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Functional Distemper Coatings with Antifungal and Antimicrobial Properties- A Review

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Abstract

Antimicrobial paints are smart protective coatings that are developed to counter the development of micro-organisms and increase the lifespan of the coating, particularly in moist and polluted environments. Traditional paints are highly prone to development of fungus, loss of colors, development of odors, and decay that lead to a lack of structural integrity. Introduction of nanotechnology has ushered in a tremendous change in formulated paints as they incorporate metal and metal-oxide nanoparticles such as silver, copper, zinc oxide, and titanium dioxide. This activity in a combination of various mechanisms is caused by the nano-additives which may include liberation of ions containing metal, formation of reactive oxygen species (ROS), photocatalytic behavior, and increased protection from UV rays. These materials are highly soluble since they are nanoscale, enhanced surface adherence, and long antimicrobial cover as compared to the classic finishes. The standardized testing standards are used in estimating the performance that such a coating can last, its ageing mechanism and ability and an accurate and reliable estimation is achieved. The paper illuminates the importance, advantages and application of metal-based nanocomposite finishing (especially silver-based and copper based antimicrobial finishing) as suggested by the improved antimicrobial activity and increasing application in the industry sector. The antifungal distemper coating is much more efficient and widely used in buildings, business and healthcare centers.

Keywords: Nanoparticles, Nanotechnology, Smart Coatings, Sustainable solution, antimicrobial properties

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1. Introduction

Antifungal and antimicrobial paints are advanced paints that are made to lessen or inhibit fungi, mold, mildew and other micro-organisms development in the deep regions of painted surfaces. There are two fundamental elements of the paint: the binder and the base. The binder is composed of various ingredients , among which there are extender, surfactant, color, and thickener, among others [1]. This industry is not only developing such paint using biodegradable biocides; reality has it that they are also working on using silver, copper, zinc oxidein the form of nano-particles, photocatalytic-active nano-titanium dioxide, and nano-silica dioxide as agents to prevent the microbial decay and chemical deterioration of the painted surfaces [2]. The biodegradable biocides are supposed to be replaced by nanomaterials in the future, enhancing the properties of the paint besides lowering the microbial colonization [3]. Anti-fungal qualities of nano-based paint make them more durable than ordinary paints. Their nanomaterials are strongly bonded to the substrate; by so doing, they lead to permanency in protecting the development of fungi. A greater percentage concentration of anti-fungal drug can be added to the paint mixture using nanoparticles. Antimicrobial agents are used to prevent growth of bacteria on the surface. They are generally applied on a small scale so as to boost the effectiveness and beauty of paints and distempers [4]. They perform better in a wide range of fungus species, providing an increased surface shielding [5]. Photochemical breakdown by UV rays typically observed in coating systems. It oxidizes and decomposes polymer films, inorganic and organic pigments.

UV stabilizers that are organic in nature might fade away. Greater UV protection generated by nanoparticles like titanium or zinc oxide leads to greater UV absorption and reflection of UV radiation that is harmful. What is more, they are not damaged regularly [6]. Theiridely used technique in the ascertaining of the pigments, structure, particle size, and their elemental composition is X-ray diffraction technique. It is because it is an important indicator to check nanoparticles in the paints [7]. Antimicrobial paints are estimated to cost 11.30 billion and are expected to have a CAGR of 13.90 per cent by 2027, in the global market, which will consist of market size of up to 28.3 billion [8]. Nano-based antifungal paints have tiny nanoparticles and a more uniform distribution of the painted area. This will imply that all areas will be well covered against fungal growth, hence no spots or irregularities will be missed. The antifungal paints prepared in nano provide massive protection from the environmental conditions of the UV radiation, moisture, and alteration of temperatures. It causes antifungal effects to be retained in the long term, particularly in harsh situations [9]. The antifungal paints applied on surfaces do not require frequent preservation and re-application as the surface is robust and efficient relative to the conventional ones, which have a significant number of microorganisms threatening the well-being of many of the world's ecosystems [10].

