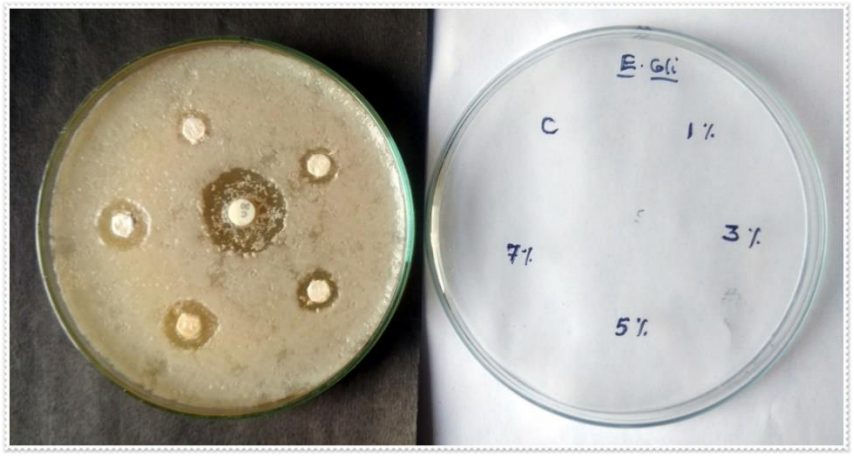


Figure 5.5: Antibacterial activities of paint samples with *E. coli*

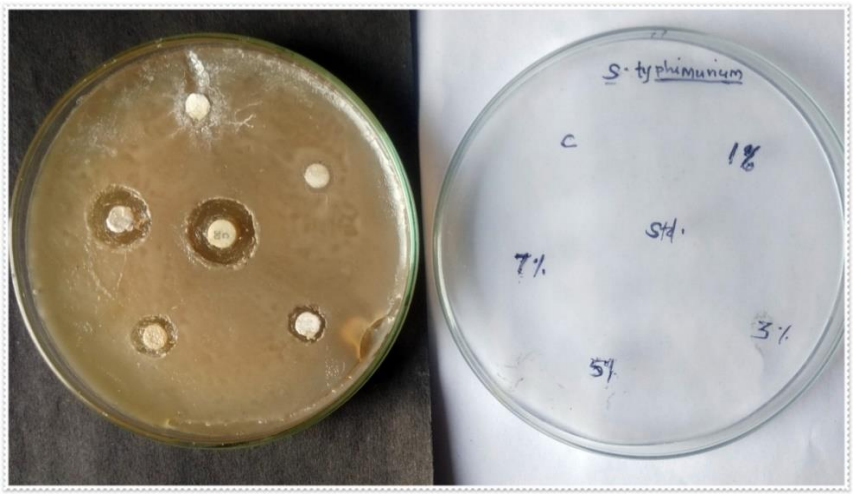


Figure 5.6: Antibacterial activities of paint samples with *S. typhi*

The antibacterial activities of the prepared percentile oil paint samples 1% TiO_2 , 3% TiO_2 , 5% TiO_2 , 7% TiO_2 , and control base paint were tested against gram positive *S.aureus* , *B.subtilis* and gram negative *E.coli*, *S. typhi*bacterial strains with the standard drug Chloramphenicol by disc diffusion method as shown in the table 5.1. Diameter in 'mm' calculated by Vernier Caliper '--'means no zone of inhibition, NA Not applicable

Table 5.1: Antibacterial activities of paint samples by disc diffusion method

Sr. No.	Sample/ Compound	Zone of inhibition in mm			
		S.aureus	***B.subtilis***	***E.coli***	***S. typhi.***
1.	**Ctrl%**	6.31	--	8.89	--
2.	**1%**	8.85	--	9.75	--
3.	**3%**	9.92	8.02	9.96	7.52
4.	**5%**	12.14	11.20	11.68	9.44
5.	**7%**	13.86	11.24	11.70	13.71
Std	**Chloramphenicol**	16.35	17.87	21.79	16.36

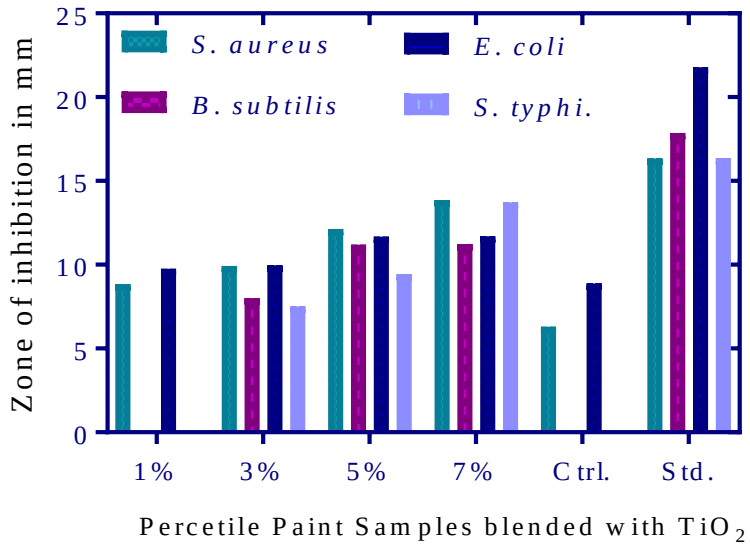


Figure 5.7: Antibacterial activities of paint samples

A set of three test for each bacteria at different percentage of TiO_2 Work conducted and the most common results were considered.

Anti-bacterial materials may avoid or resist large attachments by showing an anti-fouling impact on the surface of cells or by inactivating them. The presence of an undesirable surface topping or surface chemistry recognizing the microbes may resist or inhibit cell attachment. It was found that the zone of inhibition is more as compared to control paint sample.

5.6.2 Minimum Inhibition Concentration (MIC) Study of Paint samples:

The lowest concentration of an antimicrobial medicine that would suppress observable growth of a microbe after overnight incubation is known as the minimum inhibitory concentration (MIC) in microbiology. You choose three concentrations to test (10 g/mL, 1 g/mL, and 0.1 g/mL). The growth medium in each of these tubes has been infected with a standard concentration of bacteria as well as the appropriate antibiotic concentration. Allow the tubes to incubate overnight. Bacterial growth is shown by turbid broth tubes, while clear broth tubes indicate no growth. The antibiotic's MIC is the lowest concentration at which it does not cause growth.

A) MIC Reports:

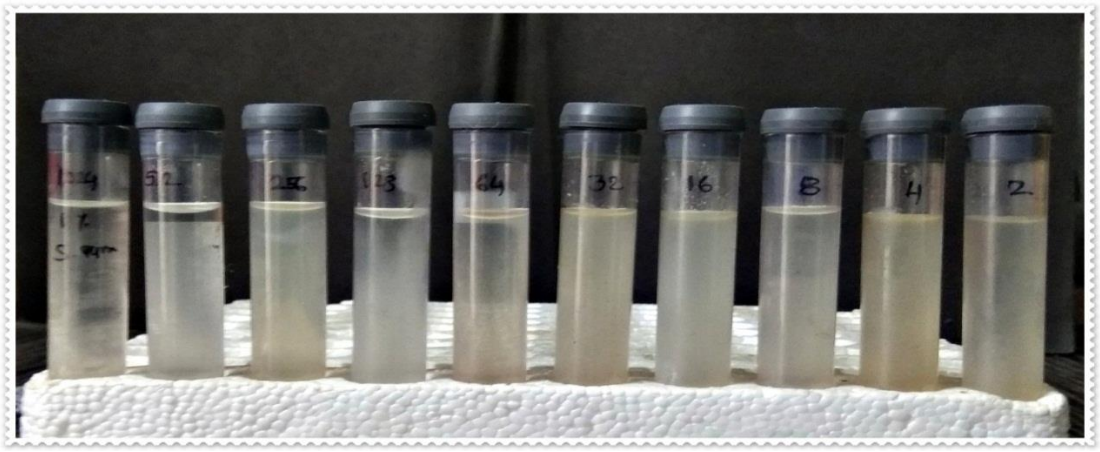


Figure 5.8: MIC of 1% TiO_2 Paint Sample on *S. aureus*

B) Results of Minimum Inhibition Concentration (MIC) of S. aureus

Table 5.2: MIC of S. *aureus* against paint samples with control

Sr. No.	Concentration (µg/mL)	Control	1%	3%	5%	7%
1	1024	-	-	-	-	-
2	512	+	+	-	-	-
3	256	+	+	+	+	-
4	128	+	+	+	+	+
5	64	+	+	+	+	+
6	32	+	+	+	+	+
7	16	+	+	+	+	+
8	8	+	+	+	+	+
9	4	+	+	+	+	+
10	2	+	+	+	+	+
11	MIC (SA)	>512	>512	>256	>256	>128

At the concentration of 1024 µg/mL, almost all the percentile paint samples vanishes the bacterium cultures, in case of 3% , 5% and 7% paint samples MIC shown at 512 µg/mL but the 7% paint sample revealed the clear MIC resulted in the 256 µg/mL in the gram positive *S. aureus* strain.

C) Results of Minimum Inhibition Concentration (MIC) of B. subtilis

Table 5.3: MIC of *B. subtilis* against paint samples with control

Sr. No.	Concentration (µg/mL)	Control	1%	3%	5%	7%
1	1024	-	-	-	-	-
2	512	+	+	+	-	-
3	256	+	+	+	+	+
4	128	+	+	+	+	+
5	64	+	+	+	+	+
6	32	+	+	+	+	+
7	16	+	+	+	+	+
8	8	+	+	+	+	+
9	4	+	+	+	+	+
10	2	+	+	+	+	+
11	MIC (BS)	>512	>512	>512	>256	>256

Almost all of the percentile paint samples eliminate the bacterial colonies at a concentration of 1024 µg/mL, whereas the MIC in the gram positive *B. subtilis* strain is 512 µg/mL in the 5 and 7 percent paint samples.

D) Results of Minimum Inhibition Concentration (MIC) of E. coli

Table 5.4: MIC of E. *coli* against paint samples with control

Sr. No.	Concentration (µg/mL)	Control	1%	3%	5%	7%
1	1024	-	-	-	-	-
2	512	+	+	-	-	-
3	256	+	+	+	+	+
4	128	+	+	+	+	+
5	64	+	+	+	+	+
6	32	+	+	+	+	+
7	16	+	+	+	+	+

8	**8**	+	+	+	+	+
9	**4**	+	+	+	+	+
10	**2**	+	+	+	+	+
11	**MIC (EC)**	**>512**	**>512**	**>256**	**>256**	**>256**

At a dosage of 1024 µg/mL, practically all the percentile paint samples kill bacteria; however, the 3%, 5% and 7% paint samples, the MIC was determined to be 512 µg/mL in the gramme negative *E. coli* strain.

E) Results of Minimum Inhibition Concentration (MIC) of S. typhimurium

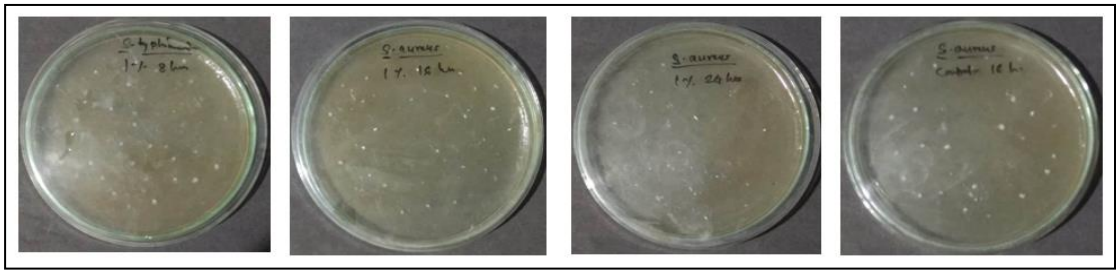
Table 5.5: MIC of S. *typhimurium* against paint samples with control

Sr. No.	Concentration (µg/mL)	Control	1%	3%	5%	7%
1	**1024**	-	-	-	-	-
2	**512**	+	+	-	-	-
3	**256**	+	+	+	+	-
4	**128**	+	+	+	+	+
5	**64**	+	+	+	+	+
6	**32**	+	+	+	+	+
7	**16**	+	+	+	+	+
8	**8**	+	+	+	+	+
9	**4**	+	+	+	+	+
10	**2**	+	+	+	+	+
11	**MIC (ST)**	**>512**	**>512**	**>256**	**>256**	**128>**

At the concentration of 1024 µg/mL, almost all the percentile paint samples vanishes the bacterium cultures, in case of 3% , 5% and 7% paint samples MIC shown at 512 µg/mL but the 7% paint sample revealed the clear MIC resulted in the 256 µg/mL in the gram negative *S. typhimurium* strain.

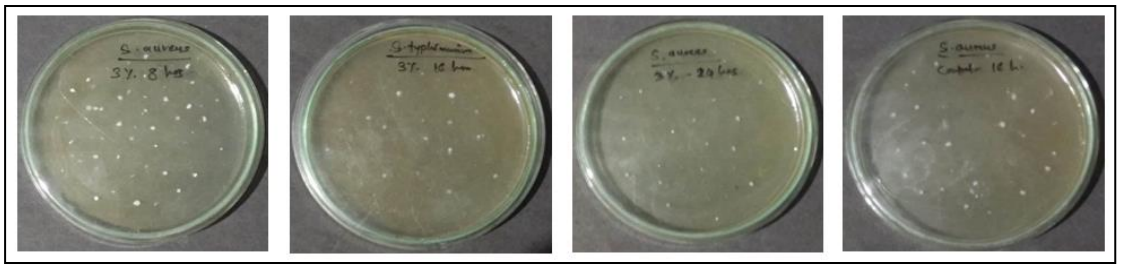
5.6.3 Time Kill Assay Properties:

A) Time kill assay Properties:



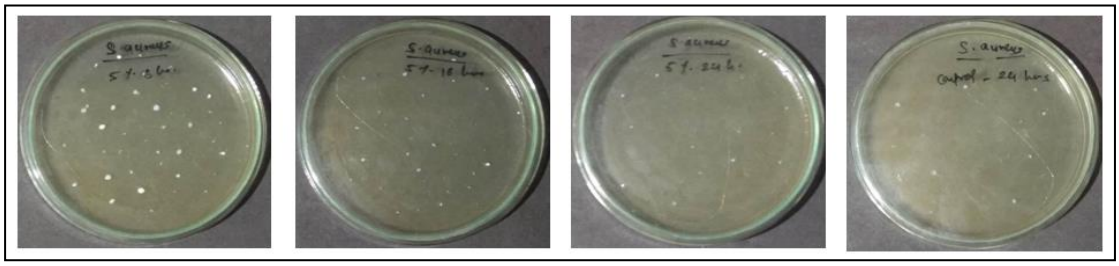
8hrs 16hrs 24hrs control

Figure 5.9: 1% sample with *S. aureus*



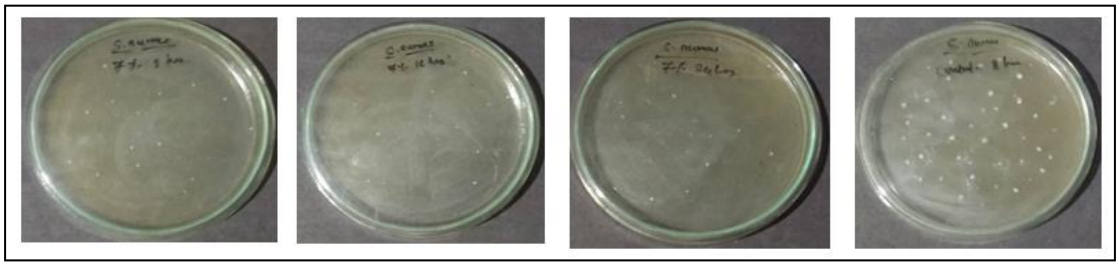
8hrs 16hrs 24hrs control

Figure 5.10: 3% sample with *S. aureus*



8hrs 16hrs 24hrs control

Figure 5.11: 5% sample with *S. aureus*



8hrs 16hrs 24hrs control

Figure 5.12: 7% sample with *S. aureus*

B) Results of Time kill assays:

Table 5.6: Time kill assay readings of the paint samples with control

Species	Time (hrs)	cfu/mL				
		Control	1%	3%	5%	7%
S. aureus	**8**	59	47	38	34	28
	16	38	36	39	28	17
	24	18	18	17	15	13
B. subtilis	**8**	--	--	29	24	32
	16	--	--	24	20	23
	24	--	--	17	11	17
E.coli	**8**	62	57	48	37	34
	16	55	43	34	28	25
	24	43	31	29	18	15
S.typhi	**8**	--	--	39	35	10
	16	--	--	26	23	07
	24	--	--	13	12	04

There was a statistically significant difference between the materials at all-time intervals (8, 16, and 24 h). Almost all the bacterial cultures of 5% and 7% paint sample decreases or gives the killing frequency at the increasing time intervals.

5.6.4 Static/Cidal Assay Properties:

A bactericidal (“cidal”) antibiotic is one that kills bacteria without reliance on the patient’s immune system to help. A bacteriostatic (“static”) antibiotic is one that prevents the organism multiplying but it is the patient’s own immune system which kills off the bacteria and leads to recovery from the infection. It doesn't matter if the patient is given a cidal or a static antibiotic since, given enough time and assistance; their immune system is usually capable of dealing with the illness show in figure 5.13. Cidal drugs are only cidal when a sufficient amount of the antibiotic is administered; at low levels or dosages, they are essentially static. Low levels, for example, might arise accidently if patients are treated with insufficient amounts (e.g. an incorrect low

dose or missing doses etc). It is worried about the influence of obesity on our capacity to obtain cidal antibiotic levels in these individuals, and also wondering whether standard dose in these enormous body masses is really creating low levels, resulting in merely bacteriostatic treatment.

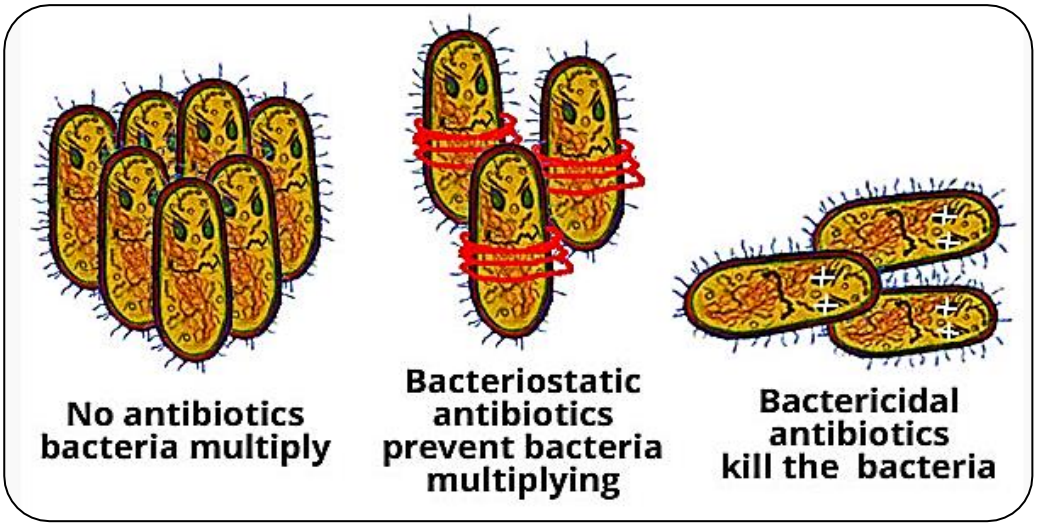


Figure 5.13: Bacteriostatic and bactericidal notion

Table 5.7: Static/Cidal growth of the paint samples with control

Species	Activity	Growth				
		Control	1%	3%	5%	7%
S. aureus	**Static**	+	+	+	+	-
	Cidal	-	-	-	-	+
B. subtilis	**Static**	NA	NA	+	-	-
	Cidal	NA	NA	-	+	+
E.coli	**Static**	+	+	+	-	-
	Cidal	-	-	-	+	+
S.typhi	**Static**	NA	NA	+	+	-
	Cidal	NA	NA	-	-	+

This experiment is performed to detect the temporary and permanent bacteria activity on the prepared paint sample. The bacteriostatic results found in 1%, 3% and 5% samples with control but 7% sample gives bactericidal activities in *S. aureus* while only 3% sample showed bacteriostatic and 5% and 7% samples showed bactericidal properties against *B. subtilis* gram positive strains. On the other hand, The

bacteriostatic results found in 1% and 3% samples with control but 5% and 7% sample gives bactericidal activities counter to *E. coli* while only 3% and 5% sample showed bacteriostatic and 7% samples showed bactericidal properties along with *S.typhi* gram negative strains.

Killing Mechanism Reaction:

The mechanisms for the main processes at the surface of the catalyst were clearly characterized. The irradiation of TiO_2 with energy-scales equal to or larger than its band-gap in the valence (e^-) band to generate holes (h+) on the conductive band of the particle leading to the promotion of electrons (e-) [28].

$$TiO_2 + hv \rightarrow TiO_2 + e^- + h^+ \quad (5.1)$$

At the TiO_2 particle surface, the holes (h^+) react with surface hydroxyl groups (OH^-) and adsorb H_2O, to form $^\bullet OH$ radicals in the following equations

$$OH^- + h^+ \rightarrow {}^\bullet OH \quad (5.2)$$

$$H_2O + h^+ \rightarrow {}^\bullet OH + H^+ \quad (5.3)$$

The electron-hole recombination is conceivable in the absence of electron acceptors. By trapping electrons via the production of superoxide ions, oxygen inhibits this recombination. The reduction's ultimate result may potentially be a radical.

$$O_2 + e^- \rightarrow O_2^{\cdot -} \quad (5.4)$$

$$2O_2^{\cdot -} + H^+ \rightarrow 2\cdot OH + O_2 \quad (5.5)$$

The Reactive Oxygen Species (ROS), such as hydroxyl radical, superoxide anions and hydrogen peroxide, generated on the surface, are considered answerable for the inactivation of the microorganism as follows;

$$\textbf{Microorganisms + ROS} \rightarrow \textbf{Inactivation} \quad (5.6)$$

The most widely accepted mechanism for ROS inactivation of microorganisms suggests that $^\bullet OH$ radicals or peroxides promote oxidation of the outer membrane, resulting in a disorder in cell permeability, even decomposition of the cell walls, and further oxidation of intracellular components, which inhibit cell respiration. The breakdown of cell integrity may eventually result in cell death. Another theory is that $^\bullet OH$ radicals are not the only species responsible for the biocide impact, and that the cooperative action may also induce per oxidation of phospholipids components of the lipid membrane, which is important for vital cellular respiration and induce apoptosis

[29-30].

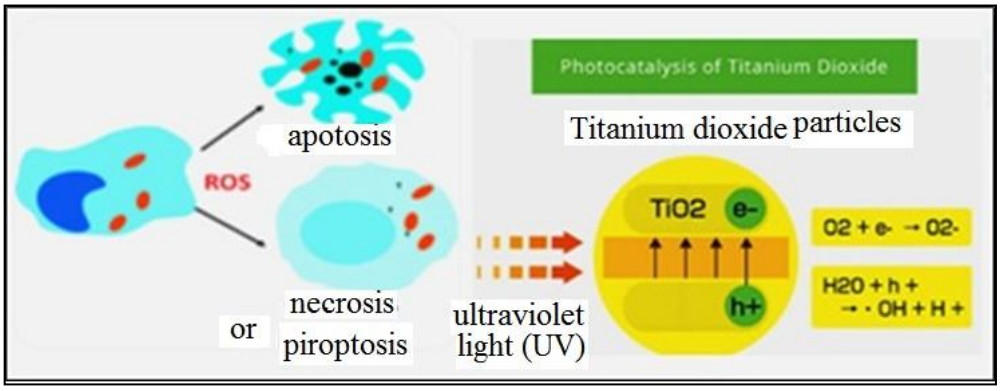


Figure 5.14: ROS and TiO_2 UV mechanism with bacteria

It is also worth mentioning that the acrylic paint used in this research includes a tiny amount of fungicide in its composition (~0.2%). Fungicidal activity in the culture media, on the other hand, was not detected in the non-photo catalytic paint sample, but only in the paint containing TiO_2. This is because light activates the production of oxidant species on the photo catalyst surface. As a result, photo activity is linked to the suppression of microorganism development by the action of radicals produced by TiO_2 microspheres when exposed to light [31].

5.7 Conclusions:

- It can be concluded that the antibacterial activity by disk diffusion method 5% TiO_2 Sample give satisfactory results for all the bacteria.
- By the MIC test S. aureus, B.subtilis, E.coli, S.typhi against the paint sample with control gives positive results for above 256 µg/mL concentration for 5% TiO_2 Sample.
- It can be concluded from time kill assay reading that the 5% TiO_2 and 7% TiO_2 sample give satisfactory results for all bacteria.
- The bacteria static results and bacteria cidal result were found to be positive for 5% TiO_2 and 7% TiO_2.
- From the above conclusion it can be concluded that the 5% TiO_2 and 7% TiO_2 sample can be preferred the intended purpose.

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CHAPTER - 6

CHAPTER – 6

ANTIFUNGAL ACTIVITIES OF COATINGS AND THEIR TESTING

6.1 Introduction:

Expanding focus is directed to the possibility that environmental pollution plays a key role in spreading impossible infectious diseases in healthcare sites subject to organism and environmental factors, and that pathogens may live on surfaces for extended interval periods [1-5]. A condition with numerous intricate factors includes taking care of the health-related diseases and occupationally procured contaminations. Some of the main sections were healthcare workers, for example, physicians, technicians, managers, nurses, medical assistants and skilled personnel, who are often subjected to blood and body fluids during most of the time they spent in the contagious field. Such fluids, including multidrug-resistant organisms such as meticillin-resistant Staphylococcus aureus (MRSA), Acinetobacter species, pathogens and Enterobacteriaceae, may spread bacteria that trigger colonization or infection. There is also a chance of virus transmission like noroviruses, respiratory viruses and bloodborne viruses which may live on surfaces for hours or days [6-9]. The main sources of methicillin-resistant Staphylococcus aureus (MRSA) in the hospital setting are asymptomatically inhabited patients and health care workers, with the latter being more commonly identified as links in the transmission of MRSA between patients in health care institutions [10]. Since the emergence of nanotechnology, attempts have been produced to supplant the biocides from antimicrobial paints since different nano-sized compounds, such as zinc oxide, titanium dioxide and silver [11]. However the silver and silver-related substances are significantly very potent antimicrobial activities against *Escherichia coli* and *Staphylococcus aureus* and many more bacterial species due to their antimicrobial effects [12-14]. Silver related antimicrobial agents gain a lot of attention as well as being a long-lasting biocide with strong thermal stability and low volatility owing to the reduced toxicity of the active Ag ion to human cells. While previous research on

silver and Ag-NPs has provided several insights into the use of silver in many fields, little is known about the toxicity of Ag-NPs, where scale and surface area are recognized as important determinants of adverse health effects [15,16].Advancing antimicrobial nano-coatings by green research approaches may be a fruitful path for future applications for the environment [17]. These materials can be accumulated either by including nano-powders that are usually in natural polymeric suspensions in the coating material or by mixing nano-powders in situ during the time that the covering material is received [18].

The biocides are generally applied to paint formulations in order to preserve the purity of the substance from microbial assault and to provide defense against any fungal and algal development in the dry picture. Many paint consumers expect their painted surface to last a long time with an aesthetic look. The microbial growth sometimes even stains the paint and deteriorates the properties of paint. Biocides for the safety of dry films play a significant role in preserving the aesthetic quality of paint and holding away any microbial development from the painted surface. In this way, the new, protected and compelling biocides are ceaselessly expected to defeated issues related with miniaturized scale living being adjustment and the improvement of safe strains [20]. Titanium dioxide pigments occur in two morphological crystalline forms that are anatase and rutile which exhibit different photo activities when combined into commercial polymers [21]. The antimicrobial activity of TiO_2 has been known for years [22] and a wide range of micro-organisms have been shown to be susceptible [23, 24]. However, although TiO_2 coated materials have been widely used for their self-cleaning activities, there has been no widespread uptake for antimicrobial use in the healthcare sector despite its potential [25, 26]. The Nano sized titanium dioxide particles may exhibit improved or new properties and are added to paints and lacquers in order to optimize the rheological or mechanical properties of the products or to give the products self-cleaning properties through either dirt repellent, photo catalytic and super hydrophilic properties [27-29].

6.2 Morphology of fungal species:

According to the research effort, the researcher opted to study the growth of fungal species such as Aspergillus niger and Aspergillus oryzae on paint coating surfaces. The following are the basic informative points about these funguses.

6.2.1 Aspergillus niger:

Aspergillus niger in relation to its anatomy, ecology, advantages, and consequences is the most widespread and most studied species in Aspergillus. Because of this, it is widely accepted that all humans and livestock are less pathogenic. A food chemist named James Currie discovered in 1917 that, when grown in a sugar-containing medium, develops citric acid in large concentrations. He removed the acid from it and researched its advantages thoroughly as a food preservative. Other experiments have also shown that it can be used in the processing of glucoamylase, alpha-galactosidase, and several other enzymes of industrial significance. Scientists also concluded that *Aspergillus niger* has distinct strains with different properties on the basis of these observations and other experiments involving morphological analysis. In 2004, a group of researchers investigating the characteristic development of Ohratoxins by *Aspergillus niger* were able to discover many organisms close to *Aspergillus niger*. These species comprise the Circumdati subgenus, a section of Nigri with 15 black-spores that are quite close to those of *Aspergillus niger* [30].

6.2.2 Aspergillus oryzae:

Aspergillus oryzae, like soy sauce, sake, bean curd seasoning and vinegar processing, is a fungus typically used in typical Japanese fermentation industries. In general, filamentous fungi are capable of generating distinct and large quantities of enzymes in a secretory fashion. Among the filamentous mushrooms, Aspergillus oryzae is thought to have considerable capacity for the secretary synthesis of several enzymes. Moreover, advances in the science of genetic modification have contributed to the implementation of Aspergillus oryzae in commercial enzyme processing in modern biotechnology. Aspergillus oryzae was used in 1988 as the first example of industrial development of a heterogeneous enzyme named lipase for laundry detergent. A filamentous fungus with septate hyphae is Aspergillus oryzae.

It demonstrates all the classic life processes: development, replication, responsiveness, and metabolism [31].

6.3 Experimental methods:

6.3.1. Antifungal testing of Paint

Here the researcher has been adopted the antifungal testing of the Titanium dioxide based paint samples in this research work.

Method used:

Federal Test System Model 141 Procedure 6271 (Mildew Resistance) is the most commonly defined agar plate test used by U.S. departments State Government. This method uses sucrose, mineral salts, agar medium, and *Aspergillus oryzae* is the inoculating organism according to TT-P-19 (Paint, Acrylic Emulsion: Exterior) specifications. The agar medium is prepared according to the references. Medium pH with 0.1N hydrochloric acid (HCl) or adjust the sodium hydroxide (NaOH) is adjusted to 5.5-6.5. The medium is autoclaved for 15 minutes at 15 lb/in. 2 ($1.034x 10^5$ Pa) and 121~ each sterile petri dish poured approximately 30mL and hardened. The inoculum is prepared by applying 0.005% non-toxic wetting agent such asTween-80 to a tubed subculture of A 10 mL sterile water. *Aspergillus oryzae*. Spores and mycelia mixture extracted by gently stroking the agar surface with a sterile camel's hairbrush. Dilute the aqueous solution to 100 mL with sterile water. The test paint is brushed and allowed to dry for 24 hours on each side of a sheet of Whatman filter paper No. 3.0. Painted paper squares, 1.25 in. (3.18 cm) side and 1/8 waterproof guide lines (0.32 cm) from each edge, centered on each console's agar surface. Diluted spore-mycelial inoculum is distributed over the painted surface and surrounding agar surface using a 1.0-1.5 mL sterile pipet. Preparing duplicate plates is essential. At 28-30°C and 90% relative humidity, the inoculated agar plates are incubated for seven days. After the incubation period, the specimens are examined microscopically. Fungal development is overlooked on the agar surface or edges of painted filter paper and such organisms are deemed to pass the test if the conditions are growth-free.

Cultures used:

Table-6.1: Culture used for testing samples

Microorganism	Strain Name	Strain reference
Fungi	Aspergillus oryzae	NCIM 570
	Aspergillus niger	NCIM 545
NCIM : National Collection of Industrial Microorganisms, National Chemical Laboratory (NCL), Pune 411008 [India]		

6.3.1.1 Antifungal Testing of coloured paint samples:

Table-6.2: Antifungal Testing of coloured paint samples

Sr.No.	Sample code	*Aspergillus oryzae*
1.	White	-
2.	Black	-
3.	Yellow	-
4.	Blue	-
5.	Orange	-
6.	White1	-
7.	White2	-
8.	White3	-
9.	White4	-
10.	White5	-
Note: '- 'No growth of *Aspergillus oryzae*		

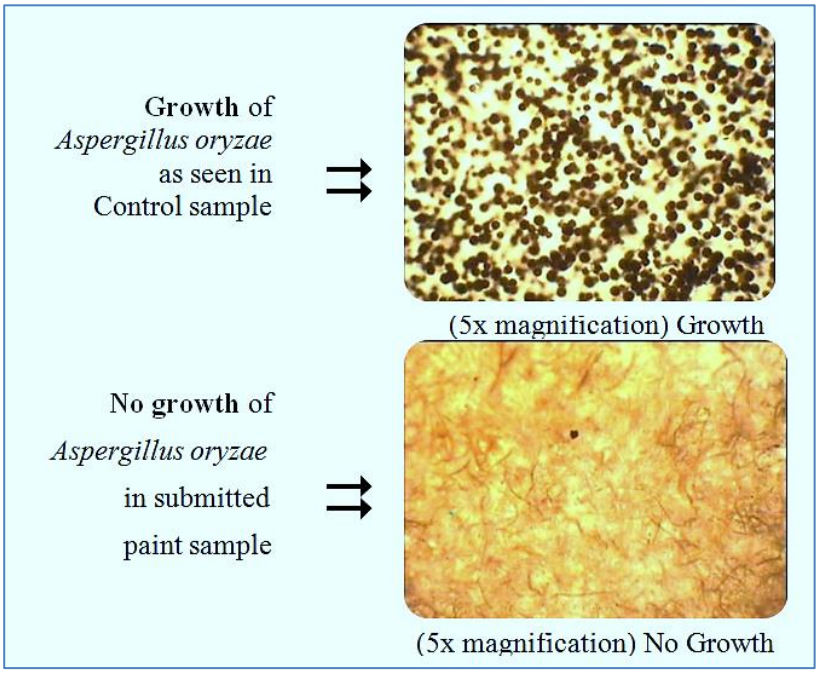

Figure 6.1: Growth of control and paint samples (Aspergillus oryzae)

Samples are visualized under: Motic Digital Biological Microscope (Model DMWB1-223) [5x magnification]

6.3.1.2 Formulation of TiO_2 Based oil Paint Samples:

The paint samples were preapared by the percetile mixture of titanium dioxide nanomaterials (TiO_2 powder) in the white coloured base oil paint with fraction of the terpentine to get homogenous mixture. The 5%, 10%, 15%, 20%, 25% and 50% paint samples were prepared and base paint control was used for the testing purpose as shown in the figure 6.2.

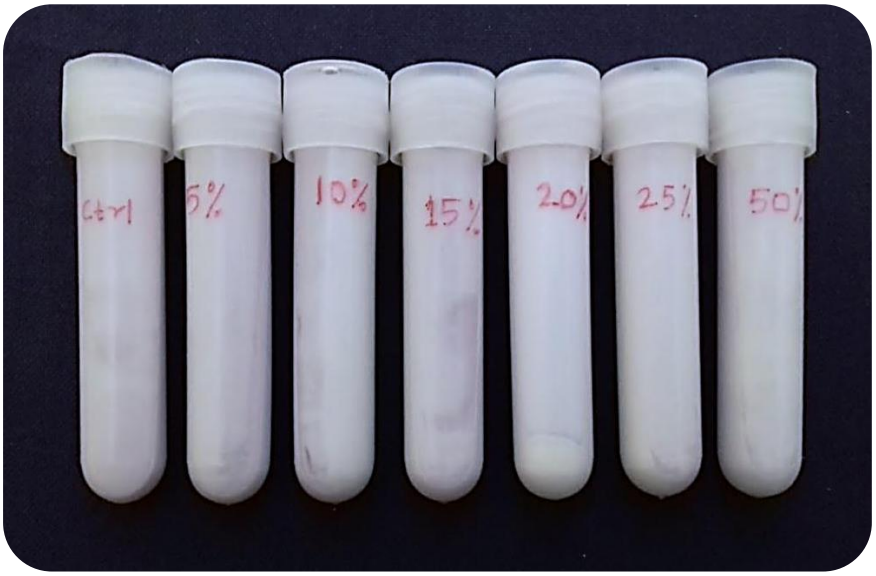

Figure 6.2: Percentile paint samples with for coating

6.3.1.3 Antifungal Testing of 5 to 50 percentile TiO_2 paint samples:

Table-6.3: Antifungal Testing of TiO_2 based paint samples

Sr. No.	Sample code	*Aspergillus oryzae*
1.	Control	+
2.	5%TiO_2	-
3.	10%TiO_2	-
4.	15%TiO_2	-
5.	20%TiO_2	-
6.	25%TiO_2	-
7.	50%TiO_2	-
Note:'-' No growth of *Aspergillus oryzae*		

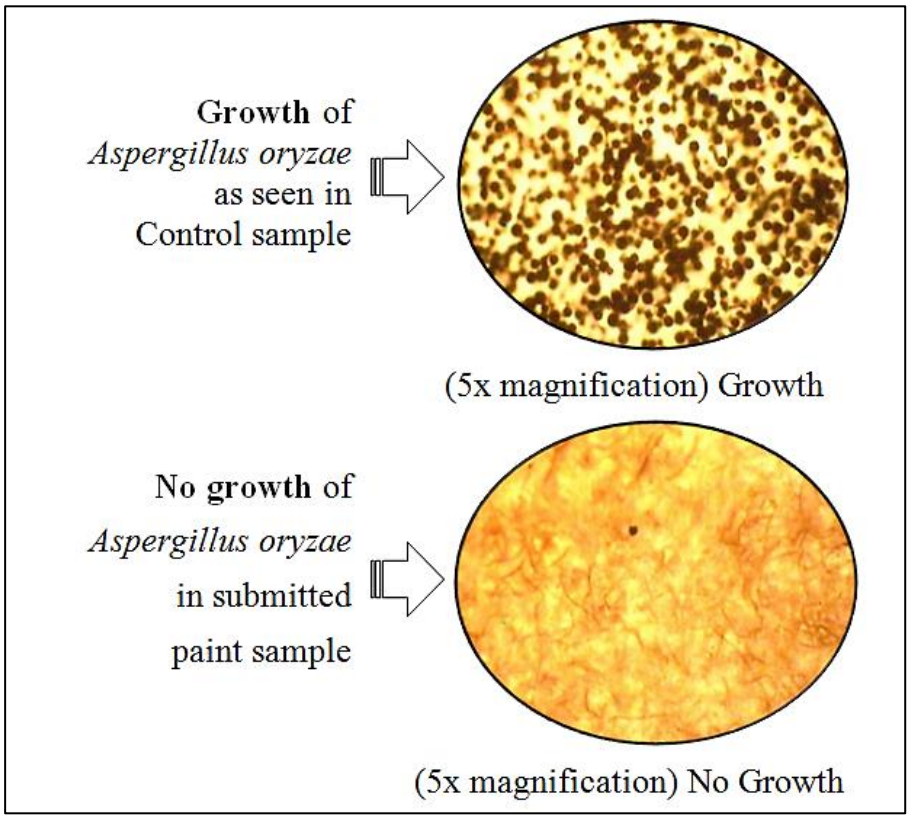

Figure 6.3: Growth of control and TiO_2 added paint samples (Aspergillus Oryzae)

Samples are visualized under: Motic Digital Biological Microscope (Model DMWB1-223) [5x magnification]

Antifungal growth on normal paint was tested along with different percentage of TiO_2 Concentration .it was found that the above no growth was detected above 10% TiO_2 sample . So the TiO_2 Concentration sample for 1%, 3%, 5% and 7% were conducted.

6.3.1.4 Formulation of TiO_2 Based Oil Paint Samples:

The paint samples were preapared by the percetile mixture of titanium dioxide nanomaterials (TiO_2 powder) in the white coloured base oil paint with fraction of the terpentine to get homogenous mixture. The 1%, 3%, 5% and 7% paint samples were prepared and base paint control was used for the testing purpose as shown in the figure 6.4.

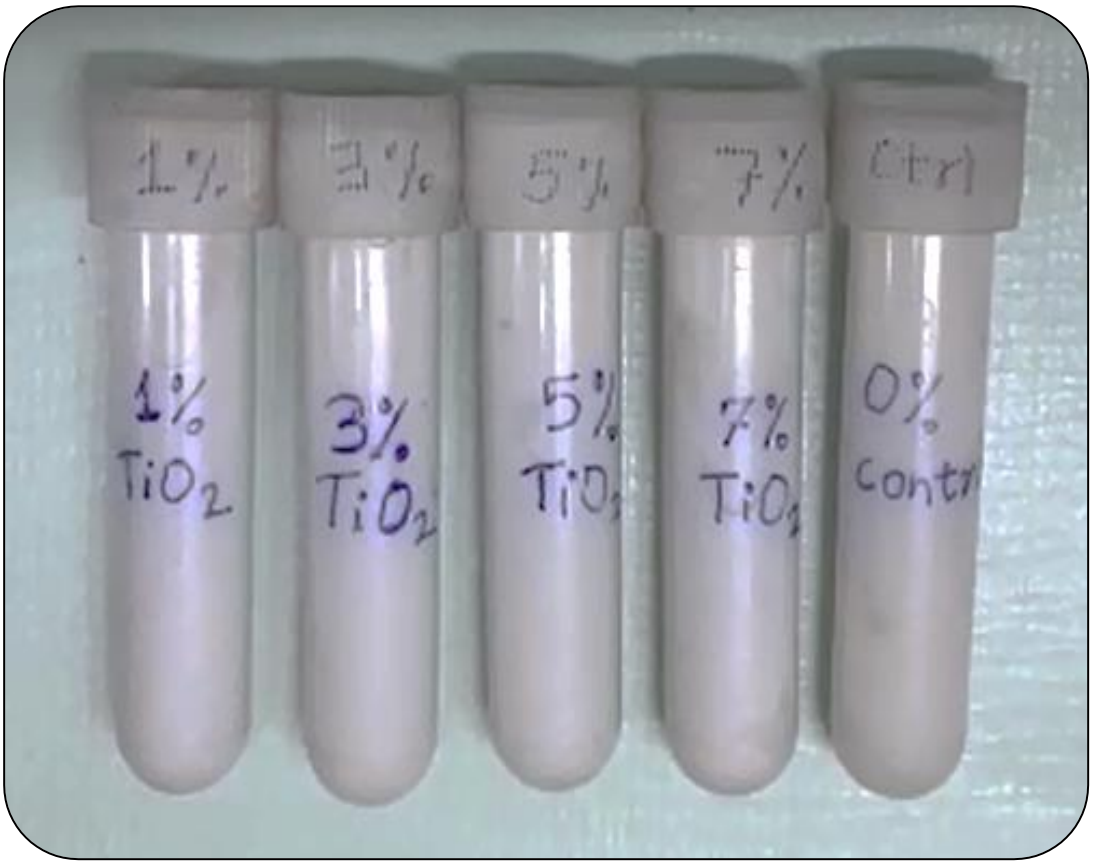

Figure 6.4: TiO_2 added paint samples (1-7%)

6.3.1.5 Antifungal Testing of 1 to 7 percentile TiO_2 paint samples:

Table-6.4: Antifungal Testing of TiO_2 based paint samples Aspergillus oryzae

Sr. No.	**Sample code**	***Aspergillus oryzae* (7th Day)**	***Aspergillus oryzae* (14th Day)**	***Aspergillus oryzae* (21st Day)**	***Aspergillus oryzae* (28th Day)**
1.	Control	+	+	+	+
2.	1 %TiO_2	-	-	-	+
3.	3 %TiO_2	-	-	-	-
4.	5 %TiO_2	-	-	-	-
5.	7 %TiO_2	-	-	-	-
					Note: '- 'No growth, '+' growth

Table-6.5: Antifungal Testing of TiO_2 based paint samples Aspergillus niger

Sr. No.	Sample code	*Aspergillus niger* (*7th Day*)	*Aspergillus niger* (*14th Day*)	*Aspergillus niger* (*21st Day*)	*Aspergillus niger* (*28th Day*)
1.	Control	+	+	+	+
2.	1 %TiO_2	-	-	-	-
3.	3 %TiO_2	-	-	-	-
4.	5 %TiO_2	-	-	-	-
5.	7 %TiO_2	-	-	-	-
Note: '-' No growth, '+' growth					

6.3.2 Antifungal activities of prepared paint samples on tiles:

6.3.2.1 Antifungal testing method by Disc Diffusion Assay:

Cultures used:

Microorganism	Strain Name	Strain reference
Fungi	Aspergillus niger	NCIM 545
	Aspergillus oryzae	NCIM 570

NCIM: National Collection of Industrial Microorganisms, National Chemical Laboratory (NCL), Pune 411008 [India]

A) Protocol

Preparation of Mueller-Hinton plate

Allow an MH agar plate to get to room temperature (one for each organism to be examined). To avoid condensation, it's best to leave the plates in the plastic sleeve while they warm up. If there is visible liquid on the surface of the agar, flip the plate and leave the lid ajar to let the excess liquid to drain and evaporate. Plates may be dried in a 35°C incubator or at ambient temperature in a laminar flow hood (usually 10 to 30 minutes). Label each MH agar plate appropriately for each organism to be examined.