Many antifungal paints are developed in such a way that they emit low volatile organic compounds (VOC) to make them environmentally friendly so that they can be used indoors. It can particularly be applied to treat residential and commercial buildings whose indoor air quality index can result in a massive problem [11]. Nanomaterials have different characteristics from bulk materials due to their small sizes, which are defined by the nano-metric scale, and result in some of them exhibiting some distinct physical, chemical, and mechanical properties. They are electrically and thermally conductive, high surface reactivity, very strong mechanically, and have improved antibacterial characteristics [12]. Nano paints of antifungal nature can be used on various types of surfaces, including wood, metal, concrete, and plastic. It is so because they may be used in very numerous ways, not only to the outside of a building, but also on the inside walls and surfaces. The small number of nano-based antifungal paints is an advantage since it does not allow the formation of biofilm, which is a colony of microorganisms that may be adsorbed to the surface and cause irreversible contamination of the surface and damage [13]. Overall, there is a solution to the problem of nano-based antifungal paints that would deter the growth of any type of fungi and provide better efficiency and environmental sustainability compared to the traditional paints [14].

2. Additives Used in Coatings Formulation

Applications of nanotechnology-based materials as smart and effective agents are so many that they can be utilized in paints and distempers. Nanotechnology and the recent necessity to apply it to the existing times have further augmented the utilization of metals (e.g., Ag, Au, Cu, Zn, etc) and metal-based compounds as metal oxides (e.g., ZnO, CuO, TiO_2) as antimicrobial agents [15]. The human eye is the most sensitive to light; it can be studied with help of available information that physical properties of nanoparticles such as their size, structure, and composition under various methodologies. Particles of the paints should be relatively smaller than the wavelength of light dispersed, which is about 0.5 microns wavelength[16].It has been noted that additives made of nanomaterials (titanium dioxide, silver, and zinc oxide) extensively used [17]. Ag nanoparticles are among the noble elements which have been of high interest since they have an effective antimicrobial property and a high diversity. Although copper-based coating can be considered to have best antibacterial action and is clearly advancing and developing as a substitute material, the amount of research on silver-based antimicrobial coating is much larger, and it can be readily obtained at scale. The antibacterial properties of ag nano-particles are attributed to release of silver ions in the process of oxidative dissolution [18]. One of high technologies that help to prevent microbial contamination is nanomaterials of metal and metallic compounds in form of nanoparticles (NPs), synthesized in recent years [19].

The compound Nano-Zinc oxide has antibacterial and antifungal properties in tiny concentrations. Studies reveal that there are numerous factors that are applicable to the antimicrobial activity of ZnO; the main one, is its ability to show photo-catalytic behaviour. Formation of ROS is inversely related to surface area of ZnO. The isolation of the Zn^{2+} ions of the ZnO nanoparticles, Its shape, and the roughness of the abrasive surface shape of the same are also important issues towards its activity [20]. The significant specific surface area and a reduced particle size of ZnO-NPs contribute to the existence of a lot of antibacterial properties. ZnO is a nanocomposite that has the property of photo-oxidation and photo-catalysis of chemical and biological species [21]. Ag-RGO nanocomposite properties as an antibacterial agent in water based acrylic paint have been studied. It demonstrated good antibacterial activity on Escherichia coli and Staphylococcus aureus. At an elevated concentration, Ag-RGO preferred inhibitory effect; it was an effective antibacterial agent [22]. The other major hindrance is the degradation of the organic coating in the presence of light, which was reported when the experiment uncovered that mesoporous TiO_2 does not harm the binder, as compared to P25 TiO_2 [23]. As has been mentioned, the application of nano-structured TiO_2 ($MTiO_2$) can decrease the contact area between the binder and photo-catalyst, therefore, significantly decreasing the risk of arbitrary photo-activity, as well as successive failure of the paint (Figure 1) [24].