Preparation of inoculum

Scratch four or five isolated colonies of the organism to be examined with a sterile inoculating loop or needle. In 2 mL of sterile saline, suspend the organism. To get a smooth suspension, vortex the saline tube then adjust the turbidity of this suspension to a 0.5 McFarland standard by adding additional organism or diluting with sterile saline if it is too heavy. This suspension should be used within 15 minutes after being prepared.

B) Antifungal testing (Disc Diffusion Assay):

Concentration of compounds

Stock solution[1024microgram per mL]of each compound was prepared in dimethyl sulphoxide. The assay was carried out by taking concentration 1024 microgram paint per disk. Hi-media antibiotics disk: Amphotericin B (10 microgram/disk) moistened with water are used as standard

6.3.2.2 Minimum Inhibition Concentration method:

Broth Dilution

In order to find out whether the remedy was any use, an assay was performed by the tube broth dilution process, which included adding 5 mL of each concentration of the extract to five milliliters of sterile Potato dextrose broth(for fungi) in separate tubes. The 0.2-mL equal volume of culture was then applied to each tube, and the samples were incubated at 27°C. The presence of turbidity in each tube was visually examined after incubation [32]**.**

Concentration of samples:

Stock solution [1024 microgram per mL] of each compound was prepared in dimethyl sulphoxide

Media Used:

Microbiological media used for bacteria is **Nutrient Broth** (Hi-media) **Composition (gL^{-1}):** Sodium chloride, 5.0; Beef extract 10.0; Peptone 10.0 (pH 7.2)

6.3.2.3 Static/Cidal Assay method:

Method used:

To assay the cidal or static activity of paint and its formulations, cells were carefully taken from the zone of clearance around the well and streaked on Potato dextrose agar (for fungi). Then the growth was observed after 48 h at30°C for fungi. Appearance of growth was considered as static, whereas no growth was considered as cidal effect [33]**.**

Media Used:

Microbiological media for fungi and yeast is **Potato dextrose agar** (all ingredients of Hi media) **Composition(gL^{-1})**: Potatoes infusion, 200; Dextrose, 20; Agar,15; Final pH (at25°C) 5.6±0.2

6.3.2.4 Material method of antifungal activities on tiles:

Antifungal screening *Aspergillus niger* (NCIM 545) and *Aspergillus oryzae* (NCIM 570) *strains* obtained from NCL, Pune were used. In the practice of material method, Microbiological media for fungi (*Aspergillus niger*) is Potato dextrose agar (Hi-media) Composition (gL^{-1}): Potatoes infusion, 200.0; Dextrose 20.0 (pH 5.2) and Microbiological media for yeast (*Candida albicans*) is MGYP (all ingredients of Hi media) Composition (gL^{-1}): Malt extract, 3.0; Glucose, 10.0; Yeast extract, 3.0; Peptone, 5.0 (pH 6.4) were used. Hi-media sterile disposable square petri-plates 120 × 12 mm dia 12 mm Ht code number CW050, 6 mm disc size (Hi-media), Digimatic Caliper used for taking the zone of inhibition.

6.3.2.5 Antifungal Protocol for Dry conditions:

Antimicrobial susceptibility testing of the surface coated paint samples were qualitatively assessed by spreading mixture of agar media assay with the dilution of *Aspergillus oryzae* and *Aspergillus niger* strains on the paint coated surfaces of the prepared tile samples kept in to the petri plates without moist condition.

6.3.2.6 Antifungal Protocol for Wet conditions:

Antimicrobial susceptibility testing of the surface coated paint samples was qualitatively assessed by diffusion assay. The agar medium is prepared according to the method. The pH of the medium is 5.5 with 0.1 N hydrochloric acid (HC1) or sodium hydroxide (NaOH). The medium is sterilized in an autoclave for 15 min at 15 lb/in. 2 (1.034×10^5 Pa) and 121~ Approximately 30 mL is poured into each sterile petri dish and allowed to harden. The inoculum prepared by adding 10 mL of sterile water containing 0.005% nontoxic wetting agent such as Tween-80 to a tubed subculture of Aspergillus oryzae. The mixture of spores and mycelia was removed by gently spreading the agar surface and the tile surfaces. The aqueous suspension to as removed and diluted with sterile water to 100 mL.

For fungi Aspergillus niger potato dextrose agar medium was used. After autoclaving, respective media were allowed to attain temperature 50℃. Then 50 mL, corresponding agar medium was poured into sterile square petri-plate (120 mm × 120 mm) which formed uniform layer of agar medium (16 mm). Then petri plates were allowed to cool to room temperature and stored in a refrigerator (2 to 8℃) until further use. A sterile cotton swab was dipped into the yeast or fungal suspension. The swab was rotated several times and pressed firmly on the inside wall of the tube above the fluid level. The corresponding agar medium plate was inoculated by streaking the swab over the entire agar surface. This procedure was repeated by streaking 2-4 times by rotating the plate. After spreading of suspensions, 2″×2″ were suspended in agar medium in which the coated paint coated surface kept it upward direction. Inoculated petri plates were kept in the refrigerator (8℃). After 15-30 min, petri-plates with yeast strain were incubated at 30℃ while petri plates inoculated with fungal strain were incubated at 28℃. After appropriate incubation period, each plate was examined by zero, seventh, fourteen, twenty one and twenty eight days. The diameters of the zones of inhibition were measured using magnifying glass.

6.4 Results and Discussion:

By Federal test method the result achieves for Aspergillus oryzae and Aspergillus niger the control paint sample shows growth for 7th to 28th days. Were as 1% TiO_2 sample shows growth at 28th days only for Aspergillus oryzae.

For 3% TiO_2,5% TiO_2,7% TiO_2 no growth is seen for Aspergillus oryzae and Aspergillus niger.

6.4.1 Antifungal Testing Properties:

The assessment of bacterial resistance to antimicrobials is an important part of treating infections in patients. Kirby and Bauer's disc diffusion method has been standardized, and it's a feasible alternative to dull dilution procedures in laboratories that don't have the resources to employ the more advanced automated microscope testing procedures. A 6 mm filter-paper disc impregnated with a known concentration of antimicrobial chemical is placed on a Mueller-Hinton (MH) agar plate, and water is absorbed from the agar into the disc. Antifungal activity begins to spread to surrounding agar. Because the antimicrobial removal rate from the disc is slower than the diffusion rate through agar, the antimicrobial concentration is highest closest to the disc, and the logarithmic drop occurs as the distance from the disc increases. The rate of antimicrobial diffusion through agar is determined by the medicinal product's diffusion and solubility properties in MH agar, as well as its molecular weight. Larger molecules diffuse at a slower rate than molecular compounds. When these factors are combined, each antibiotic has a specific break-point site that is susceptible to it [34].

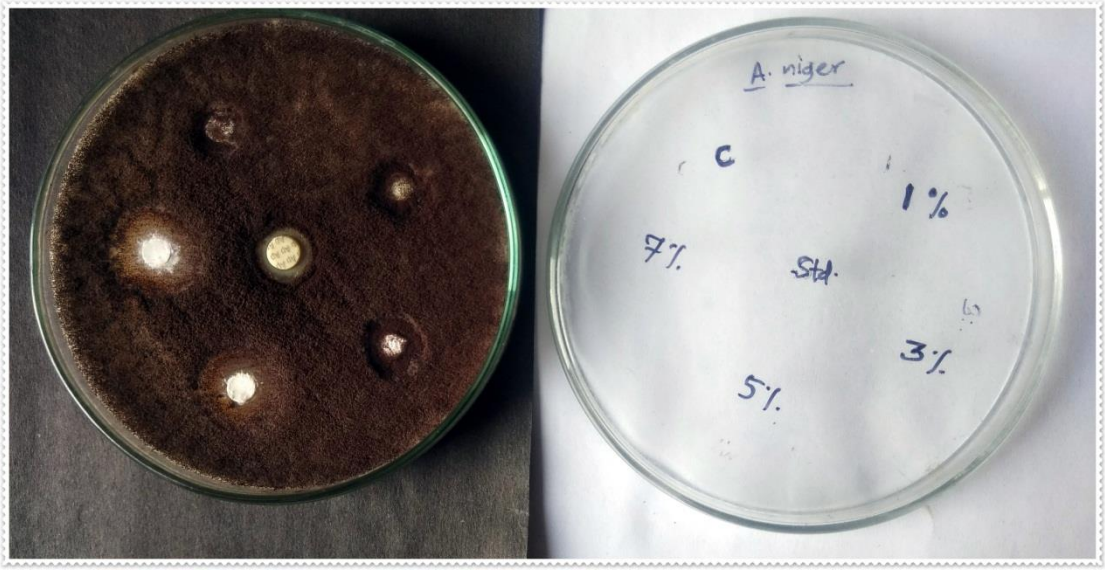

Figure 6.5: Antifungal activities of paint samples with Aspergillus niger

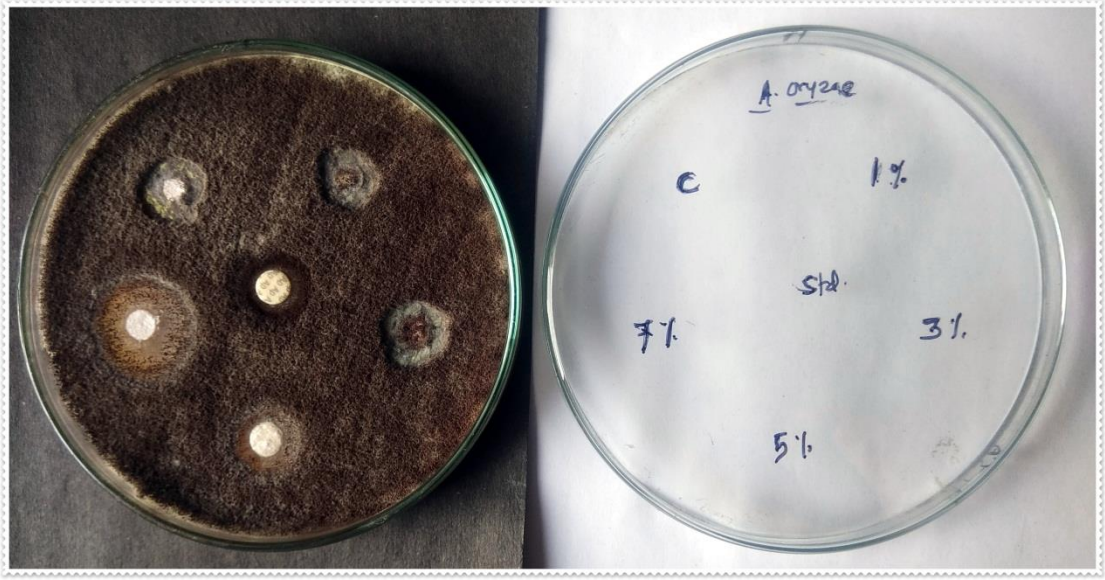

Figure 6.6: Antifungal activities of paint samples with Aspergillus oryzae

The antifungal activities of the prepared percentile oil paint samples 1% TiO_2 , 3% TiO_2 , 5% TiO_2 , 7% TiO_2 , and control base paint were tested against Aspergillus *niger* and Aspergillus *oryzae* fungal strains with the standard drug Amphotericin-B by disc diffusion method as shown in the table 6.6. Diameter in 'mm' calculated by Vernier Caliper '--'means no zone of inhibition, NA Not applicable

Table 6.6: Antifungal activities if paint samples by disc diffusion method

Sr. No.	Sample/ Compound	Zone of inhibition in mm	
		A.niger	*A. oryzae*
1.	**Ctrl%**	--	--
2.	**1%**	--	--
3.	**3%**	--	-
4.	**5%**	9.25	13.42
5.	**7%**	16.22	18.53
Std	**Amphotericin-B**	12.35	12.23

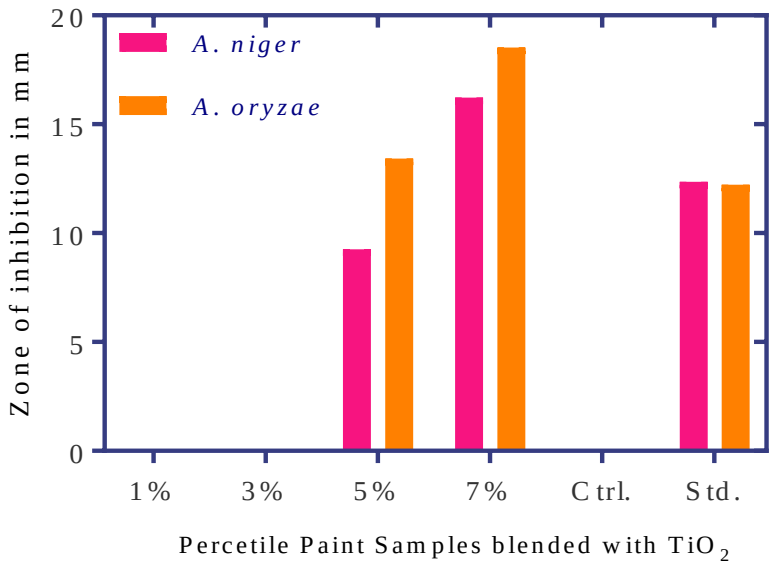

Figure 6.7: Antifungal activities of paint samples

Anti-fungal compounds may prevent or resist big attachments by having an anti-fouling effect on cell surfaces or by inactivating them. The presence of an unwanted surface coating or surface chemistry that recognizes microorganisms may reject or impede cell adhesion. The huge array of antifungal compounds is rapidly expanding. The significant zone was observed in 5% sample against *A. oryzae* and larger zones were found in 7% samples of both *A. niger* and *A. oryzae* fungal stains.

6.4.1.1 Minimum Inhibition Concentration (MIC) of fungi of Paint samples:

Dilution techniques are used to determine antimicrobial medicines' minimum inhibitory concentrations (MICs) for the evaluation of antimicrobial susceptibility, which are then used to calibrate other methods such as disc diffusion. MIC approaches are extensively used in comparative testing of new medications. They are used in clinical laboratories to determine the susceptibility of organisms that provide misleading disc test results, to test species for which disc tests are not trustworthy, and when a more precise clinical result is required. Serial dilutions of the antibiotic, reflecting varying antibiotic concentrations, are administered to a growth medium in separate test tubes.

To determine an antibiotic's MIC on fungus. Each of these tubes' growth media has been infected with a conventional fungus concentration as well as the corresponding antibiotic concentration at three distinct concentrations (10 g/mL, 1 g/mL, and 0.1 g/mL). Allow at least 24 hours for the tubes to incubate. Fungal development is shown by turbid broth tubes, whereas clear broth tubes indicate no fungal growth.

B) MIC Reports:

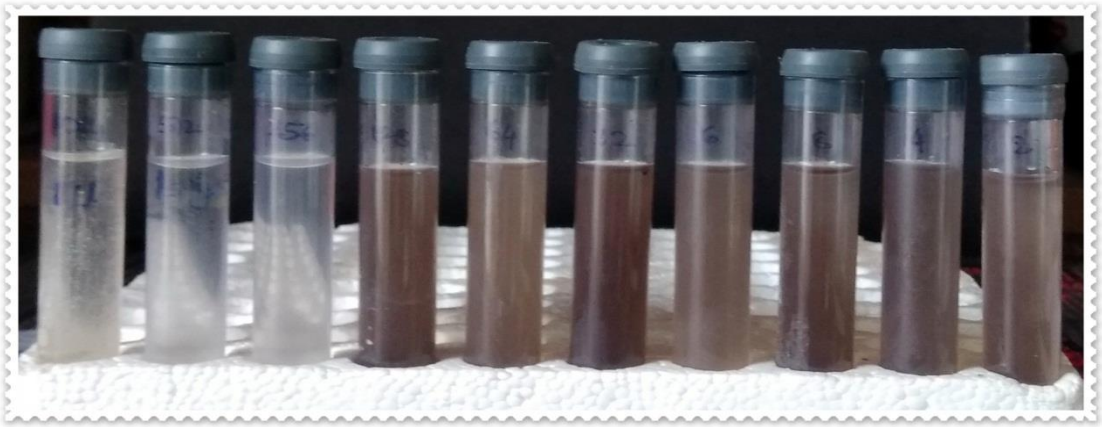

Figure 6.8: MIC of 1% TiO_2 Paint Sample on Aspergillus *niger*

C) Results of Minimum Inhibition Concentration (MIC) of Aspergillus niger

Table 6.7: MIC of Aspergillus niger against paint samples with control

Sr. No.	Concentration (µg/mL)	Control	1%	3%	5%	7%
1	1024	-	-	-	-	-
2	512	-	-	-	-	-
3	256	-	-	-	-	-
4	128	+	+	+	+	-
5	64	+	+	+	+	+
6	32	+	+	+	+	+
7	16	+	+	+	+	+
8	8	+	+	+	+	+
9	4	+	+	+	+	+
10	2	+	+	+	+	+
11	MIC (AN)	>512	>512	>256	>256	>128

+ means growth of microbial strain; -means no growth of microbial strains

At the concentration of 256 to 1024 µg/mL, almost all the percentile paint samples vanishes the fungal cultures but the 7% paint sample revealed the clear MIC resulted in the 128 µg/mL in Aspergillus niger fungal strain.

D) Results of Minimum Inhibition Concentration (MIC) of Aspergillus oryzae

Table 6.8: MIC of Aspergillus oryzae against paint samples with control

Sr. No.	Concentration (µg/mL)	Control	1%	3%	5%	7%
1	1024	-	-	-	-	-
2	512	-	-	-	-	-
3	256	+	+	+	+	-
4	128	+	+	+	+	+
5	64	+	+	+	+	+
6	32	+	+	+	+	+

7	**16**	+	+	+	+	+
8	**8**	+	+	+	+	+
9	**4**	+	+	+	+	+
10	**2**	+	+	+	+	+
11	**MIC (AO)**	**>512**	**>512**	**>256**	**>256**	**>128**

+ means growth of microbial strain; -means no growth of microbial strains

At the concentration of 512 to 1024 µg/mL, almost all the percentile paint samples vanishes the fungal cultures but the 7% paint sample revealed the clear MIC examined in the 256 µg/mL in Aspergillus oryzae fungal strain.

6.4.1.2 Static/Cidal Assay Properties:

A fungicidal (CIDAL) antibiotic is one that kills fungus without reliance on the patient's immune system to help. A fungistatic (STATIC) drug is one that prevents the organism multiplying. It doesn't matter if the patient is given a cidal or static drugs since, given enough time and assistance; their immune system is usually capable of dealing with the illness. The cidal drugs are only cidal when a sufficient amount of the antibiotic is administered; at low levels or dosages, they are essentially static. Historically, practitioners favored 'cidal' antifungal medicines, especially in severely sick patients. However, research to support the idea that using a 'cidal' agent first resulted in improved patient outcomes has been insufficient.

In the context of Aspergillus, do these disparate results owe only to the timing of medication treatment, or may there be other variables at play, such as whether the conidia germinated prior to drug administration Espinel-Ingroff examined the MICs and MFCs of amphotericin B and voriconazole against germinated and ingeminated conidia. The Voriconazole's MIC and MFC were both 0.5 g/mL, although amphotericin-B's MFC was somewhat higher, particularly in germinated conidia.

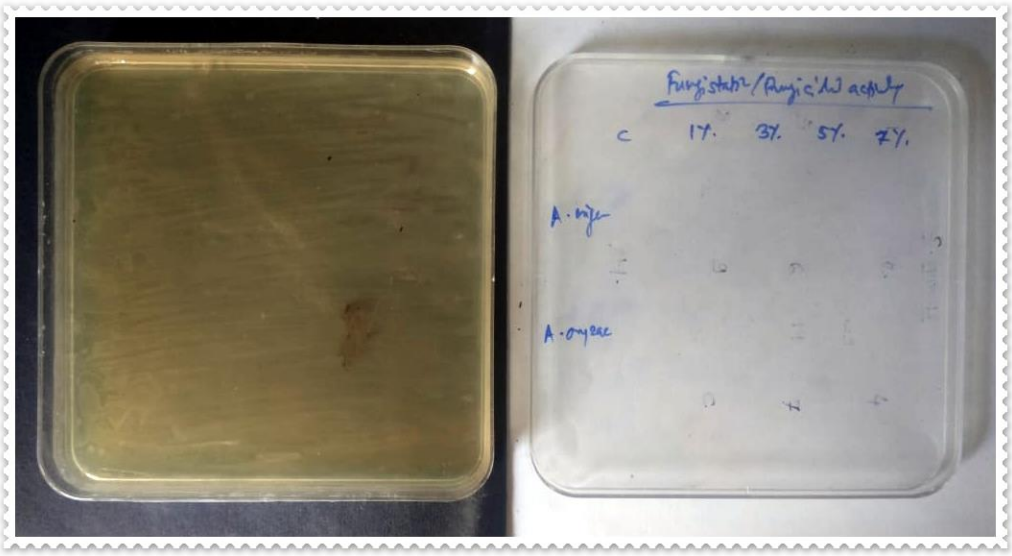

Figure 6.9: Fungi static and fungicidal report of the paint samples

Table 6.9: Static/Cidal growth of the paint samples with control (Fungi)

Species	Activity	Growth				
		Control	1%	3%	5%	7%
A.niger	**Static**	NA	NA	NA	-	-
	Cidal	NA	NA	NA	+	+
A.oryzae	**Static**	NA	NA	NA	+	-
	Cidal	NA	NA	NA	-	+

As per bacteriostatic and bactericidal activities of the percentile TiO_2 based paint samples were obtained for 1%, 3%, 5% and 7% concentrations equaling one time and substantial times the MIC, respectively. The bacteriostatic results found with control but 5% and 7% sample gives bactericidal activities in Aspergillus niger while only 5% sample showed bacteriostatic and 7% sample showed bactericidal properties against Aspergillus oryzae fungal strains.