3. Mode of Action

Antimicrobial technologies are based on two strategies. These are some of the significant mechanisms that occur including contact killing of microbial mechanisms that feature the inclusion of materials having biocide actives released to kill microbes. Common biocides are silver, copper and quaternary ammonium compounds. Other mechanism serves purpose of repelling in microbes with aid of antimicrobial polymer and hence microbial attachment is prohibited [25]. Under humid conditions, fungi such as Aspergillus, Penicillium, Pleurotus, Cladosporium and Aureobasidium proliferate over the painted surfaces staining them and causing structural damages [26]. Light-responsive C-doped TiO_2 nanoparticles that include paints have been studied on the effects. This was found to show that blue and violet light photo-catalysis is able to restrain the fungi by interfering with their natural activities and decreasing the concentration of toxins [27]. The addition of C-doped TiO_2 to commercial paint reduced the size of the fungal spores dramatically under normal living conditions and yielded a 38 percent reduction in growth of fungi after 83 hours. The Aspergillus niger, Aspergillus terreus, and Rhizopus Arrhizus were strains of fungi that were used to ascertain the antifungal properties of acrylic paints, contained Ag nanoparticles [28]. Commercially prepared paint containing carbon-doped titanium dioxide nanoparticles can be linked with considerable antifungal effects. Photocatalytic paint led to size reduction of fungus spores by 0.47 cm to 0.32 cm resulting in about 37 percent decrease, demonstrates capability of preventive effect of the fungal growth in normal condition [29]. Nevertheless, in its absence, the size of the fungal spore increases between 0.47 cm to 0.8 cm after 86 hours, which means approximately 85 percent growth in size. This implies that although C-doped TiO2 can shrink the size of the fungal spores without the use of light, its photocatalytic property in the light can surprisingly increase the growth of the fungi, indicating that the photolysis phenomenon does not significantly impact the inhibition of spore generation [30]. The fungi samples were placed on its surface, and the photocatalytic paints of various concentrations were put with the commercial paint as shown in a. bdemonstrates, that about 0.001L of this paint was mixed with about 0.01 L of commercial paint. The third one was the blend of 0.002 L photocatalytic paint and 0.01 L commercial paint. Finally, the last d means that 0.003L of photocatalytic paint was mixed with 0.01L of commercial paint (Figure 2) [31]. ZnO is so desired as a conducting material and it is also an antibacterial and antimicrobial coating [32]. Besides, ZnO nanoparticles possess excellent photocatalytic properties which enhance their antibacterial effect. ZnO nanoparticles are also capable of producing ROS under UV light [33]. Contacts of antimicrobial chemicals cannot be moved on surface of material in contact-killing method covalently, which results in massive destruction of surfaces attached (Figure 3) [34].

4. Testing Methods for Performance Evaluation

There are those organizations that have come up with tests to gauge the performance of coatings. These are the ISO Test of antimicrobial activity on surfaces, ASTM Standard Test Method of determining the antimicrobial activity and effectiveness of immobilized antimicrobial additives under active contact conditions and JIS Z 2801 Test of antimicrobial activity and effectiveness [35]. The Organization for Economic Cooperation and Development (OECD) has reiterated the fact that the standards, which are suitable at a worldwide level to examine the articles and the goods of antimicrobial chemicals, are numerous. One of them is ASTM D5590-94: Accelerated Agar Plate Assay to establish paint Film and Coating Resistance to Fungal Development. The second is SS345:2015 test (Singapore Standard), which is of emulsion paint that is resistant to microbes. Third is this TESHSA NSI method, a testing method of antibacterial activity on coating [35]. Qualitative tests are used to determine activity of fungi and microbes, and most evaluations are determined by qualitative tests. The ageing processes were selected and modified based on the investigations that were four in number. Natural Ageing (NA): 1488 hours at 23 degree celcius and 58 percentage of relative moisture in the laboratory; High Temperatures (HT): 1488 hours at 101 degC and 56 percentage of relative moisture [36]. A desiccator was employed in order to reach 86 percentage of relative humidity (RH) at 20 celcius; this was achieved by using a properly mixed solution of KCl salt at 1488 hours. A 0.5 weight of ZnO NPs (56 nm) in aqueous paint was mixed into a bentonite clay composite that had been altered. The inorganic composite was also tested against the A. nige common fungus which is reported to be antifungal. ZnO build-up increased the fungicidal effect of coating. According to the antifungal test, ZnO/Clay composite used in fresh and dry paint triggered its reaction [37]. Such a summation of the changes in the macroscopic properties and color parameters is possible, according to the selection of a great number of ageing processes (Figure 4).

4.1. Natural Ageing

The specimens in the laboratory were not characterized by any significant large or micro level morphological development. The clone which has the zinc white is peculiar one; it was discovered to be a bit smoked. In microscopic analysis, it was established that the high temperatures caused the appearance of clear spots on the outer surfaces of zinc white and titanium. The highest concentration of the surfactants is transferred on the surface of the film, and this causes such patches to appear yellow-greenish when exposed to ultraviolet light. As it has been already discussed, GC-MS and FT-IR ATR are the main procedures which were employed in order to determine a large variety of additives, including surfactants [38].

4.2. Ageing treatments (especially at high temperatures

They can enhance the migration of surfactants, thereby becoming visible on painted surfaces as they are widely studied. High temperature ageing of all made replicas provided most relevant changes in the concentration [39].

5. Advantages of Using Smart Coatings

Coating with these characteristics can reduce the necessity to regularly decontaminate the painted surfaces to eliminate infection, which will reduce the costs of chemical sanitization, and the number of workers will be lowered to offer an environmentally friendly ecosystem and prevent the development of bacterial resistance in the community. The need of frequent re-painting and loss of materials can be reduced using antimicrobial additives (e.g. Ag, Cu, ZnO nanoparticles) that cannot be done through conventional coating on the surface [40]. For the welfare of the family, the surroundings, it is essential to consider the minimization of microbial infections inside and outside of healthcare facilities because of the extended human lifespan, the ageing population increase, and the consequent increase in population vulnerability. Approximately one in five individuals is immunocompromised, and they are easily vulnerable to severe attacks by fungal attacks [41].

6. Recent Advances and Emerging Trends

In the previous three years, approximately 75 percent of the paint surfaces researched had metals or metallic compounds as nanoparticles [42]. This is due to increased accumulation of atoms at the surface of materials and hence high surface reactivity. Consequently, nanomaterials are currently considered to be highly important in terms of bio-nanotechnology as well as the natural sciences. The metal-based antimicrobial coating is on the way to innovative technology as it offers the solution to the microbial challenge in a broad spectrum of application [43]. Antimicrobial paints resist the unavoidable deterioration of paints by eliminating germs when in contact whereas the paints remain durable and sustainable.