6.4.2 Method of Antimicrobial Testing of Formulated Paint on Surface Coating:

The preapared paint samples were coated on the back surface of the tiles by using brush. Double coats were applied on the surface of the tiles and dried off. The percentile proportion of the paint samples 1%, 3%, 5% and 7% TiO_2 nanomaterial mixed with base oil paint coated on the surface with the control of base paint and labelled it as shown in the figures. All the sample were ready for antifungal test in the dry and wet condition condition.

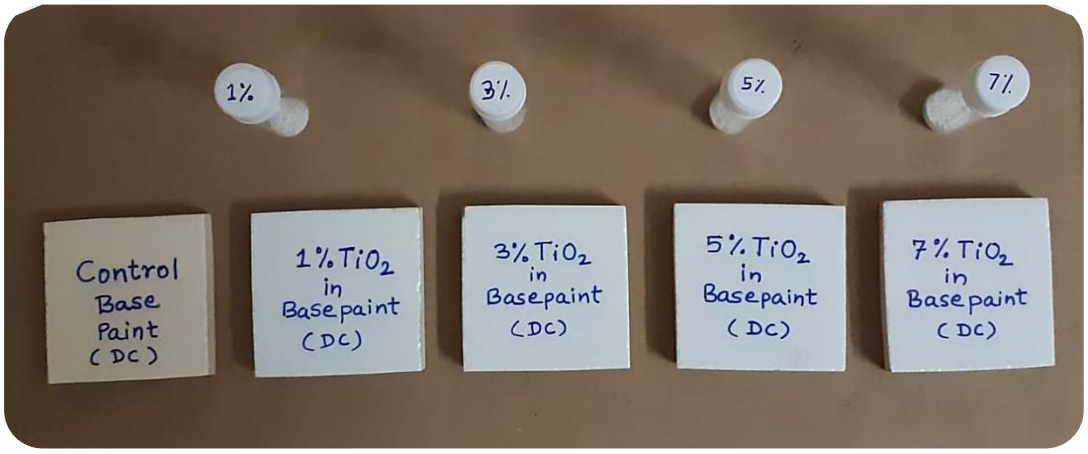

Figure 6.10: TiO_2 added paint coated tiles (1-7%) for dry test

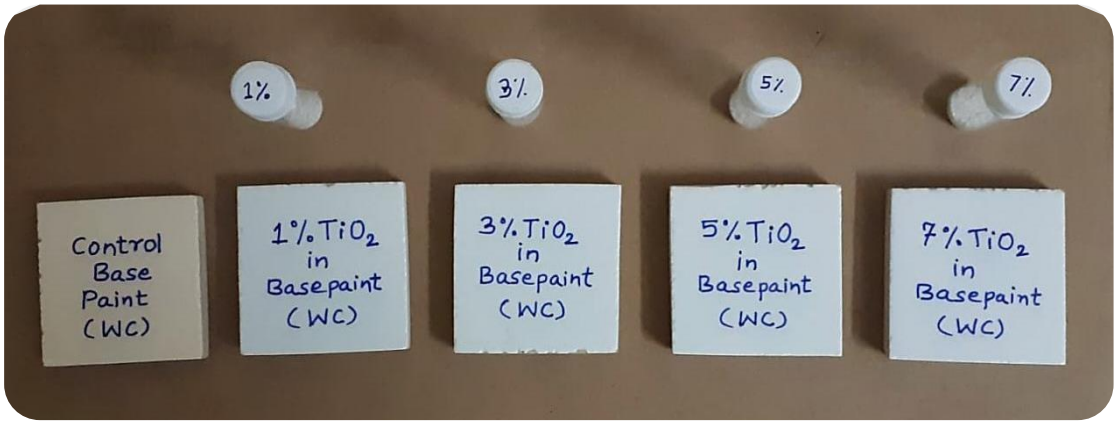

Figure 6.11: TiO_2 added paint coated tiles (1-7%) for wet test

6.4.3 Application and antifungal testing of paint samples on surfaces

6.4.3.1 Dry Culture Results of *Aspergillus niger*:

In the beginning of the antifungal activities of the prepared percentile oil paint samples 1% TiO_2 , 3% TiO_2 , 5% TiO_2 , 7% TiO_2 , and control base paint was applied on the plain surfaces on the back side of the tiles were tested against *Aspergillus niger* fungus strain in dry conditions and mole counts were taken. No Growth (NG) was found in dry condition as shown in the table 6.10.

Table-6.10: Dry Culture Result of AND

***Aspergillus niger* Dry Culture Result (AND) Mole Counts**						
Sr. No.	**Concentrations (%)**	**0th Day**	**7th Day**	**14th Day**	**21st Day**	**28th Day**
1	1% TiO_2	NG	10	18	32	36
2	3% TiO_2	NG	7	12	28	32
3	5% TiO_2	NG	1	2	7	13
4	7% TiO_2	NG	2	5	14	18
5	Control	NG	4	7	9	10

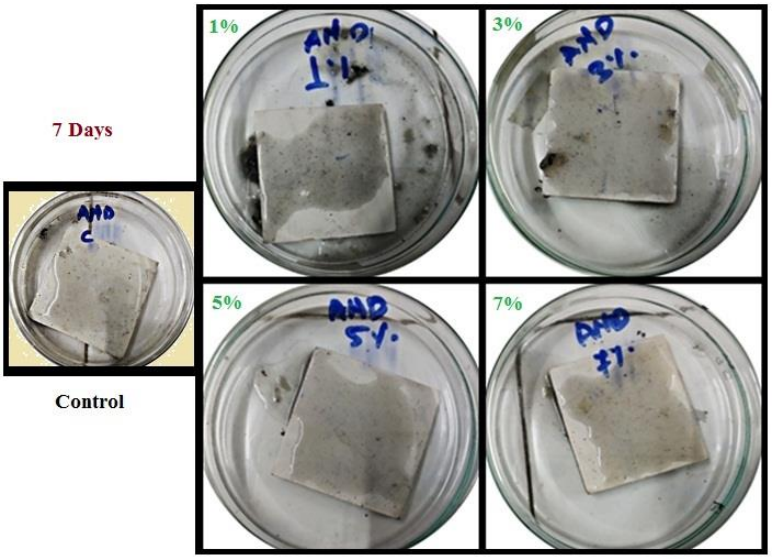

Figure 6.12: Aspergillus niger Dry Culture 7th day activity (1-7%)

AND-07 Days: In the 7th of the antifungal activities of the above prepared percentile painted samples. The antifungal growth of *Aspergillus niger* found on 1% TiO_2 concentration of the coated sample 10 moles, 3% TiO_2 concentration of the coated sample 7 moles, 5% TiO_2 concentration of the coated sample1 (one) mole, 7% TiO_2 concentration of the coated sample 2 moles, and control base paint 4 moles dry condition.

AND-14 Days: In the 14th of the antifungal activities of the above prepared percentile painted samples. The antifungal growth of *Aspergillus niger* found on 1% TiO_2 concentration of the coated sample 18 moles, 3% TiO_2 concentration of the coated sample 12 moles, 5% TiO_2 concentration of the coated sample 2 moles, 7% TiO_2 concentration of the coated sample 5 moles, and control base paint 7 moles dry condition.

AND-21 Days: In the 21st of the antifungal activities of the above prepared percentile painted samples. The antifungal growth of *Aspergillus niger* found on 1% TiO_2 concentration of the coated sample 32 moles, 3% TiO_2 concentration of the coated sample 28 moles, 5% TiO_2 concentration of the coated sample 7 moles, 7% TiO_2 concentration of the coated sample 14 moles, and control base paint 9 moles dry condition.

AND-28 Days: In the 28th of the antifungal activities of the above prepared percentile painted samples. The antifungal growth of *Aspergillus niger* found on 1% TiO_2 concentration of the coated sample 36 moles, 3% TiO_2 concentration of the coated sample 32 moles, 5% TiO_2 concentration of the coated sample 13 moles, 7% TiO_2 concentration of the coated sample 18 moles, and control base paint 10 moles dry condition.

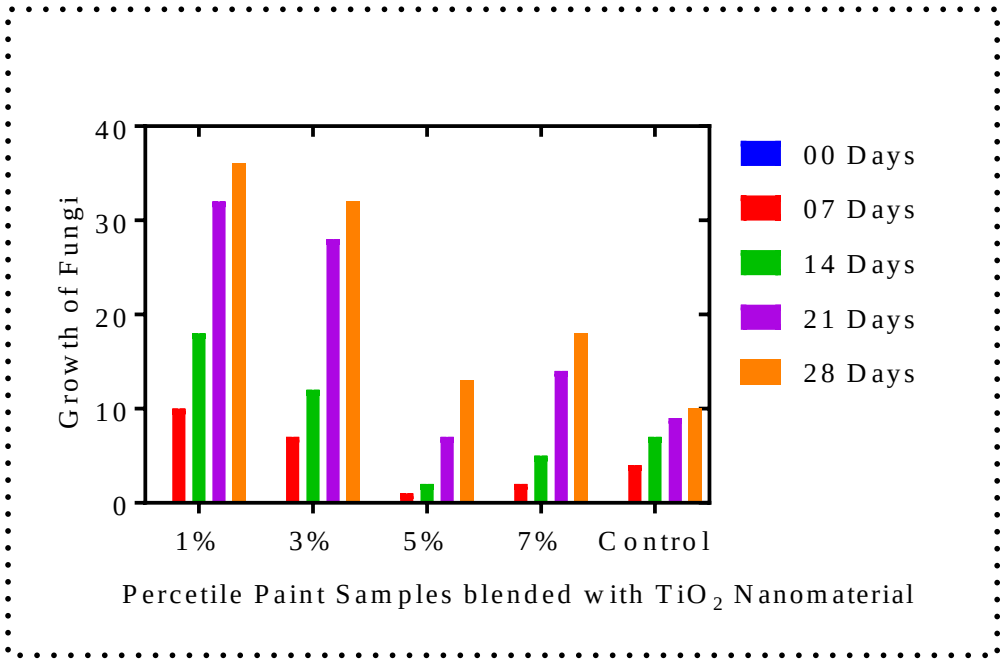

Figure 6.13: Aspergillus Niger Dry Condition (AND)

6.4.3.2 Wet Culture Results of *Aspergillus niger*:

In the start of the antifungal activities of the prepared percentile oil paint samples 1% TiO_2 , 3% TiO_2 , 5% TiO_2 , 7% TiO_2 , and control base paint was applied on the plain surfaces on the back side of the tiles were tested against *Aspergillus niger* fungus strain in wet conditions and mole counts were taken. No Growth (NG) was found in wet condition as shown in the table 6.11.

Table-6.11: Wet Culture Result of AND

Aspergillus Niger Wet Culture Result (ANW) Mole Counts						
Sr. No.	**Concentrations (%)**	**0^{th} Day**	**7^{th} Day**	**14^{th} Day**	**21^{st} Day**	**28^{th} Day**
1	1% TiO_2	NG	211	352	338	218
2	3% TiO_2	NG	288	428	387	281
3	5% TiO_2	NG	21	43	32	26
4	7% TiO_2	NG	106	120	76	53
5	Control	NG	233	245	251	263

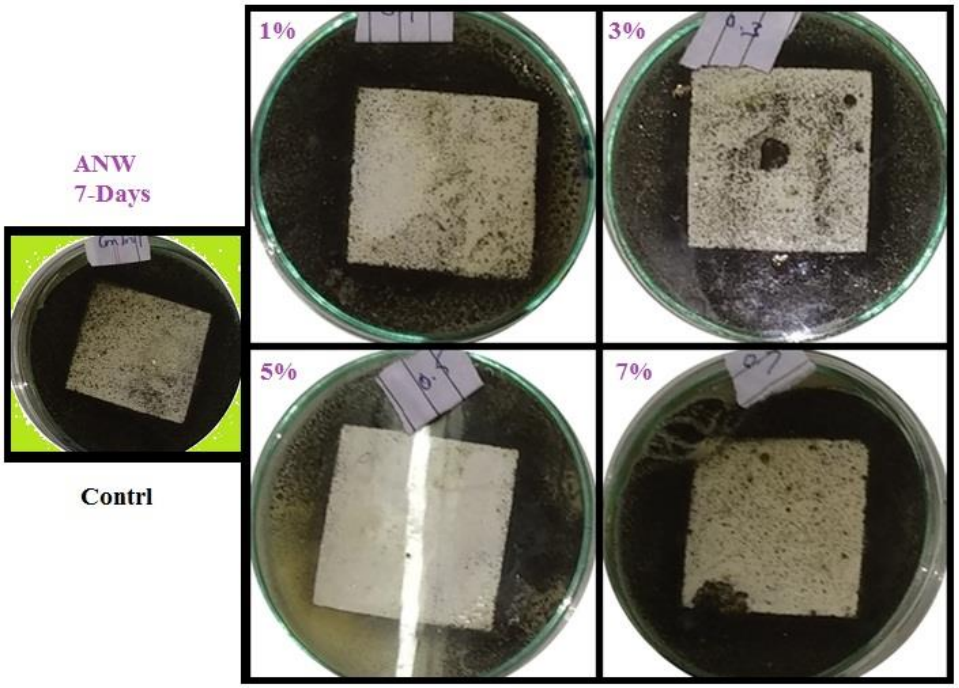

Figure 6.14: Aspergillus Niger Wet Culture 7th day activity (1-7%)

ANW-07 Days: In the 7th of the antifungal activities of the above prepared percentile painted samples. The antifungal growth of *Aspergillus niger* found on 1% TiO_2 concentration of the coated sample 211 moles, 3% TiO_2 concentration of the coated sample 288 moles, 5% TiO_2 concentration of the coated sample 21 moles, 7% TiO_2 concentration of the coated sample 106 moles, and control base paint 233 moles in wet condition.

ANW-14 Days: In the 14th of the antifungal activities of the above prepared percentile painted samples. The antifungal growth of *Aspergillus niger* found on 1% TiO_2 concentration of the coated sample 352 moles, 3% TiO_2 concentration of the coated sample 428 moles, 5% TiO_2 concentration of the coated sample 43 moles, 7% TiO_2 concentration of the coated sample 120 moles, and control base paint 245 moles in wet condition.

ANW-21 Days: In the 21st of the antifungal activities of the above prepared percentile painted samples. The antifungal growth of *Aspergillus niger* found on 1% TiO_2 concentration of the coated sample 338 moles, 3% TiO_2 concentration of the coated sample 387 moles, 5% TiO_2 concentration of the coated sample 32 moles, 7%

TiO_2 concentration of the coated sample 76 moles, and control base paint 251 moles in wet condition.

ANW-28 Days: In the 28th of the antifungal activities of the above prepared percentile painted samples. The antifungal growth of *Aspergillus niger* found on 1% TiO_2 concentration of the coated sample 218 moles, 3% TiO_2 concentration of the coated sample 281 moles, 5% TiO_2 concentration of the coated sample 26 moles, 7% TiO_2 concentration of the coated sample 53 moles, and control base paint 263 moles in wet condition.

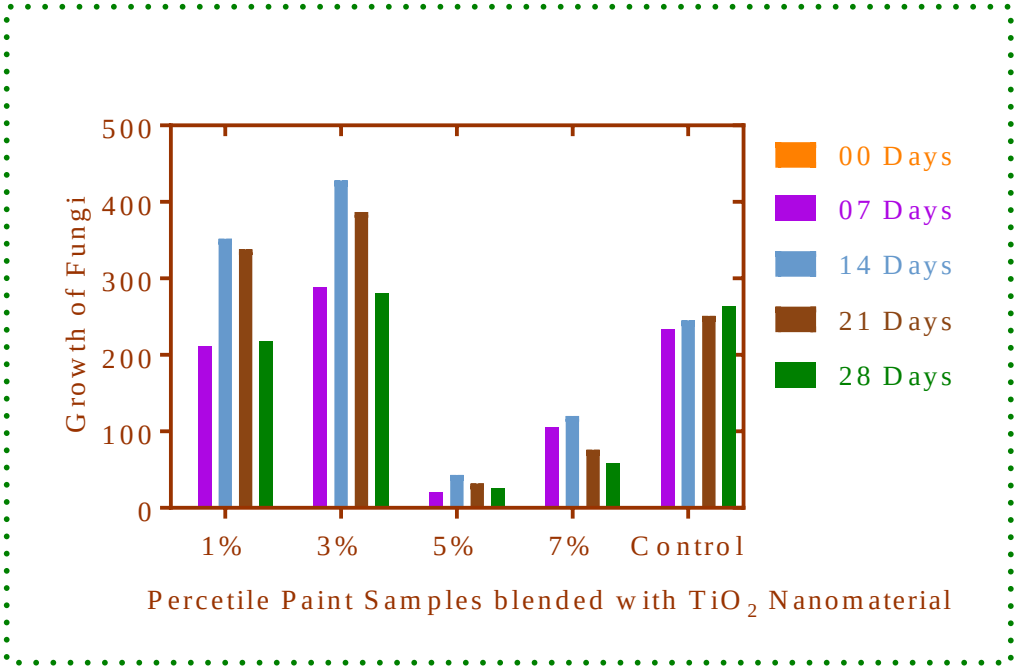

Figure 6.15: Aspergillus Niger Wet Condition (ANW)

6.4.3.3 Dry Culture Results of *Aspergillus Oryzae*:

In the beginning of the antifungal activities of the prepared percentile oil paint samples 1% TiO_2 , 3% TiO_2 , 5% TiO_2 , 7% TiO_2 , and control base paint was applied on the plain surfaces on the back side of the tiles were tested against *Aspergillus Oryzae* fungus strain in dry conditions and mole counts were taken. No Growth (NG) was found in dry condition as shown in the table 6.12.

Table-6.12: Dry Culture Result of AOD

***Aspergillus Oryzae* Dry Culture Result (AOD) Mole Counts**						
Sr. No.	**Concentrations (%)**	**0th Day**	**7th Day**	**14th Day**	**21st Day**	**28th Day**
1	1% TiO_2	NG	5	52	110	118
2	3% TiO_2	NG	6	8	12	18
3	5% TiO_2	NG	4	4	8	10
4	7% TiO_2	NG	7	8	10	12
5	Control	NG	20	35	32*	41*
'*' tile colour changed						

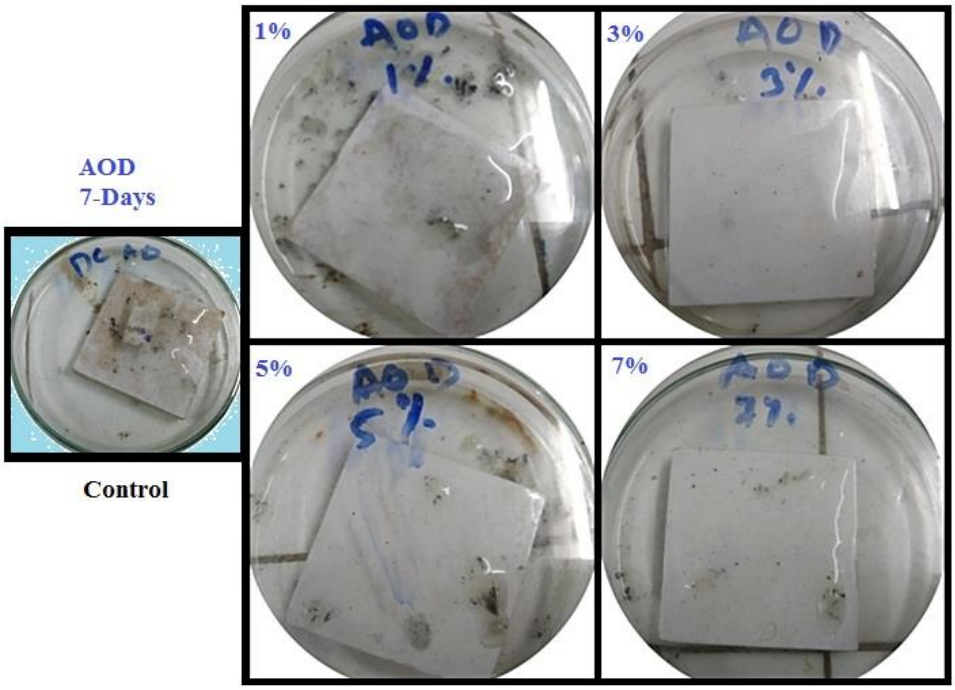

Figure 6.16: Aspergillus Oryzae Dry Culture 7th day activity (1-7%)

AOD-07 Days: In the 7th of the antifungal activities of the above prepared percentile painted samples. The antifungal growth of *Aspergillus Oryzae* found on 1% TiO_2 concentration of the coated sample 5 moles, 3% TiO_2 concentration of the coated sample6moles, 5% TiO_2 concentration of the coated sample 4 moles, 7% TiO_2 concentration of the coated sample 7 moles, and control base paint 20 moles dry condition.

AOD-14 Days: In the 14th of the antifungal activities of the above prepared percentile painted samples. The antifungal growth of *Aspergillus Oryzae* found on 1% TiO_2 concentration of the coated sample 52 moles, 3% TiO_2 concentration of the coated sample 8 moles, 5% TiO_2 concentration of the coated sample 4 moles, 7% TiO_2 concentration of the coated sample 8 moles, and control base paint 35 moles dry condition.

AOD-21Days: In the 21stof the antifungal activities of the above prepared percentile painted samples. The antifungal growth of *Aspergillus Oryzae found* on 1% TiO_2 concentration of the coated sample 110 moles, 3% TiO_2 concentration of the coated sample 12 moles, 5% TiO_2 concentration of the coated sample 8 moles, 7% TiO_2 concentration of the coated sample 10 moles, and control base paint found 32 moles with the colour change of tile in dry condition.

AOD-28 Days: In the 28thof the antifungal activities of the above prepared percentile painted samples. The antifungal growth of *Aspergillus Oryzae* found on 1% TiO_2 concentration of the coated sample 118 moles, 3% TiO_2 concentration of the coated sample 18 moles, 5% TiO_2 concentration of the coated sample 10 moles, 7% TiO_2 concentration of the coated sample 12 moles, and control base paint 41 moles with the colour change of tile in dry condition.

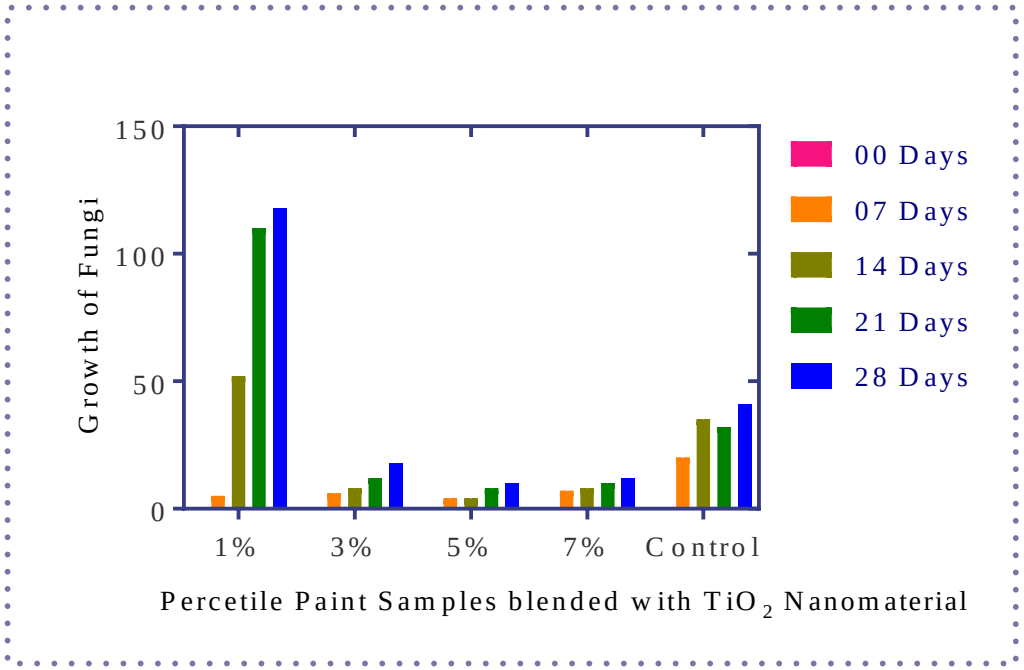

Figure 6.17: *Aspergillus Oryzae* Dry Condition (AOD)

6.4.3.4 Wet Culture Results of *Aspergillus Oryzae*:

In the start of the antifungal activities of the prepared percentile oil paint samples 1% TiO_2 , 3% TiO_2 , 5% TiO_2 , 7% TiO_2 , and control base paint was applied on the plain surfaces on the back side of the tiles were tested against *Aspergillus Oryzae* fungus strain in wet conditions and mole counts were taken. No Growth (NG) was found in wet condition as displayed in the table 6.13.

Table-6.13: Wet Culture Result of AOW

***Aspergillus Oryzae* Wet Culture Result (AOW) Moles Counts**						
Sr. No.	**Concentrations (%)**	**0th Day**	**7th Day**	**14th Day**	**21st Day**	**28th Day**
1	1% TiO_2	NG	10	402	389	401
2	3% TiO_2	NG	4	426	368	372
3	5% TiO_2	NG	0	273	189	148
4	7% TiO_2	NG	0	251	272	192
5	Control	NG	2	382	426	427

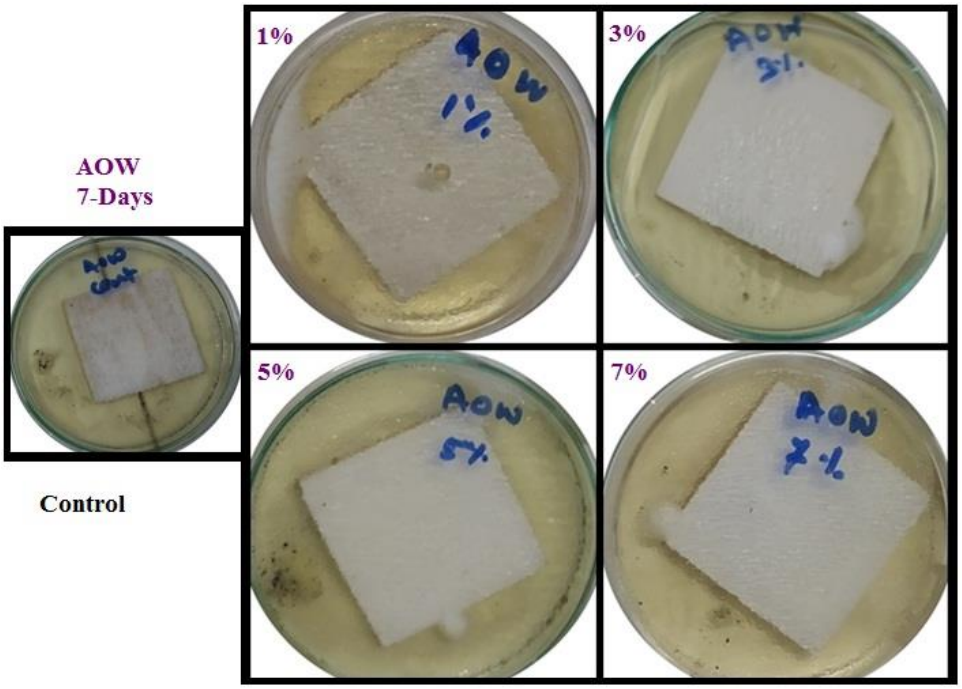

Figure 6.18: Aspergillus Oryzae Wet Culture 7th day activity (1-7%)

AOW-07 Days: In the 7th of the antifungal activities of the above prepared percentile painted samples. The antifungal growth of *Aspergillus Oryzae* found on 1% TiO_2 concentration of the coated sample 10 moles, 3% TiO_2 concentration of the coated sample4moles, 5% TiO_2 and 7% TiO_2 concentration found no growth, and control base paint 2 moles in wet condition.

AOW-14 Days: In the 14th of the antifungal activities of the above prepared percentile painted samples. The antifungal growth of *Aspergillus Oryzae found* on 1% TiO_2 concentration of the coated sample 402 moles, 3% TiO_2 concentration of the coated sample 426 moles, 5% TiO_2 concentration of the coated sample 273 moles, 7% TiO_2 concentration of the coated sample 251 moles, and control base paint 382 moles in wet condition.

AOW-21 Days: In the 21stof the antifungal activities of the above prepared percentile painted samples. The antifungal growth of *Aspergillus Oryzae* found on 1% TiO_2 concentration of the coated sample 389 moles, 3% TiO_2 concentration of the coated sample 368 moles, 5% TiO_2 concentration of the coated sample189 moles, 7% TiO_2 concentration of the coated sample 272 moles, and control base paint 426 moles in wet condition.

AOW-28 Days: In the 28th of the antifungal activities of the above prepared percentile painted samples. The antifungal growth of *Aspergillus Oryzae* found on 1% TiO_2 concentration of the coated sample 401 moles, 3% TiO_2 concentration of the coated sample 372 moles, 5% TiO_2 concentration of the coated sample 148 moles, 7% TiO_2 concentration of the coated sample 192 moles, and control base paint 427 moles in wet condition.

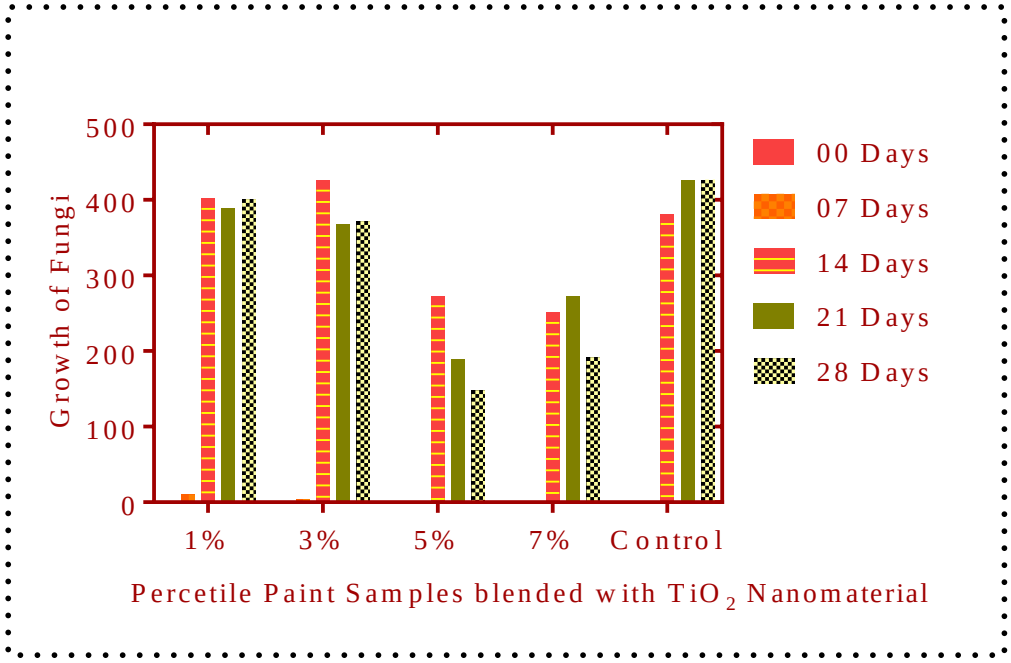

Figure 6.19: Aspergillus Oryzae Wet Condition (AOW)

6.5 Conclusions:

- From the Federal test method, the 5% TiO_2 and 7% TiO_2 sample shows no growth for Aspergillus oryzae and Aspergillus niger,
- The antifungal zone of inhibition for 5% TiO_2 and 7% TiO_2 sample for Aspergillus oryzae and Aspergillus niger give better results than standard.
- MIC for antifungal gives a low concentration at 128 µg/mL for 5% TiO_2 and 7% TiO_2 for Aspergillus niger and above 256 µg/mL concentration for 5% TiO_2 and 7% TiO_2 for Aspergillus oryzae.
- Static and cidal test for Aspergillus niger kills fungus permanently at 5% TiO_2 and 7% TiO_2 but Aspergillus oryzae kills permanently at 7% TiO_2 paint sample and cidal at 5% TiO_2 paint sample.
- The Aspergillus niger and Aspergillus oryzae dry culture and wet culture test shows satisfactory results for 5% TiO_2 and 7% TiO_2 paint sample.
- We can concluded that 5% TiO_2 and 7% TiO_2 paint sample give better results as compare to control paint sample. therefore, it can be proposed for the surface coating of building.

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CHAPTER - 7

CHAPTER – 7

PHOTOCATALYTIC INHIBITION OF FUNGI

7.1 Introduction:

The current growth of drug-resistant bacteria around the world the parallel decrease in all scholarly activities Towards laboratories and pharmacy firms the development of modern, combat-resistant antibacterial agents the management of life threatening strains faces a significant danger with pathogens. It is important, therefore, to grow novel antimicrobial techniques that are non-invasive and non-toxic which work more effectively and more rapidly than the antibiotics of today, and which pathogens are not readily able to establish tolerance to one interesting response to conventional antibiotics is Photocatalytic Antimicrobial Inactivation [1-2].

Antimicrobial blue light therapy, which is a specialized form of antimicrobial photo-catalytic therapy, is currently gaining increasing popularity due to its intrinsic antimicrobial effect. Without exogenous photo-sensitization being applied by antimicrobial blue light therapy decreases the risk of possible adverse effects on eukaryotic cells, decreasing the likelihood of injury to human tissues. In comparison, as opposed to antimicrobial photo-catalytic treatment, the effect of antimicrobial blue light therapy on non-pathogenic microorganisms can be slightly decreased. In view of these features, there is a growing interest in investigating the possible application of antimicrobial blue light therapy to the sensitization of healthcare facilities, for example in the disinfection of hospital wards, patient rooms and operating rooms of enrolled patients. Taking advantage of a wave length of 405 nm, High Intensity Narrow Spectrum light may be used by installing special lighting systems in the chosen space. Compared to the normal manual cleaning, which, by being incredibly worker-dependent, has a lot of flexibility, this form of sensitization may be more efficient [3-5].

In a recent report, optical photo catalytic antibacterial behavior was reported in Fe-containing TiO_2 NPs against both gram-negative and gram-positive bacteria under fluorescent light. Like Akhavan et al., Layda et al. also reported the visible light photo-inactivation of gram-negative bacteria using CNT–doped TiO_2 thin films generated by a dip-coating process. After modification TiO_2 NPs become visible light

active material and useful for photo-inactivation bacteria, but the time needed for photo-inactivation is more when compare to UV light exposure. Since the UV-A light can be observed, there is potential to concurrently create an antibacterial light with rapid photo-killing of bacteria [6-7].

Therefore, there is a need to think about it carefully and establish an appropriate plan to avoid or diminish the spread of infectious diseases in medical facilities. In an attempt to deter or even to remove any bacterial pollution, the self-sterilizing surfaces are able to minimize the rate of complete bacterial infection from infected surfaces. In the view of the above consideration here the researcher has to prepare antibacterial or anti-biofouling surface coating paints, especially at the nanoscale. The powdered titanium dioxide nanomaterial-based oil paints with different percentages demonstrated strong antifungal properties of the titanium dioxide nanomaterial with paint. In the view of results, it was noticed that the TiO_2based oil paint used for surface coating function could be used with the UV light potential surface coating materials.

7.2 Basics of Photocatalytic:

Photo catalytic treatment refers to the use of a light source visible light of a sufficient wavelength, an oxidizing agent like molecular oxygen, O_2 and an intermediate agent (photosensitizing agent, PS) capable of consuming and transmitting energy from the light source to the molecular source. Oxygen resulting in the development of extremely cytotoxic organisms' single oxygen ($^1O_2$), hydrogen peroxide (H_2O_2) and free radicals such as superoxide (O^-) and hydroxyl radical induces multi-targeted damage to and degradation of living tissues [8-9]. These reactive oxygen species can be produced by two mechanisms or pathways, known as type-I and type-II, requiring the existence of oxygen molecule. The photosensitizer in the singlet ground state receives a photon in the presence of light, producing the excited singlet state. Then, by returning to the singlet ground state with fluorescence emission, it can lose energy or it can be transformed into the long-lived triplet state by an intersystem crossing method. By phosphorescence emission, this excited triplet-state PS can decay to ground status or can react with a substrate, namely an electron donor molecule. In this

situation, the development of radical ions may lead to radical ions that react with oxygen in the ground state ($3O_2$), creating ROS (type-I mechanism). The excited triplet-state PS can also directly transfer energy to molecular oxygen, supplying the excited singlet state (type-II mechanism). In figure 7.1 shows processes can occur concurrently, but the prevalent one is, in general, type-II. Irreversible harm to proteins, nucleic acids and lipids can be induced by cytotoxic organisms [10-11].

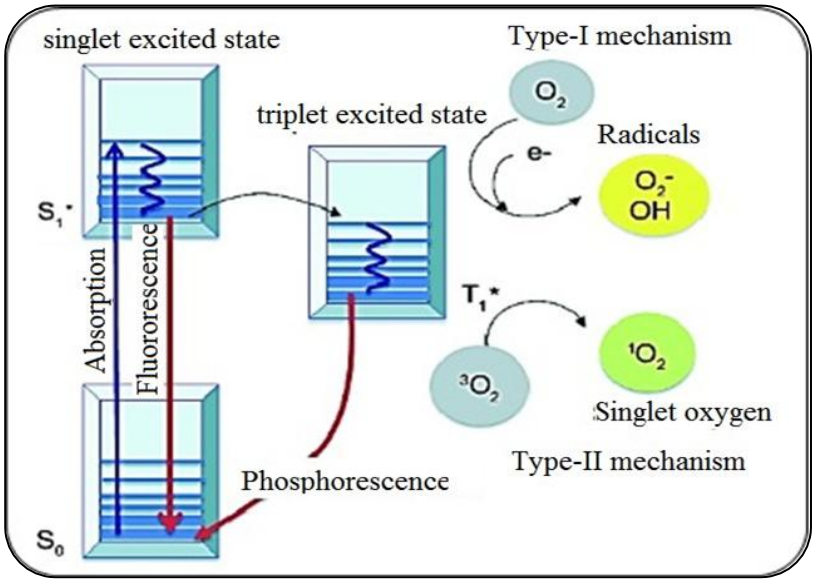


Figure 7.1: Phosphorescence emission

7.2.1 Photocatalytic:

Photo catalytic is a concept of, relating to, or having the property of intensifying or inducing a toxic reaction to light as in the destruction of cancer cells stained with a light-sensitive dye in living systems. Microbial exposure to either exogenous or endogenous photo-sensitizer molecules is needed by the principle of photo-catalytic inactivation, accompanied by visible light energy, usually wavelengths in the red/near infrared region that induce photo-sensitizer excitation resulting in the creation of singlet oxygen and other reactive oxygen species that react with intra-cellular components, and co-components.

Concept of Photocatalytic Therapy:

In both neoplastic and non-neoplastic disorders, photo catalytic therapy (PCT) is a comparatively recent therapeutic modality involving the light stimulation, in the presence of molecular oxygen, of such dyes (photosensitizers) that the target tissue

has picked up quite selectively. Therefore, for the procedure to precede, all three components like photosensitizer, light and oxygen have to be effective. The concept of photodynamic therapy was discovered by Oskar Raab and Hermann von Tappeiner in 1900 [13] who noticed that Paramecium spp. After staining with acridine orange, protozoans were destroyed and eventual exposed to bright light. In the 1970s, PCT was originally introduced as a cancer drug after porphyrins were shown to be exclusively contained in tumours [14]. Since then, PCT has been used clinically for the treatment of multiple malignancies and is an accepted medication for the destruction of age-related macular degeneration through choroidal neovascularization. Antimicrobial PCT has recently been suggested as an alternative solution to dispersed infections. Photodynamic treatment requires the usage of a non-toxic light-sensitive dye named a photosensitizer to match the absorption range of the PS, paired with harmless visible light of the required wavelength. The PS enters an excited state after photon absorption that may interfere with atmospheric oxygen, resulting in the creation of reactive oxygen species (ROS). PCT is a strongly selective modality as first undesirable cells or tissue can be attacked by the PS and second cell death is spatially confined to regions where light is added to the required wavelength. Since certain PS binds to microbial cells easily and selectively, it was proposed that PCT could be used as an anti-infective approach; in the mid-1990s, turn out to be representativeness [15-17].

Photocatalytic Rehabilitation Mechanism:

When the photosensitizer receives a photon and undergoes simultaneous or concurrent decays that result in reactions of intramolecular energy transfer, the mechanism is triggered. Photo-oxidation by radicals (type-I reaction), photo-oxidation by singlet oxygen (type-II reaction) and non-oxygen photoreaction (type-III reaction) are the major classes of reaction. These processes may occur concurrently or in competition. Briefly, it is triggered to an excited singlet condition after the photosensitizer absorbs radiation. By the emission of light (fluorescence) or heat, molecules in this condition readily decay back to the ground state, or they may cross to the triplet state. Furthermore, molecules can undergo reactions of type I and III in the excited singlet state. In the triplet condition, the photosensitizer may react with ground-state oxygen to create a single-state oxygen (type-II reaction), decay through phosphorescence to

the ground state, or undergo type I and III reactions. In PDTT, single oxygen (a non-radical but extremely reactive source of oxygen) is normally recognized as the most harmful species. Some reactive oxygen species can also be involved in the tumor ablation induced by PCT [18-20]

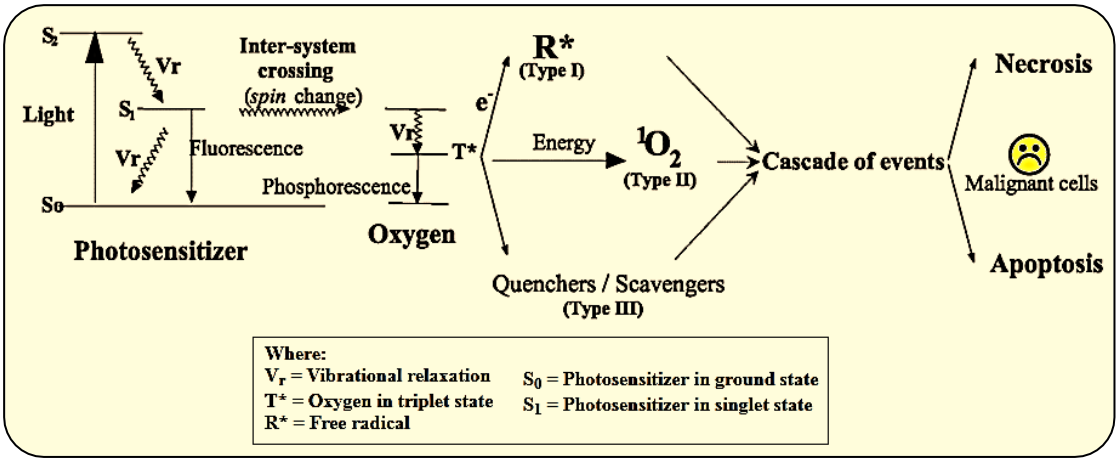


Figure 7.2: Process of Photocatalytic Therapy

It is also important to thoroughly elucidate the dynamic essence of the tumor reaction to PCT. The processes of photocatalytic therapy show in figure 7.2. In malignant cells or inside tumor vasculature cells, PCT depends on photocatalytic incidents. In the above case, deep symptoms, including blood flow stasis, vascular breakdown, and vascular leakage, can result from damage to the tumor vasculature. PCT has been shown to cause apoptosis means a controlled mechanism of cell death responsible for the orderly elimination of cells during normal tissue development. Apoptosis results from the signaling of cell stress in response to toxic agents and culminates in the activation of a cascade of cysteine proteases, known as capsizes, that catalyze the final degradation of key cellular proteins, including the poly (ADP-ribose) polymerase nuclear protein. The first clinical symptoms of PCT reaction are gross edema and erythema in animal systems [21-24].

7.2.2 Photocatalytic TiO_2:

For several years, TiO_2 photocatalytic properties have been reported, but optimizing the photo-catalytic activity under visible light for antimicrobial applications remains a problem. The photo-catalytic activity improvement techniques are to raise surface region, decrease the duration of the carrier migration path, pick more active facets and expand the band distance into the visible spectrum. Most of the research attention has been centered on nanoparticles which, compared to bulk phases, have a higher specific surface area and a shorter excited migration route to an active surface due to decreased recombination of electrons and holes at internal crystal defects, crystal thicknesses smaller than 15 nm reported higher photo-catalytic activity than poly-crystals [25-29].