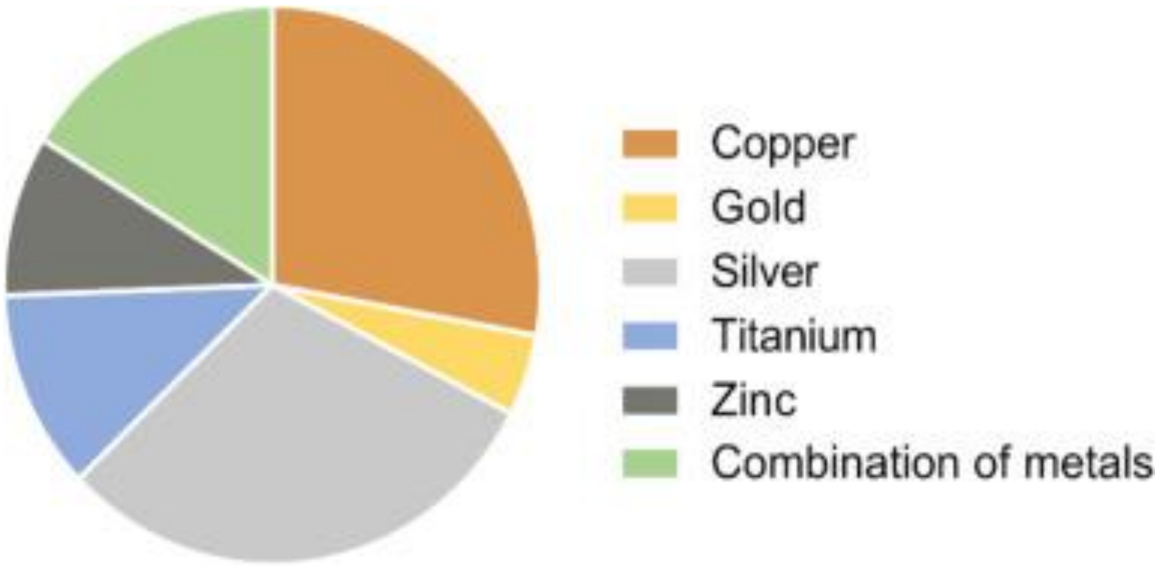

Figure 1: Distribution of widely used metals in anti-microbial coatings

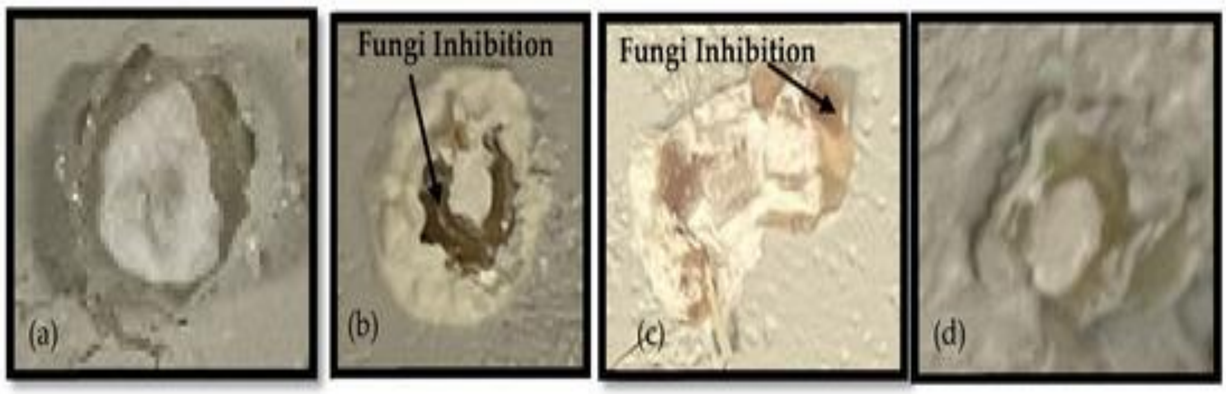

Figure 2: Various states of fungi application on photocatalytic paint

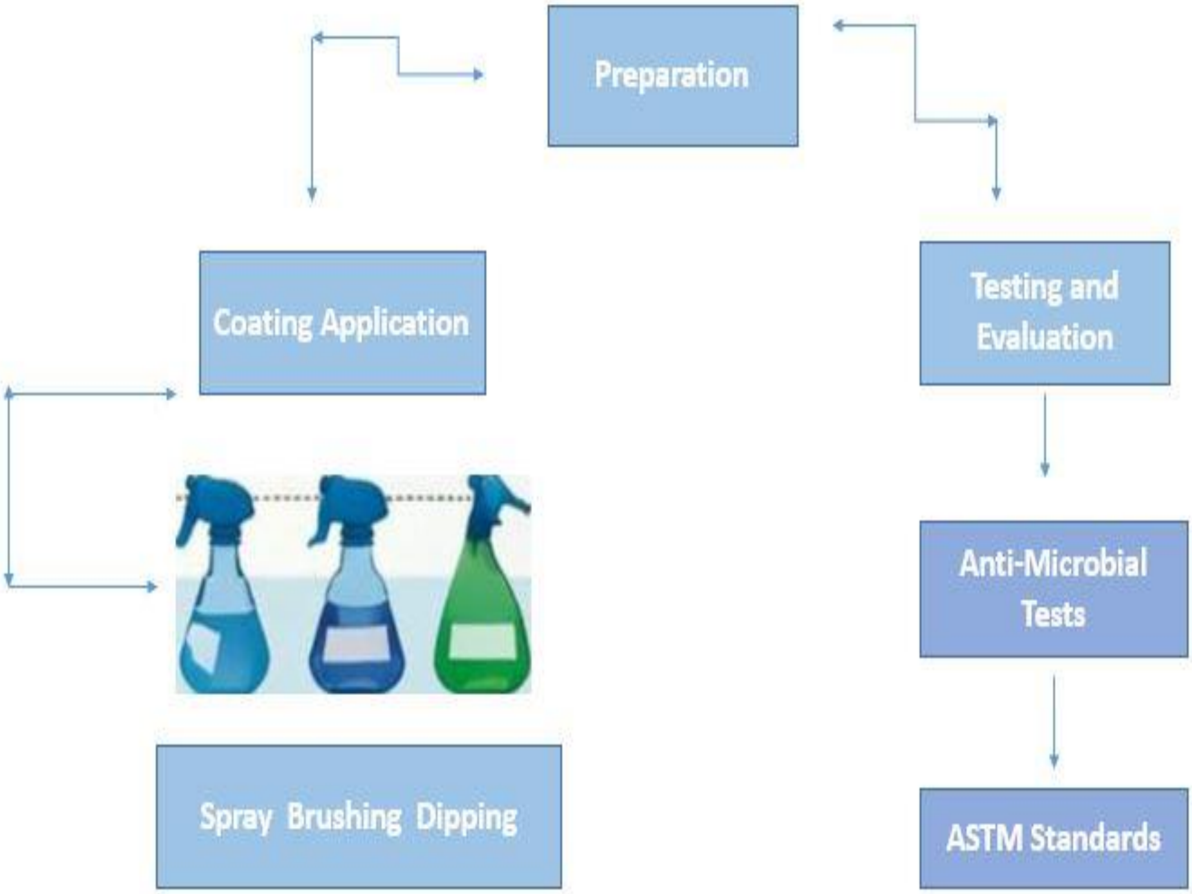

Figure 3: Mechanism of Action used in Coatings

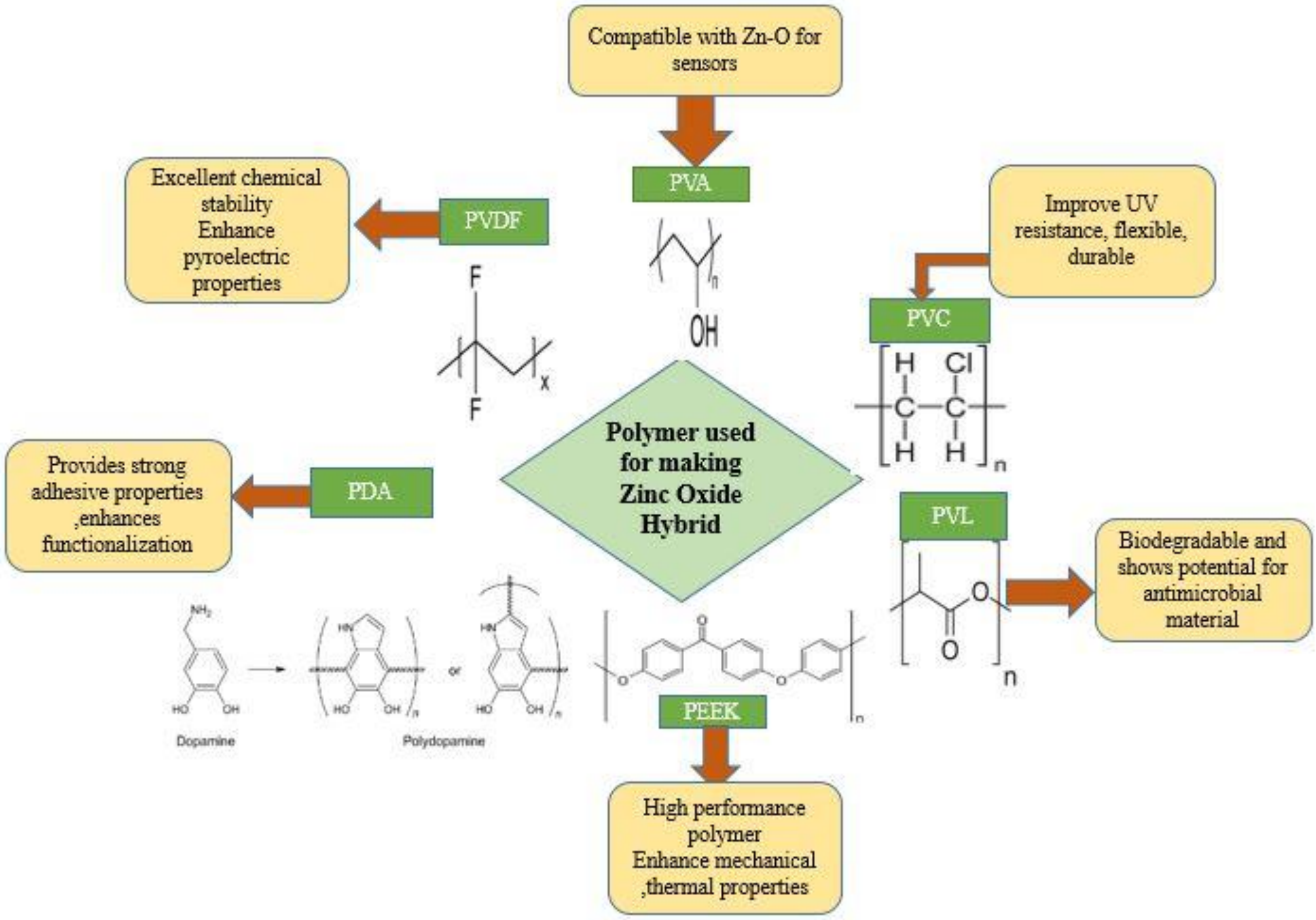

Figure 4: Formulation of ZnO from various polymers

Antimicrobial paint additives can be used in numerous sorts of paints and coating, which are easily and economically used [44]. All these demonstrate a gigantic improvement in new materials, formulations, and methods of application that make antimicrobial coating more effective and varied. The innovations lead to the production of nanocomposite coating, which is made up of metallic (Nano)particles that are involved with other components utilized in different applications s [45]. A large number of discussed coatings are silver metal based that proves the wide research of this metallic component. During the production of goods, such a coating is normally applied to goods, and the paint is one of the targeted sectors. The most notable process that causes the antimicrobial effect of such coatings is the dissociation of the silver ions, and is studied in in vitro experiments of silver-based formulated coatings [46]. Ag metal in the form of nano-particle drew the attention