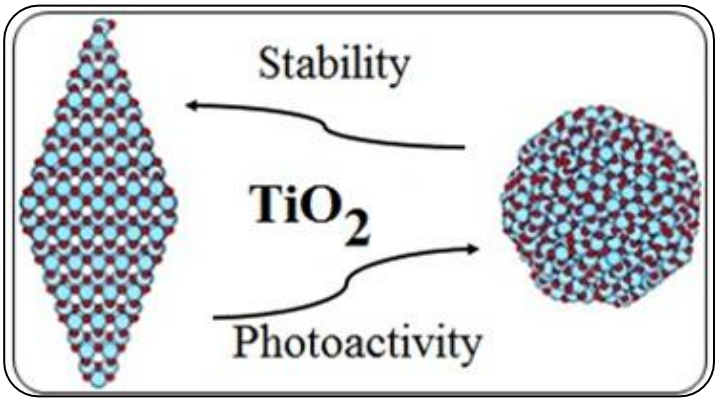
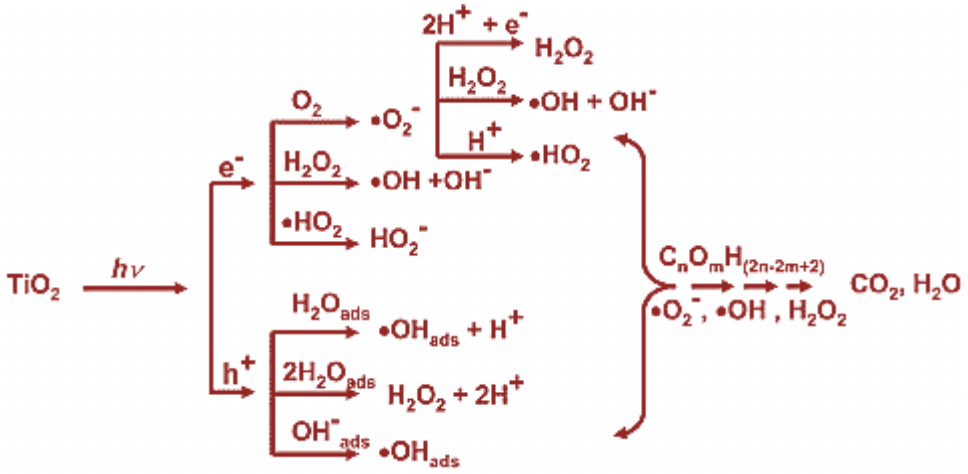


Figure 7.3: Photo activity of TiO_2

Upon the absorption of light by the photo catalyst, it causes the photochemical transition by consuming light as shown in the figure 7.3. This method for achieving stronger photo catalytic operation allows one to have at least one reactant in contact with the catalyst's surface. Unlike non-catalytic reactions, the degree of an association between the solid and reactant relies on both chemisorption and physical adsorption. The actual adsorption is the condensation of a canister vapour to form liquid or the liquefaction of gas on a solid surface, attributable to molecular contact, by Van der Waals forces. The reason for chemisorption is that electrochemical rearrangement contributes to electrostatic attraction between both phases. The larger the pore size and basic surface area of the adsorbent, the greater would be the adsorption and desorption to and from reaction mixture [30].

Reaction Mechanism of Photocatalytic TiO_2:

Photo catalysis occurs as a compound is responsible for operating on an active part (surface phenomenon), resulting in a chemical reaction. The strongly oxidized organisms (such as a radical), though possessing free electrons which could become in a specific way from an adsorbed water or oxygen molecule interacting with the photoreaction created holes and electrons. A fluorescence in the same pattern as in real light, a fluorescent spectrum of optical wavelengths, is generated by irradiation of light having an intensity greater than the energy gap (3.2 eV) corresponding to UV wavelengths of 290~380 nm. The electrons are exited from the valence band to the conduction band, and in doing so, they leave behind photo generated gaps in the conduction band. In this process, excited electrons and holes behave similarly to chemical reactions, usually implying that energy is passed from one to the other and each may be used to do work. Owing to photo-activated redox reactions, nanostructures of Titania may result in a number of photo–induced phenomena. This can include a model of the most widely used pathways to explain the photo generation of reactive radicals, the reactivity of the radical, and its ability to react with oxygen [31].



The rate of recombination is reduced when photo-generated charge carriers compete with the recombination propensity. In comparison to other semiconductors, TiO_2 has a slow rate of charge carrier recombination, resulting in longer electron diffusion lengths figure 7.4. The mechanism that creates a single photon, a photo-generated electron-hole pair, requires at least 0.1ns to influence chemical reactions. The presence of localized states within titanium dioxide's band gap traps photo-generated

charge carriers and adds to increased carrier separation[32].

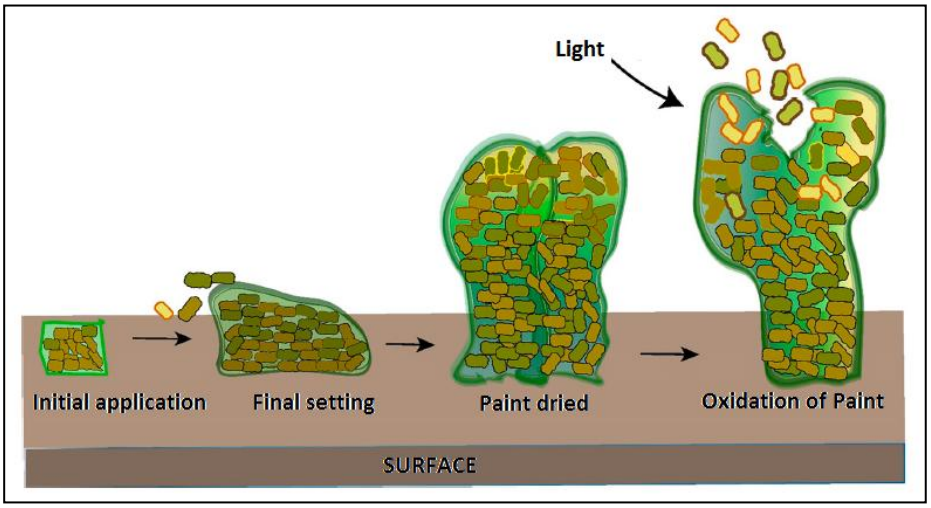


Figure 7.4: Photo activity of TiO_2 based paint on surface coating

7.2.3 Photocatalytic TiO_2 antifouling paint for healthcare:

According to figures published by the CDC, one in every four patient- borne infections is a life-threatening infection that the healthcare system in the world faces every year [33]. figure 7.5 shows Photocatalytic activity cycle. HAIs are triggered by a host of various species, one of which is Methicillin Resistant Staphylococcus aureus (MRSA), Clostridium difficile (*C. difficile*) and Escherichia coli (*E. coli*). At the latest count, the European Center for Disease Prevention and Control reports that more than 4 million HAIs occur throughout Europe per year and that about 37,000 perish as a direct consequence. A similar disorder of HAIs is present in the whole world. In the past ten years the Centers for Disease Control has placed in motion a range of measures to eliminate health-care-associated diseases, including screening, monitoring, and strengthened infection control recommendations. Primary care physicians have to be most conscious when working with diseases at admitted patients such as central line-associated bloodstream, catheter-associated urinary tract infections and surgical site infections. MRSA diseases and the flu rates of hospital acquired infections have been on the rise [34-38].

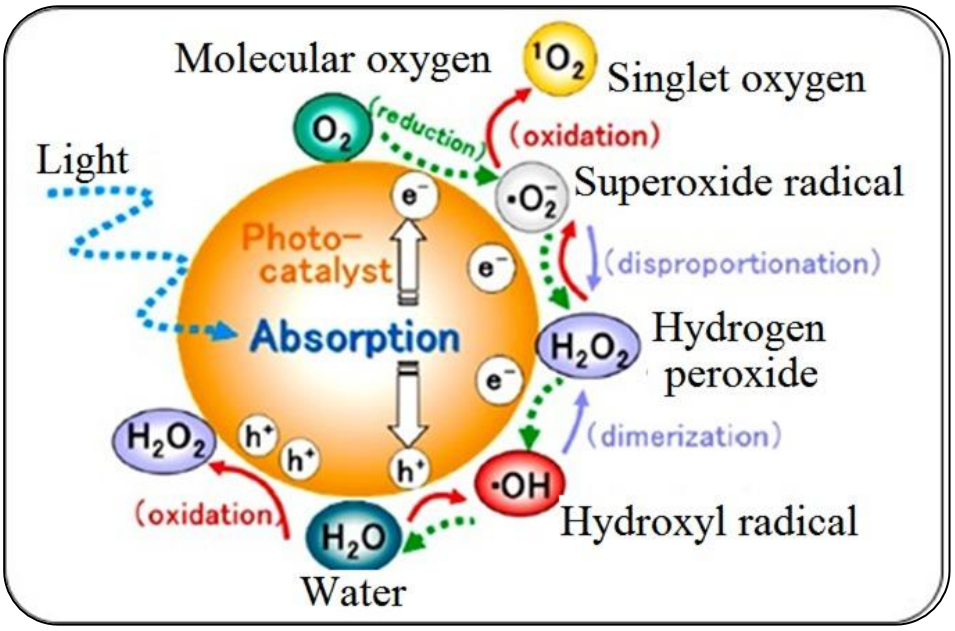


Figure 7.5: Photocatalytic activity cycle

7.3 Experimental Methods:

7.3.1 UV Study of the TiO_2 based paint samples:

A) Materials Method and Instrument:

The Instruments used Spectroquant Pharo 100 UV/Visible Spectrophotometer available at Dr. D.Y. Patil School of Technology, Pune. 1%, 3%, 5% and 7% TiO_2 prepared paint samples, base paint, Toluene, Graduated Pipette, GraphPad Prism Analysis Software etc.

B) Experimental Procedure:

In the beginning of the experimental process, initially tolerance were uncorrected by using toluene solution. The 0.5 mL prepared paint samples (1%, 3%, 5%, 7% TiO_2 and base paint) were taken and diluted with the 4.5 mL of toluene shacked until homogeneous solution occurs and became 1% sample. Then the solution is poured in to the cuvette (5 mL) and the checked the absorbance at 10 mm with the different wavelength (320 nm, 400 nm and 520 nm) and calculated the transmittance by using the formula $\mathbf{A = 2 - \log_{10} \%T}$ [39-48] as shown in the table 7.1.

7.3.2 Antifungal testing method after U.V. treatment

Antifungal testing (Disc Diffusion Assay):

Cultures used:

Microorganism	Strain Name	Strain reference
Fungi	Aspergillus niger	NCIM 545
	Aspergillus oryzae	NCIM 570

NCIM: National Collection of Industrial Microorganisms, National Chemical Laboratory (NCL), Pune 411008 [India]

A) Protocol

Preparation of Mueller-Hinton plate

Allow an MH agar plate to get to room temperature (one for each organism to be examined). To avoid condensation, it's best to leave the plates in the plastic sleeve while they warm up. If there is visible liquid on the surface of the agar, flip the plate and leave the lid ajar to let the excess liquid to drain and evaporate. Plates may be dried in a 35°C incubator or at ambient temperature in a laminar flow hood (usually 10 to 30 minutes). Label each MH agar plate appropriately for each organism to be examined.

Concentration of compounds

Stock solution [1024microgram per mL] of each compound was prepared in dimethyl sulphoxide. The assay was carried out by taking concentration 1024 microgram paint per disk. Hi-media antibiotics disk: Amphotericin B (10 microgram/disk) moistened with water are used as standard.

7.4 Results and Discussion:

7.4.1 UV Study of the TiO_2 based paint samples:

Observation Outputs:

Table 7.1: Absorbance and Transmittance of Paint Samples

Sr. No.	Concentrations (%)	Wavelengths (nm)					
		320 nm		400 nm		520 nm	
		AU	%T	AU	%T	AU	%T
1	1% TiO_2	0.416	38	0.524	30	0.616	24
2	3% TiO_2	0.634	22	0.795	16	0.836	15
3	5% TiO_2	0.781	17	0.767	17	0.851	14
4	7% TiO_2	2.312	0.49	1.972	1	2.124	0.75
5	Ctrl (Base Paint)	0.294	51	0.267	54	0.357	44

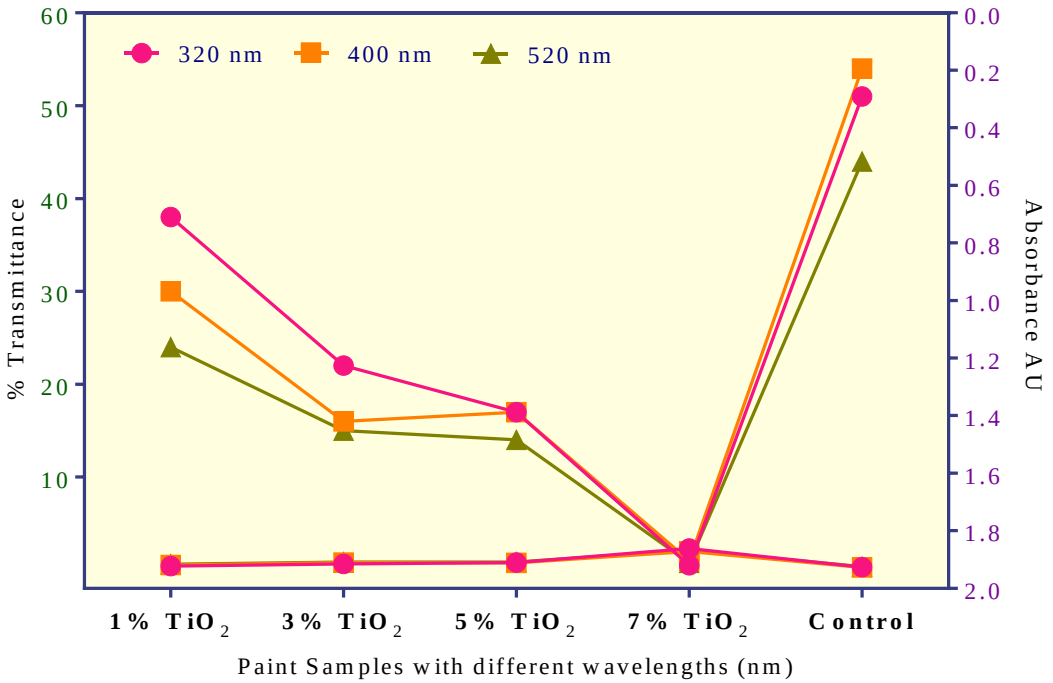


Figure 7.6: Absorbance and Transmittance graph of different wavelength (nm)

It was observed in the figure 7.6 that; increase in percentile TiO_2 in the base paint the Transmittance and absorbance also increases in 320 nm, 400 nm and 520 nm wavelengths as compared to the control base paint.

7.4.2 Antifungal testing of paint samples after U.V. treatment:

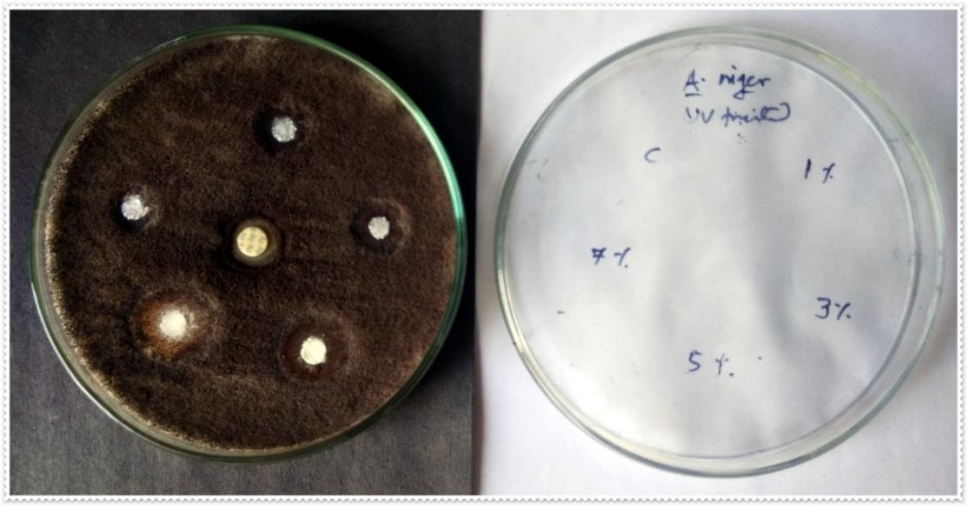


Figure 7.7: Antifungal activities of paint samples after UV treatment with *A. niger*

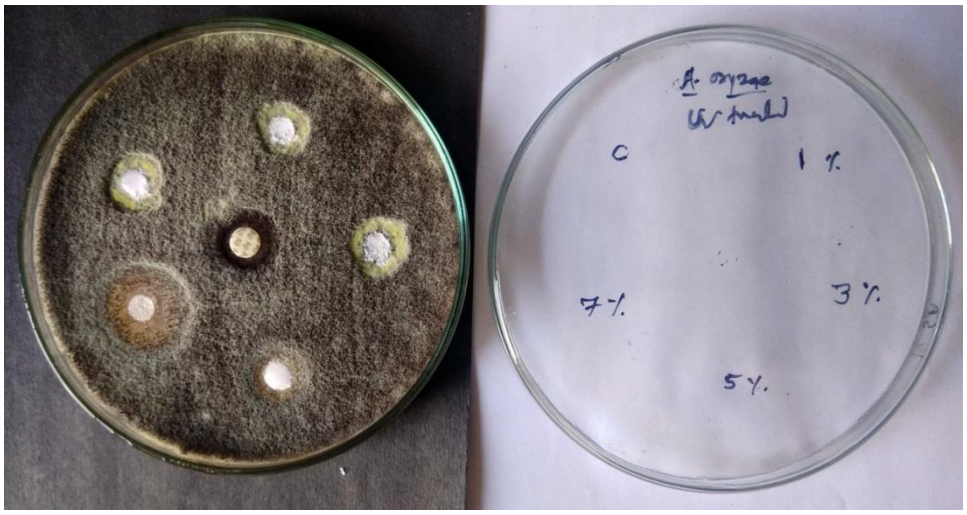


Figure 7.8: Antifungal activities of paint samples after UV treatment with *A. oryzae*

After UV treatment shown in the figure 7.7 and 7.8, the antifungal activities of the prepared percentile oil paint samples 1% TiO_2 , 3% TiO_2 , 5% TiO_2 , 7% TiO_2 , and control base paint were tested against *A. niger* and *A. oryzae* fungal strains with the standard drug Amphotericin-B by disc diffusion method as shown in the table 7.2. Diameter in 'mm' calculated by Vernier Caliper '--'means no zone of inhibition, NA Not applicable

Table 7.2: Antifungal activities of paint samples by disc diffusion method (UV)

Sr. No.	Sample/ Compound	Zone of inhibition in mm	
		A.niger	*A. oryzae*
1.	**Ctrl%**	--	12.54
2.	**1%**	--	11.48
3.	**3%**	10.63	12.61
4.	**5%**	15.22	17.45
5.	**7%**	17.52	19.37
Std	**Amphotericin-B**	12.35	13.23

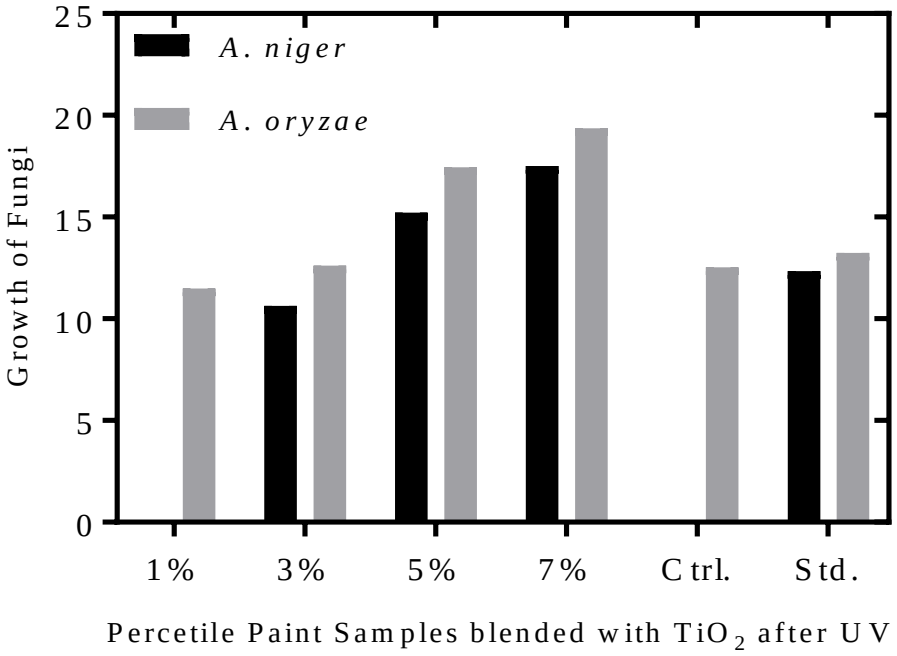


Figure 7.9: Antifungal activities of paint samples after UV treatment

Substantial attachments to the fungus may be inhibited or prevented by treating the fungus-infected cells with anti-fungal chemicals, which have an anti-fouling impact on cell surfaces or inactivate the cells. If an undesired surface coating or surface chemistry exists that detects microbes, then it may prevent or reject cell attachment. The constantly growing diversity of antifungal agents includes thousands of chemicals. *A. oryzae* and *A. niger* were both identified as having antifungal zones of

inhibition significance after UV treatment; the significant zone was detected in 5% and 7% of the whole *A. oryzae* stain, while a bigger zone was observed in 5% and 7% of the whole *A. niger* stain as compared to the control and standard drug as shown in the figure 7.9.

Before and after UV treatment comparison of antifungal results

Table 7.3: Before and after UV treatment comparison

Sr. No.	Sample/ Compound	Zone of inhibition in mm			
		Before UV		After UV	
		A.niger	*A. oryzae*	*A. niger*	*A. oryzae*
1.	**Ctrl%**	--	--	--	12.54
2.	**1%**	--	--	--	11.48
3.	**3%**	--	--	10.63	12.61
4.	**5%**	9.25	13.42	15.22	17.45
5.	**7%**	16.22	18.53	17.52	19.37
Std	**Amphotericin-B**	12.35	12.23	12.35	13.23

7.5 Conclusions:

- According to UV study it was observed that; increase in percentile TiO_2 in the base paint Transmittance and absorbance also increase in 320 ,400 and 520 nm wavelengths as compared to the control base paint.
- The antifungal activity test by disc diffusion method for UV give 15.22 mm zone of inhibition for 5% TiO_2 *A. niger* and 17.52 for 7% TiO_2 respectively and A.oryzae it is 17.45 and 19.37mm 5% TiO_2 and 7% TiO_2 which are satisfactory.
- When compare with standard and control paint sample antifungal activity can be avoided before and after the exporter of UV ray which make the paints suitable for health care building.
- In the comparison of antifungal testing of the paint sample before and after UV treatment a significant increase in the zone of inhibition was achieved after the UV treatment. It can be concluded that the UV treatment report for 5% TiO_2 and 7% TiO_2 paint sample gives very good results against A. niger and A. oryzae fungal strain which is suitable for the intended purpose.