of researchers as they have a broad spectrum with a very effective antibacterial effect [47]. Ag nanoparticles exhibit antibacterial properties due to the liberation of silver ions in the process of oxidative dissolution. Silver nanoparticles (AgNPs) are also better than some commonly used biocides including Biotin T in terms of inhibitory effect, and in most cases, they offer long lasting stabilize bactericidal effect [48]. Over the past five years, research and several studies have been conducted concerning antimicrobial finishes on a metal basis. The most investigated and the most used types of coatings are silver-based, based on nano-sized particles combined with other metals [49]. The antimicrobial performance is found to be highest in coating comprising of copper where coating is in form of a metal thin layer. Despite potential and use of metal antimicrobial coatings in overcoming microbial contamination, more studies are needed, they should be fully utilized and sustainable use is required in various settings possible [50].

7. Conclusions

The antimicrobial and antifungal distemper layers is a significant advancement to the coatings industry that has come about due to the incorporation of nanotechnology, smart materials and improved performance engineering. The traditional paint systems continue to be defined by the inability to resist microbial degradation, dis-colouration and reduced capacity to promote their stability in the face of environmental pressure. On the other hand, nano-sized formulations, particularly those that involve Ag, Cu, ZnO and TiO 2 nanoparticles, are more effective in protection because mechanisms are comprehensible, like the discharge of ions, the creation of ROS, photo-catalysis, and blockage of attachment and the biofilms formation by microbes. The recent works and development also say that there has been growing interest in metal- based antimicrobial agents, and currently silver-based composites are being studied most intensively, and copper-based thin films are being found to possess the highest level of effectiveness. Simultaneous progress in standardized methods of testing (ASTM, ISO, JIS) also complement this to modernize ageing techniques to enhance the methodology of the development of these antimicrobial methods of coating. This variation in their properties that characterizes them as high-performance products, more resistance, and eco-friendly has greatly contributed to the fact that such products are perceived as the alternatives that should be implemented in such cases when the material has to be durable over time in addition to being resistant to microbes. This area would also need more studies to achieve its immense potential.

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