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CHAPTER - 8

CHAPTER – 8

COST ANALYSIS OF NANO-TiO_2 PAINT

8.1 Introduction:

The 20th century has seen a significant evolution in paint formulation and technology which is likely to relate to the new conservation challenges frequently presented by modern oil paintings, including unpredictable water- and solvent-sensitivity. The surface area, defined as square feet, is quantified by colour, but manufacturers market and quote vast volumes of painting supplies per gallon. Traditionally, a coverage area per gallon is recommended by paint suppliers depending on the type of paint and such factors. Usually, the planned colour coverage zones vary from 200 and 300 square feet per gallon of paint. Bear in mind that the proposed covering regions are commonly called a "rule-of-thumb" and pollution, multiple coats and irregular surface situations cannot be accounted for. The number of square feet protected by a gallon of paint is heavily contingent on whether the masonry wall is made of smooth or "split-face" units in respect to painting an external masonry wall. The technique in which the paint chemicals are applied is another issue that influences the volume of materials used but also the efficiency. The estimator must consider the requirements of the project and determine the most efficient approach for adding the paint material required. The study of how paint formulations and additives can affect paint ageing and corrosion processes is a core field of investigation [1]. The proven triggers of exposure found so far involve the deposition of magnesium sulphate hepta-hydrate (epsomite) on certain paint surfaces due to the existence of magnesium carbonate in paint formulations that can react with sulphur dioxide. A similar research established a clear association between water sensitivity and pigment type: zinc oxide and lead formulated paints were consistently non-water sensitive [2-3]. The analysis also found that water sensitive paints were generally not associated with a higher degree of oxidation compared to non-sensitive paints, although certain strongly oxidized paints (mostly including Fe) were not associated with a higher degree of oxidation compared with non-sensitive paints [4-7].

According to the directive 2004/42/CE of the European Union (EU) on paints and varnishes and refinished products for automobiles, paint is classified as a product which produces a film having a decorative, protective or other functional effect on the surface of a surface' and in the sense of the Directive, a film is a continuous layer resulting from the application of one or more coats to a substrate [8]. Both oil and water-based items contain dye. In business research, the words ‘paints’ are sometimes confused with ‘paints and coatings’ or ‘coatings’, where we collectively use the word ‘paint’. The global demand of paint was measured at 36.1 million tons in 2006 [9-10]. The paint production has risen dramatically in developing countries in recent years, although deterioration is seen in developed countries.

8.2 Model of the single room for the application of paint:

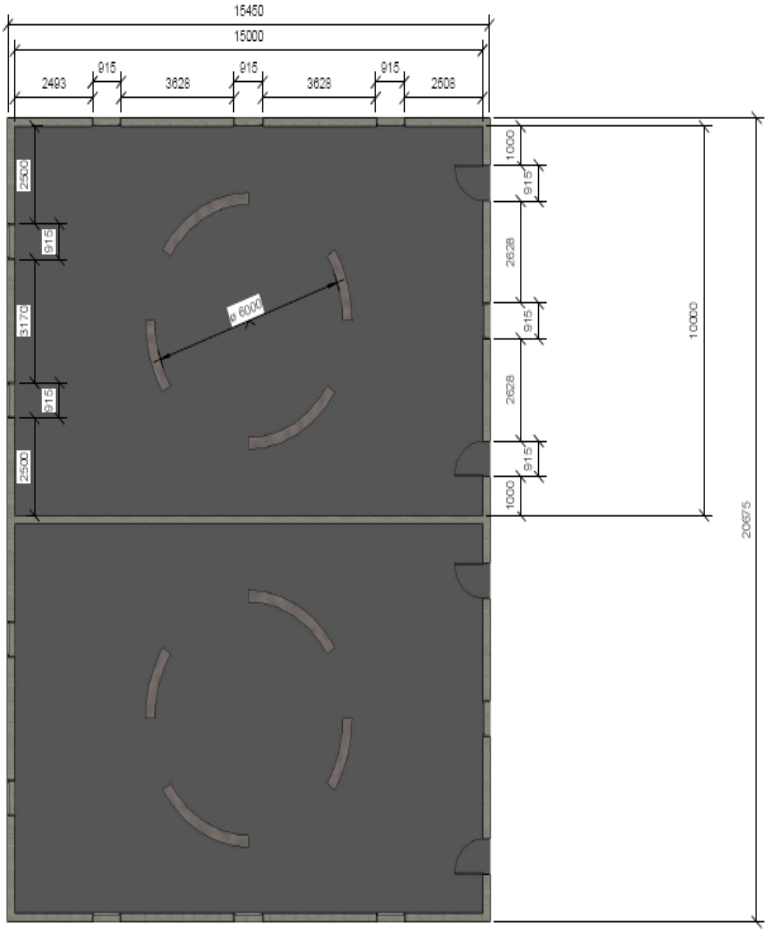

Figure 8.1: Building Model Plan Details

8.3 Cost analysis of paint for interior of single room:

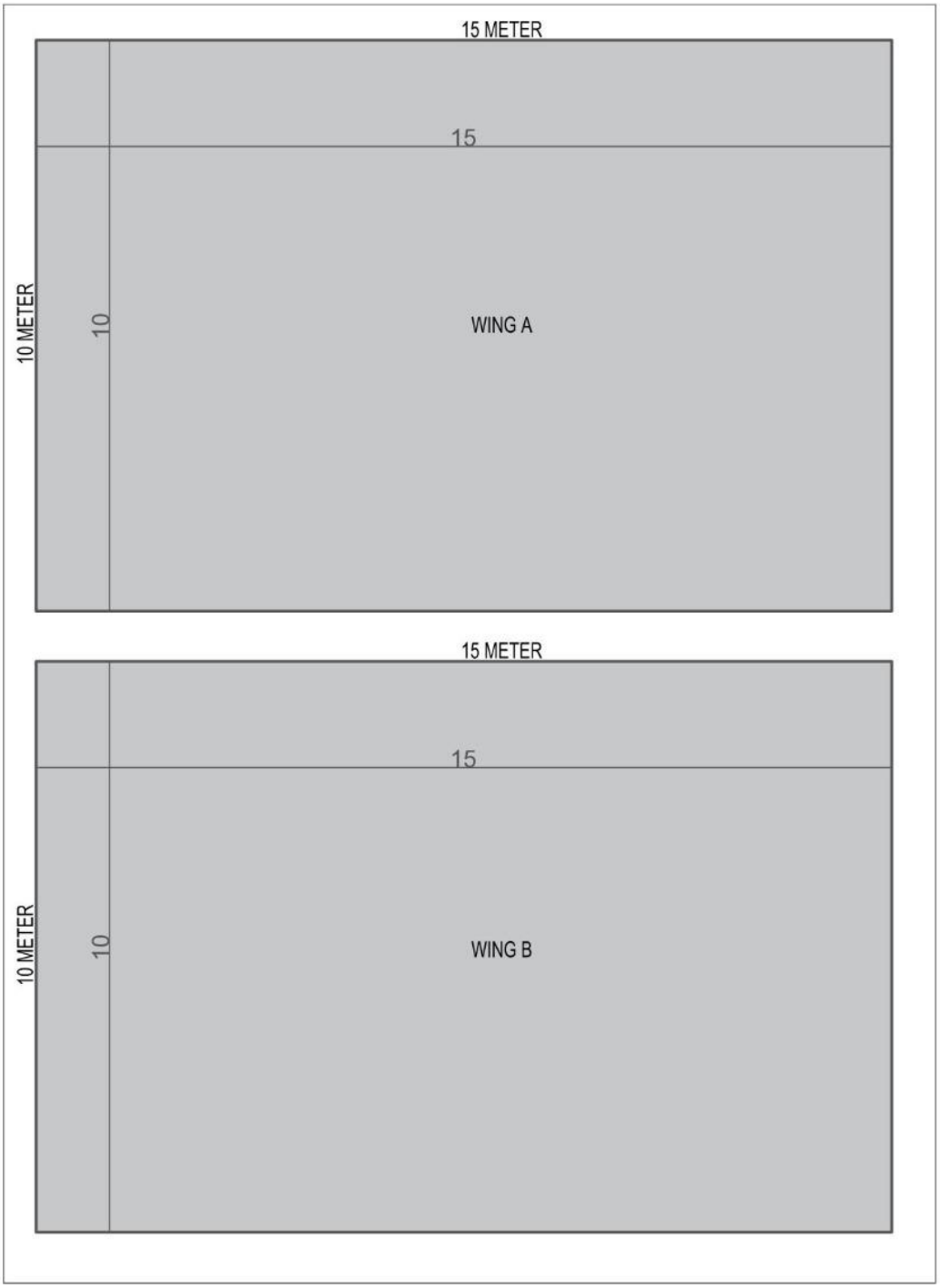

Figure 8.2: Building Plan

A . Area of [A] Wing

1) Total Surface Area = (15 + 10) 2 × 3 = 150 M^2

2) Top of Room = (15 ×10) = 150 M^2

B. Area of [B] Wing

1) Total Surface Area = (15 + 10) × 2 × 3 = 150 M^2

2) Top of Room = (15 × 10) = 150 M^2

Deduction in the area of Windows and Doors.

Total Area of [A] wing = 140. 916 + 150

= 290.916 m^2

Net Area of [B] wing = 140.916 m^2

Area of [B] wing ceiling = 150

Total Area of [B] wing = 140. 916 + 150

= 290.916 m^2

8.4 Cost analysis of Nano TiO_2 paint for interior of single room:

There has been significant study and practical interest in mixing TiO_2 photo-catalysts with cement materials to manufacture photo-catalytic usable goods. To fulfill their numerous photo-electrocatalytic functions, such as air-purifying, antibacterial, and self-cleaning properties, only solar light (UV component) is desirable. Among them the ability to self-clean is a desirable property for building materials, especially for interior surfaces. Generally, it is anticipated that the architectural efficiency of the buildings can be enhanced. As a consequence, it is possible to reduce the expense of regular repairs. Thus there is a strong interest in developing such photo-catalytic goods from an eco-friendly viewpoint [19-21].

Labor cost for [A] wing: -

Putti		= Area of A wing x rate per Sqm	
		= 290.916 × 50 = 14, 545.8	= Rs. 14, 546=00
1)	Primer	= 290.916 × 8 = 2327.32	= Rs. 2328=00
2)	1st Colour Coat	=290.916 × 8 = 2327.32	= Rs. 2328=00
3)	2nd Colour Coat	=290.916 ×7 = 2036.41	= Rs. 2037=00
		Total Amount for A wing	= 21,239=00

Similarly

Labor cost for [B] wing: -

Total Amount for [B] wing = 21,239=00

Material required for [A] wing for good surface

	Putti	- 7.50 × 290.916/9 = 242. 43 = 250 Kg.	
1)	Primer: -	- 1 × 290.916/9= 32. 32	= 33 Lit.
2)	1st Colour Coat	- 1 × 290.916/9= 32. 32	= 33 Lit.
3)	2nd Colour Coat	- 0.75 ×290.916/9 = 24.24	= 25 Lit

Similarly

Material required for [B] wing.

8.5 Comparison of paint and Nano TiO_2 paint:

In order to enhance their performance and the consistency of the atmosphere in which they are inserted, self-cleaning paints are capable of degrading contaminants present on their surface. These paint forms include in addition to the normal materials, photo-catalytic particles, such as TiO_2 in the UV. Minimizing the photo-catalytic impact of titanium dioxide particles in paint coatings is typically beneficial since certain organic compounds may be mineralized in a non-selective fashion by the oxidant species photo-generated on the TiO_2 surface. This photo-catalytic effect allows the contaminants present on the coating surface to degrade, contributing to the

characteristic of self-cleaning, but it may also decrease the consistency of the active substance present in the paint formulation. The resilience of the paint is very poor rendering its application economically unfeasible. It is therefore very important to find a compromise between the photo-cleaning quality and the consistency of the paint in order to create a self-cleaning paint formulation [22-24]. Titanium dioxide (TiO_2) integrated cement materials typically exhibit several photo-catalytic features, including the capacity to self-clean [25]. This thesis explored the method of adding a TiO_2 containing paint (clear in colour) directly to the surface of self-compacting architectural plasters. Under Ultraviolet light irradiation, its antifungal activities were evaluated. The findings revealed that the prepared percentile sample coated with TiO_2 paint showed both a strong potential to strip antifungal, photo-catalytic and a sturdy resistance to weathering in all conditions. Preliminary results from this analysis found that without TiO_2 paint sample suffered a decrease in activity relative to the 1 to 7% TiO_2 mixed paint sample in presence of UV light. The TiO_2 mixed paint sample coated surfaces had both a strong self-cleaning capability and a robust weathering resistance under UV visible light irradiations among the three TiO_2 application methods

Details Material cost of OK Paint Company

	Putti	- 40 Kg.- Rs. 1000=00
1)	Primer: -	- 1 Lit. - Rs. 110=00
2)	Colour	- 1 Lit. - Rs. 150=00

[A] Wing Paint cost for 0 % without TiO_2

1)	Putti	= 250 Kg. × 25 = 6250
2)	Primer: -	= 33 × 110 = 3630
3)	1st Colour coat	= 33 × 150 = 4950
4)	2nd Colour Coat	= 25 × 150 = 3750
		= 18, 580.00 Rs

5% TiO_2 Paint cost for [B] wing

1)	Putti	= 250 x 25 = 6250
2)	Primer: -	= 33 x 110 = 3630
3)	5 % TiO_2 1st Colour coat	= 33 x 1050 = 34650
4)	5 % TiO_2 2nd Colour Coat	= 25 x 1050 = 26250
		= 70780.00 Rs

7% TiO_2 Paint cost for [B] wing

1)	Putti	= 250 x 25 = 6250
2)	Primer: -	= 33 x 110 = 3630
3)	5 % TiO_2 1st Colour coat	= 33 x 1470 = 48510
4)	5 % TiO_2 2nd Colour Coat	= 25 x 1470 = 36750
		= 95140.00 Rs

Cost analysis of Nano TiO_2 paints (unit conversion):

Area in sq ft. = 290.916 ×10.764

= 3131.4198 Sq ft.

A) Wing paint cost for base paint without TiO_2

$$= \frac{18580}{3131.4198} = 5.9344 \text{ Rs/sq ft.}$$

= 63.8778 Rs/sq mt.

B) Wing paint cost for Nano TiO_2

5% TiO_2 paint cost for [B] wing

$$= \frac{70780}{3131.4198} = 22.6031 \text{Rs/sq ft.}$$

= 243.2997 Rs/sq mt.

7% TiO_2 paint cost for [B] wing

$$= \frac{95140}{3131.4198} = 30.3823 \text{ Rs/sq ft.}$$

= 327.0350 Rs/sq mt.

8.6 Conclusions:

- It is found that the cost of 5% and 7% TiO_2 sample is more than the available paint without TiO_2. From various test perform it was found that 5% and 7% TiO_2 sample give fairly good results. Considering the functionality, the surface coated with these sample are on hire side then the available paint. Considering the objective of the prepared paint sample increased in the paint cost is acceptable
- The cost of 5% TiO_2 paint sample and 7% TiO_2 sample have difference of 84 Rs/sq mt. from both the paint give fairly good results but when compare to costing 5% TiO_2 paint is preferred. for a premium range 7% TiO_2 paint sample able considering.

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CHAPTER - 9

CHAPTER – 9

SUMMARY & CONCLUSIONS

9.1 Summary:

The paint samples were preapared by the percetile mixture of titanium dioxide nanomaterials (TiO_2 powder) in the white coloured base oil paint with fraction of the terpentine to get homogenous mixture. The 1%, 3%, 5% and 7% samples were prepared and base paint control was used for the testing purpose. The preapared paint samples were coated on the back surface of the tiles by using brush. Double coats were applied on the surface of the tiles and dried off. The percentile proportion of the paint samples 1%, 3%, 5% and 7% TiO_2 nanomaterial mixed with base oil paint coated on the surface with the control of base paint.

The wide variety of antibacterial surfaces that has been recognized is rapidly expanding. Antibacterial surfaces are successful of repelling bacterial cells, preventing their attachment or inactivating or killing cells that do come into contact with the surface. It is, therefore, important to understand the mechanisms responsible for the antibacterial action. The antibacterial activities of the prepared percentile oil paint samples 1% TiO_2 , 3% TiO_2 , 5% TiO_2 , 7% TiO_2 , and control base paint were tested against gram positive *S.aureus* , *B.subtilis* and gram negative *E.coli, S. typhi* bacterial strains with the standard drug Chloramphenicol by disc diffusion method. Almost all of the percentile paint samples eliminate the bacterial colonies at a concentration of 1024 µg/mL, whereas the MIC in the bacterial strains with the 3, 5 and 7 percent paint samples. There was a statistically significant difference between the materials at all-time intervals (8, 16, and 24 h). Almost all the bacterial cultures of 7% paint sample decreases or gives the killing frequency at the increasing time intervals. As bacteriostatic and bactericidal activities of the percentile TiO_2 based paint samples were obtained for 1%, 3%, 5% and 7% concentrations equaling one time and substantial times the MIC, respectively. The bacteriostatic results found in 1%, 3% and 5% samples with control but 7% sample gives bactericidal activities in *S. aureus* while only 3% sample showed bacteriostatic and 5% and 7% samples showed bactericidal properties against *B. subtilis* gram positive strains. On the other hand, The

bacteriostatic results found in 1% and 3% samples with control but 5% and 7% sample gives bactericidal activities counter to *E. coli* while only 3% and 5% sample showed bacteriostatic and 7% samples showed bactericidal properties along with *S.typhi* gram negative strains.

The antifungal activities of the prepared percentile oil paint samples 1% TiO_2 , 3% TiO_2 , 5% TiO_2 , 7% TiO_2 , and control base paint were tested against *A. niger* and *A. oryzae* fungal strains with the standard drug Amphotericin-B by disc diffusion method. Almost all of the percentile paint samples eliminate the fungal colonies at a concentration of 1024 g/mL, whereas the MIC in the bacterial strains with the 3, 5 and 7 percent paint samples. As per bacteriostatic and bactericidal activities of the percentile TiO_2 based paint samples were obtained for 1%, 3%, 5% and 7% concentrations equaling one time and substantial times the MIC, respectively. The bacteriostatic results found with control but 5% and 7% sample gives bactericidal activities in *A. niger* while only 5% sample showed bacteriostatic and 7% sample showed bactericidal properties against *A.oryzae* fungal strains. According to application point of view, antifungal susceptibility testing of the surface coated paint samples were qualitatively assessed by spreading mixture of agar media assay with the dilution of *Aspergillus oryzae* and *Aspergillus niger* strains on the paint coated surfaces of the prepared tile samples kept in to the petri plates with and without moist condition. Antifungal susceptibility testing of the surface coated paint samples was qualitatively assessed by diffusion assay. Anti-fouling surfaces may withstand or prevent cell attachment due to the presence of an unfavorable surface topography or surface chemistry with recognize to the microorganisms. The formulation of TiO_2 based oil paint have been used for surface coating purpose and checked their antifungal potency against *Aspergillus niger* and *Aspergillus Oryzae* fungus in dry and wet conditions for seven, fourteen, twenty-one and twenty eight days growth of organism on the surfaces was recorded and compared both dry and wet conditions.

Table 9.1: Dry and wet result comparison of *Aspergillus niger*

***Aspergillus niger* Dry and Wet Culture Result Colony Counts (Moles)**									
Sr. No.	**Concentrations (%)**	**7th Day**		**14th Day**		**21st Day**		**28th Day**	
		Dry	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**
1	**1% TiO_2**	10	211	18	352	32	338	36	218
2	**3% TiO_2**	7	288	12	428	28	387	32	281
3	**5% TiO_2**	1	21	2	43	7	32	13	26
4	**7% TiO_2**	2	106	5	120	14	76	18	53
5	**Control**	4	233	7	245	9	251	10	263

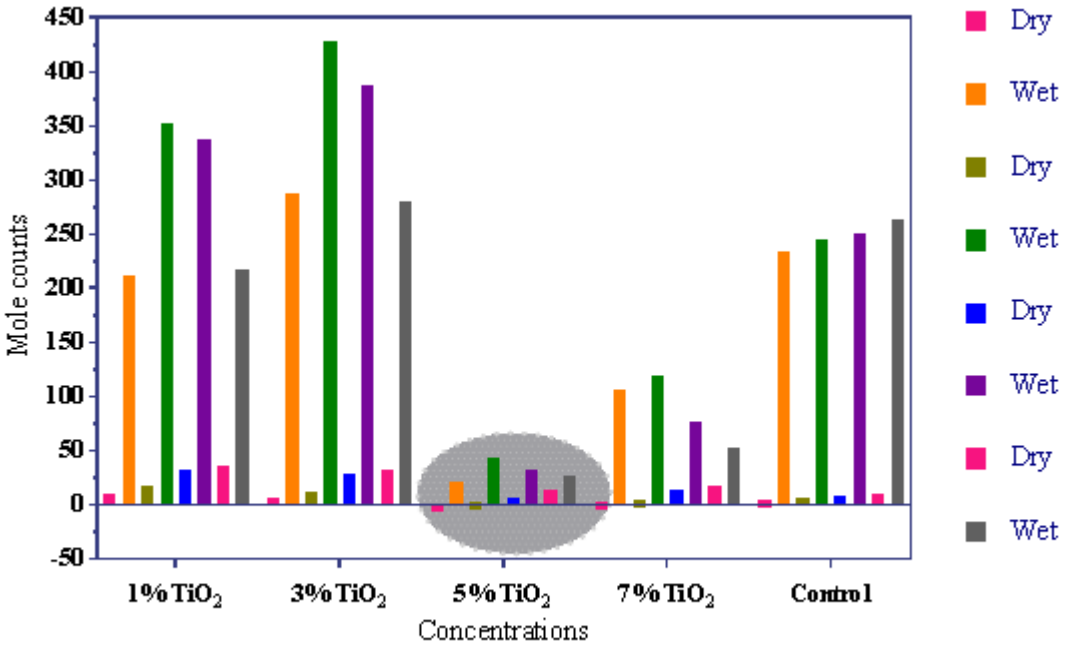

Figure 9.1: *Aspergillus niger* Dry and Wet Culture Result

Table 9.2: Dry and wet result comparison of *Aspergillus oryzae*

***Aspergillus oryzae* Dry and Wet Culture Result Colony Counts (Moles)**									
Sr. No.	**Concentrations (%)**	**7th Day**		**14th Day**		**21st Day**		**28th Day**	
		Dry	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**
1	**1% TiO_2**	5	10	52	402	110	389	118	401
2	**3% TiO_2**	6	4	8	426	12	368	18	372
3	**5% TiO_2**	4	0	4	273	8	189	10	148
4	**7% TiO_2**	7	0	8	251	10	272	12	192
5	**Control**	20	2	35	382	32*	426	41*	427
'*' tile colour changed									

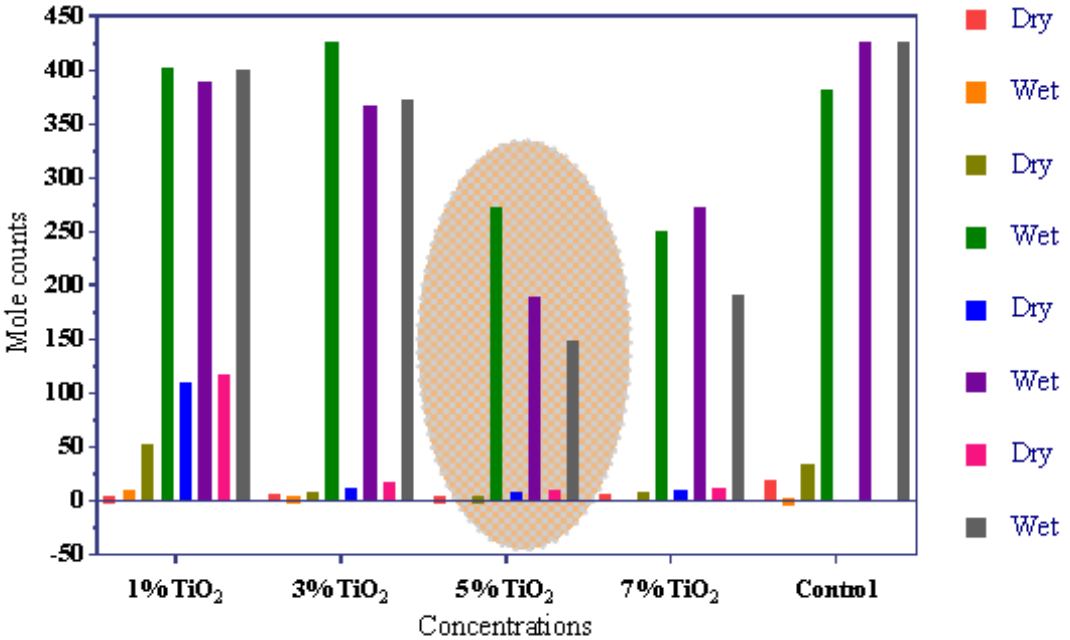

Figure 9.2: *Aspergillus oryzae* Dry and Wet Culture Result

9.2 Conclusions:

The newly emerging range of oil paint surfaces that have the functionality of killing any microorganism that come into contact with them, the killing mechanism being based specifically on their surface structure can also prove to be a precise beginning factor for a new and progressive course in the design of biomaterials as an alternative to the traditional, chemical-based approaches. Greater consideration must be given to analyzing the role that surface topography performs in the creation of an antibacterial or anti-biofouling surface, particularly at the nanoscale. The formulated oil paint coatings containing titanium dioxide nanomaterial with variable percentages showed reasonable antimicrobial activity Aspergillus niger and Aspergillus oryzae fungus in dry and wet conditions. In the view of results it was found that the TiO_2 based oil paint used for surface coating purpose might be used for the future surface coating materials. The point wise concluding remarks are listed as follows;

1) It can be concluded that the antibacterial activity by disk diffusion method 5% TiO_2 Sample give satisfactory results for all the bacteria.
2) By the MIC test S. aureus, B.subtilis, E.coli, S.typhi against the paint sample with control gives positive results for above 256 µg/mL concentration for 5% TiO_2 Sample.
3) It can be concluded from time kill assay reading that the 5% TiO_2 and 7% TiO_2 sample give satisfactory results for all bacteria.
4) The bacteria static results and bacteria cidal result were found to be positive for 5% TiO_2 and 7% TiO_2.
5) From the above conclusion it can be concluded that the 5% TiO_2 and 7% TiO_2 sample can be preferred the intended purpose.
6) From the Federal test method, the 5% TiO_2 and 7% TiO_2 sample shows no growth for Aspergillus oryzae and Aspergillus niger,
7) The antifungal zone of inhibition for 5% TiO_2 and 7% TiO_2 sample for Aspergillus oryzae and Aspergillus niger give better results than standard.
8) MIC for antifungal gives a low concentration at 128 µg/mL for 5% TiO_2 and 7% TiO_2 for Aspergillus niger and above 256 µg/mL concentration for 5% TiO_2 and 7% TiO_2 for Aspergillus oryzae.
9) Static and cidal test for Aspergillus niger kills fungus permanently at 5% TiO_2

and 7% TiO_2 but Aspergillus oryzae kills permanently at 7% TiO_2 paint sample and cidal at 5% TiO_2 paint sample.

10) The Aspergillus niger and Aspergillus oryzae dry culture and wet culture test shows satisfactory results for 5% TiO_2 and 7% TiO_2 paint sample.
11) We can concluded that 5% TiO_2 and 7% TiO_2 paint sample give better results as compare to control paint sample. therefore, it can be proposed for the surface coating of building.
12) In the result of the UV spectral analysis, the 5% TiO_2 based paint showed good transmittance and absorbance as compare to other samples with the base paint. It might be predicted the good transmittance and the reflection which is beneficial for healthcare rooms atmosphere due to activation of TiO_2 nano materials antimicrobial properties.
13) Preliminary results from the above analysis found that without TiO_2 paint sample suffered a decrease in activity relative to the 1 to 7% TiO_2 mixed paint sample in presence of UV light.
14) The photodynamic disinfection process and therapy used in the health care sectors were deliberated. The photo catalytic properties of TiO_2 have been reported, and optimizing the photo-catalytic activity under visible light for antimicrobial applications on the nano TiO_2 based 1%, 3%, 5% and 7% oil paints UV visible activity checked with the different wavelengths.
15) According to UV study it was observed that; increase in percentile TiO_2 in the base paint Transmittance and absorbance also increase in 320 ,400 and 520 nm wavelengths as compared to the control base paint.
16) The antifungal activity test by disc diffusion method for UV give 15.22 mm zone of inhibition for 5% TiO_2 A.niger and 17.52 for 7% TiO_2 respectively and A.oryzae it is 17.45 and 19.37mm 5% TiO_2 and 7% TiO_2 which are satisfactory.
17) When compare with standard and control paint sample antifungal activity can be avoided before and after the exporter of UV ray which make the paints suitable for health care building.
18) In the comparison of antifungal testing of the paint sample before and after UV treatment a significant increase in the zone of inhibition was achieved

after the UV treatment. It can be concluded that the UV treatment report for 5% TiO_2 and 7% TiO_2 paint sample gives very good results against A. niger and A. oryzae fungal strain which is suitable for the intended purpose.

19) It is found that the cost of 5% and 7% TiO_2 sample is more than the available paint without TiO_2. From various test perform it was found that 5% and 7% TiO_2 sample give fairly good results. Considering the functionality, the surface coated with these sample are on hire side then the available paint. Considering the objective of the prepared paint sample increased in the paint cost is acceptable

20) The cost of 5% TiO_2 paint sample and 7% TiO_2 sample have difference of 84 Rs/sq mt. from both the paint give fairly good results but when compare to costing 5% TiO_2 paint is preferred. for a premium range 7% TiO_2 paint sample able considering.

21) Concerned with avoiding or inhibiting the formation of significant adhesions, anti-bacterial materials demonstrate a resistance to cell attachment or may even eliminate the formation of adhesions. Resisting or inhibiting cell attachment may be caused by a surface contaminant or the presence of an unwanted surface contaminant, and also, the presence of microbe-detecting molecules might either aid or hinder cell attachment. More and more new antibacterial compounds are coming onto the market, making it challenging to cope with bacterium strains. It was seen in all the bacterial gram-positive and gram-negative strains, however no significant growth was seen for any of the percentile paint samples as compared to the standard medications.

22) Substantial attachments to the fungus may be inhibited or prevented by treating the fungus-infected cells with anti-fungal chemicals, which have an anti-fouling impact on cell surfaces or inactivate the cells. If an undesired surface coating or surface chemistry exists that detects microbes, then it may prevent or reject cell attachment. The constantly growing diversity of antifungal agents includes thousands of chemicals. *A. oryzae* and *A. niger* were both identified as having one or more MIC zones of significance after UV treatment; the significant MIC zone was detected in 5% and 7% of the whole *A. oryzae* stain, while a bigger MIC zone was observed in 5% and 7%

of the whole *A. niger* stain as compared to the control and standard drug.

23) It was also observed that the 5% and 7% paint samples were moderately beneficial in model cost analysis.

24) TiO_2 surface coating is an impressive technology to deal with health issues caused by life threatening bacterial, fungal and pathogenic infections.

25) TiO_2 surface coating might be used to prevent the spread of fungus, bacteria and pathogens in high risk public areas with shared contact surfaces such as trains, hospitals, hotels, museums and so on.

9.3 Future Scope:

TiO_2 nano-particles containing paint directly to the surface of self-compacting antimicrobial coatings. Under Ultraviolet light irradiation, its antifungal activities can be examined for the future applications.

CURRICULUM VITAE

- **PERSONAL INFORMATION:**

Name:	:	Mr. Milind Manikrao Darade
Educational Qualification	:	B.E (Civil), M.E. (Civil -Construction & Management),
Contact. No.	:	Mob. +91-9420033100, +91-8830162785.
E-mail address	:	milind.darade04@gmail.com
Presently working as	:	Assistant Professor
Address (Office)	:	Dr D Y Patil School of Engineering and Technology, Lohegaon -412105
Address (Resi.)	:	Sr No 90 Near Anand Park Road No 1-C Lane No C-3 Dhanori Pune-411015
Marital Status	:	Married and have two daughters
Nationality	:	Indian
Language known	:	English, Marathi, Hindi.
Date of Birth	:	15/04/1988
Fathers Name & Address	:	Mr Manikrao Patloba Darade. Ambika Niwas Adarsh Colony Ambajogai Dist- Beed Pin -431517
Total Experience (Teaching):		**10 Years and 01 Months (Till August. 2021)**
Key skills	:	# Administration of Engineering, # Teaching and motivating to Civil Engineering Students, # Handle Construction Site with quality work,

- **EDUCATIONAL QUALIFICATION:**

Sr. No	Examination	Institution	Board / University	Year of passing	% of Marks
1	**Ph.D. (Civil Engineering and Environmental Engineering)**	Dr.D.Y.Patil University Kolhapur	Dr.D.Y.Patil University Kolhapur	Thesis submitted on August 2021	
2	**ME (Construction & Management)**	MIT,Pune	Pune University	2012	7.35
3	**BE (Civil)**	MGM's, Jawaharlal Nehru Engineering College, Aurangabad.	Dr. BAMU Aurangabad	2010	72.86%
4	**HSC**	Shri Yogeshwari Mahavidyalaya	S S C & H S C Board, Aurangabad.	2005	71.00%
5	**SSC**	Shri Yogeshwari Nutan Vidhyalaya Ambajogai	S S C & H S C Board, Aurangabad.	2003	68.13%

- **TEACHING EXPERIENCE:**

Sr. No	Post/ Designation	Institution	Period		Total Experience
			From	To	
1	Asst. Professor in Civil Engineering	Dr. D. Y. Patil School of Engineering & Technology, Lohegaon, Pune - 412105.	1/1/2013	Till Date	8Years 7Month (Till 31/08/2021)
2	Lecturer in Civil Engineering & Head of Civil Engineering	Dr. D. Y. Patil School of Engineering & Technology, Lohegaon, Pune - 412105.	04/08/2011	31/12/2012	1 Years 5 Months

- **EXTRA CURICULAR PARTICIPATION AND ACHIEVEMENTS:**

1. Actively Participation in National Level Technical Event **EIFFEL** (model making competition) in 2009.
2. Actively worked in **DISCIPLINE COMMITTEE** at National Level Technical Event 2007**.**

• RESEARCH PUBLICATIONS:

1. Milind M. Darade, Satish R. Pawaskar(2018) "Surface Coated Building Studies in Health Care Sectors- A Review " International Journal of Engineering Development and Research 2018 (IJEDR) | Vol. 6, (1), pp. 789-792.
2. Milind M. Darade, Satish R. Pawaskar, Dr. S. H. Pawar (2019). "Antimicrobial Activities of Tio2 Nano-Powder Based Surface Coatings For Health Care Applications". Journal of Emerging Technologies and Innovative Research (JETIR), Vol. 6, (6), pp.106-1013.
3. Antibacterial Activities of TiO2 Nano Composite paint communicate to sci journal.
4. Antifungal Activities and Photo disinfection of TiO2 Nano Composite paints for Health care in Building communicate to techno-press journal.

BOOK CHAPTER

Photocatalytic Disinfection of Pathogens with TiO2 Nanocomposite paints to control the spread of communicable diseases in a book Entitle "Innovative Applications of Nanotechnology for Diagnosis, Treatment and Prevention of Life Threatening Diseases" Edited By: R.K.Sharma and S. H. Pawar, Published by: Cambridge Scholars Publishing in 2021.(Accepted)

• SEMINARS/WORKSHOPS/CONFERENCES ATTENDED :

1. Induction Program on "Basic Civil and Environmental Engineering at Singhgad College of Engineering Vadgaon Pune from 3rd and 4th August2012.
2. Two Day Faculty Development Program on "Laboratory Experiments in Fluid Mechanics-II" at Vishwakarma Institute of Information Technology, Pune. From 11th & 12th June 2013.
3. One Day Workshop on "BE Civil (2012 Course) Syllabi Drafting" at AISSMS College Of Engineering, Pune on 10 June 2015.
4. National Level Seminar on "Advances In Civil Engineering" at Dr D Y Patil School of Engineering & Technology, Lohegaon, From 11th And 12 February2015.
5. Amar 2015- Poster Presentation on date 17 march 2015 at D. Y. Patil Education Society, Kolhapur.
6. Anveshan-2015- Poster Presentation on date 29th December 2015 at D. Y. Patil Education Society, Kolhapur.
7. Amar 2016- Poster Presentation on date 25th & 26th March 2016 at D. Y. Patil Education Society, Kolhapur
8. One Day Workshop on "Revision of S.E. Civil Engineering Syllabus-CBCS-2015 Pattern" at Vishwakarma Institute of Information Technology, Pune. From 4th April 2016.
9. Two Day Conference On "Civil Post Graduate 2016"at AISSMS College of Engineering, Pune From 9th and 10th June 2016.
10. Stream cells, molecular biology and bioinformatics. (SMB workshop2016) on date 09th & 10th July 2016 at D. Y. Patil Education Society, Kolhapur

11. One Day Workshop on "Syllabus Revision of Post Graduate Civil Engineering Construction & Management "at MIT Kothrud, Pune. On 3rd January 2017.
12. One Day Workshop on" Smart Cities Development "at G.H.Raisoni College of Engineering & Management, Pune on 21th January 2017.
13. Anveshan 2016-17- Poster Presentation on date 14th February 2017 at D. Y. Patil Education Society, Kolhapur.
14. One Day ASCE International Summit on "International Students Chapter" At Dr D Y Patil Institute of Technology, Pimpari, Pune. On 28th February 2017.
15. International conference on nanotechnology addressing the convergence of material science, biotechnology and medical science during 9th - 11th November 2017 at D. Y. Patil Education Society, Kolhapur.
16. Two Day State Level Seminar sponsored by SPPU, Pune on "Digital Land Survey & Mapping" at G. H. Raisoni College of Engineering & Technology, Wagholi, Pune from 24th to 25th January 2018.
17. Session Chair Person of Two days "Fifth Civil PGCON-2018" at Imperial College of Engineering & Research, Wagholi, Pune from 11th to 12th June 2018.
18. One Day Symposium on Cancer Biology: Research and Therapeutics on date 6th September 2018 at D. Y. Patil Education Society, Kolhapur.
19. 5th International Conference on Angiogenesis Research: Targeted Angiogenesis Therapy" jointly with National Centre for Cell Science, Pune on 26-27th October 2018 at D. Y. Patil Education Society, Kolhapur.
20. Two Day State Level workshop on "Recent Trends in Civil Engineering for sustainable development" at Dr. D. Y. Patil School of Engineering, Lohegaon, Pune from 25th to 26th February 2019.
21. One Day FDP on "Advanced Research areas in Civil Engineering & Opportunities in Abroad" at Dr. D. Y. Patil School of Engineering & Technology, Lohegaon on 25th January 2019.
22. Anveshan 2020- Poster Presentation on date January 27th 2020 at D. Y. Patil Education Society, Kolhapur
23. Organized National Virtual Conference on "Applications of Physics in Nanoscience & Medical Field" at Sangameshwar College, Solapur, on 12/12/2020 organised by Department of Physics, Sangameshwar College (Autonomous), Solapur.
24. One-week online Faculty Development Program on "Entrepreneurship in Material Testing and consultancy Services in Civil Engineering (NABL Accreditation)" from 21st to 25th December 2020
25. One Week Faculty Development Program on "Advanced Surveying and Geo-Informatics" organized by Department of Civil Engineering in association with IQAC-MSRIT sponsored by AICTE from 24th to 29th August, 2020 at Ramaiah Institute of Technology, Bengaluru.

- **Papers:**

1. Milind M Darade*", Project Crashing to Solve Time-Cost Trade-Off" SSRG International Journal of Civil Engineering, 1 January 2016, Vol.3, PP.10-27.
2. Milind M. Darade, Sheikh Mohd. Tausif "A Study to Enhance Total Profit in Building Industry by Material Waste Management" Journal of Computing Technologies (2278 – 3814),2105, VOL 4.PP6-11.
3. Darade Milind.M, Kadam Sagar.P "Comparing Rapid Wall Panel Construction Over Conventional Construction with Respect to Cost and Time of Construction" International Journal on Recent and Innovation Trends in Computing and Communication, June2106, Vol- 4, PP-346-348
4. Milind M Darade, Vishrantkumar Zambre, "Compilation of Alternative Building Components and Common Distresses Found Through Building Condition Assessment" International Journal of Science and Research, March 2016, Vol-5,PP1155-1157.
5. Milind Darade, Rahul Kolhe "Detail Analysis of Delay in Construction Projects" IJISET, December -2014, Vol-1, PP 71-73.
6. Milind Darade, Venumadhav Yemul, "Occupational Safety and Health in Construction Industry for High Rise Building", IJISET, DECEMBER-2014, VOL-1, PP-322-324.
7. Milind Darade, Anagha katti, "project crashing to solve time -cost tradeoff", IJCE, June-2017.
8. Milind Darade, Monika Mhaske, "Construction waste minimizations" IAETSD, June-2017.
9. Milind Darade, Yogita Jadhav, "Safety audits & alternative solution to BRTS route" IAETSD, June-2017.
10. Milind Darade, Yogita Jadhav, "Alternative solution on kiwale phata to aundh BRTS route" IRJET, June-2017.
11. Milind Darade, Sagar Shinde, "Techno -economic analysis of slum rehabilitation housing project by" Pardhanmantri avas yojana using rapid wall techniques" IJRTCC, July-2017.
12. Milind Darade, Sayyad Jasmin N, "A review of health risk on construction site" IRJET, July-2017.
13. Prof. Milind Darade, Sayyad Jasmin N, "on site risk analysis of construction project", IJRASE, July-2017.
14. Milind Darade, Pratik R Desai, "Overall equipment effectiveness in construction equipments (Impementation of OEE for improving performance and quality output of the equipment)", IJRASE, July-2017.
15. Milind Darade, Akshaykumar P. Udasi, Analysis of Causes and Effects of Delays in Construction Projects, International Research Journal of Engineering and Technology (IRJET), Volume 5, Issue 5, May 2018
16. Milind Darade, Akshaykumar P. Udasi, Delays in Construction Projects: Causes, Effects and Impacts of RERA, International Journal for Research Trends and Innovation, Volume 3, Issue 7, June 2018
17. Milind Darade, Apiha Sonawne, Analysis of Labor Productivity in Indian Building Construction and Methods to Improve Productivity, IJRTI, Volume 3, Issue 7, July 2018

18. Milind M. Darade, Mayur P. Chounde, FEASIBILITY STUDY OF METRO RAIL PROJECT IN PUNE CITY, International Research Journal of Engineering and Technology (IRJET), Volume: 06 Issue: 05 | May 2019
19. Milind M. Darade, Mayur P. Chounde, Planning of New Route of Pune Metro Rail, IJRASET, Volume: 07 Issue: 06 | June 2019
20. Milind M. Darade, Pradip K. Patil, Assessment of Water Supply Management for PMC Area, IJSART - Volume 6 Issue 6 – JUNE 2020
21. Milind M. Darade, Pradip K. Patil, 24x7 Water Supplies for PMC Area, International Journal of Innovative Research in Science, Engineering and Technology, Volume 9, Issue 8, August 2020
22. Milind M. Darade, Ganesh Pisal, RISK MANAGEMENT FOR PPP MODELS IN URBAN WATER SUPPLY PROJECTS, Volume:02/Issue:07/July-2020, International Research Journal of Modernization in Engineering Technology and Science
23. Milind M. Darade, Pradip Patil, study of hazard identification and safety management in underground metro construction project : a case of Pune metro, international journal for science and advance research in technology, Volume 6,Issue 8 in August 2020
24. Milind M. Darade, Pradip Patil, Underground Railway Safety Analysis: A Case of Pune Metro, IJIRT, August 2020

- **Department and College Development Activities carried out**

Name of College	Major Responsibilities		Lab Development
	College Level	Department Level	
Dr. DYPSOET, Lohegaon, Pune	**Assistant sr. Supervisor,** Played the important role in Data Preparation & Uploading for AICTE. Supportive role during the LIC Visits. College Examination Officer (CEO) from 21st August 2018 to till date. One-point contact in NAAC Work	**HOD Civil, ME Coordinator [Construction & Management]** Academic Planning, Preparation & Conduction PR/Oral Examination Revision of SE Civil syllabus-2013, Two Day Work Shop.	**Planning, Installation, Testing of following labs:** SOM Lab, FM Lab, CT Lab, Geotechnical Lab, Surveying Lab, Advance Surveying Lab Geology Lab.

DECLARATION:

I consider myself familiar with field of Civil Engineering. I am confident of my ability to work in team. I hereby declare that the information furnished above is true, complete and correct to the best of my knowledge and belief.

Place: Kolhapur
Date: 27/08/2021

Mr. DARADE MILIND MANIKRAO