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Coatings and the environment: a review of problems, progress and prospects

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Abstract. Coatings are surface protection applications providing decorative, functional, or both applications on their applied substrates. Its application on substrates can be ingases, liquids, or solids. The environmental issues stemming from coating application, especially those from petroleum base feedstock, cannot be over-emphasised.This paper is poised to examine the merits of biodegradable synthesised polymeric coatings from a renewable source (plant seed oils).Using seed oil as a feedstock for organic coatings involves functionalising the seed oil to create a reactive site for polymerisation.The use of nanoparticles also helps to fine-tune coatings properties, and sometimes they provide thermal stability, adhesion, chemical resistance, electrical conductivity, anticorrosive, antimicrobial, hydrophobicityproperties, etc.

Keywords: Coatings, biodegradable, nanoparticles, antimicrobial, functionalization.

1. Introduction.

Coatings are materials prepared from liquids that form films after curing or drying upon application to a substrate[1,2]. Ong et al. [2] defined coating as a substance that covers when topically applied to a substrate.Coatings protect surfaces from the vagaries of the weather, like ultraviolet (UV) exposure, corrosion, scratch, and abrasion, andenhance the aesthetics of the surfaces [3,4]. Coatings can be applied to glass, ceramic, wood, metal, or concrete [3]. Although coatings are used in many ways and for many reasons, no single formulation solves all problems, no one-size-fits-all formulation. The solution, therefore, is to employ specific characteristics of the different types of coatings to mitigate the identified challenges. Some unique functional properties are recently being explored in coatings, such as antibacterial, antifouling, self-healing, self-cleaning, and hydrophobic properties [1]. Coatings are traditionally synthesised from petroleum resources, like polyethylene, polyvinyl chloride, polypropylene, alkyd resin, and polyurethane [5]. Polyurethanes are synthesised from reactions between diols and diisocyanate derived from petroleum sources [6, 7].

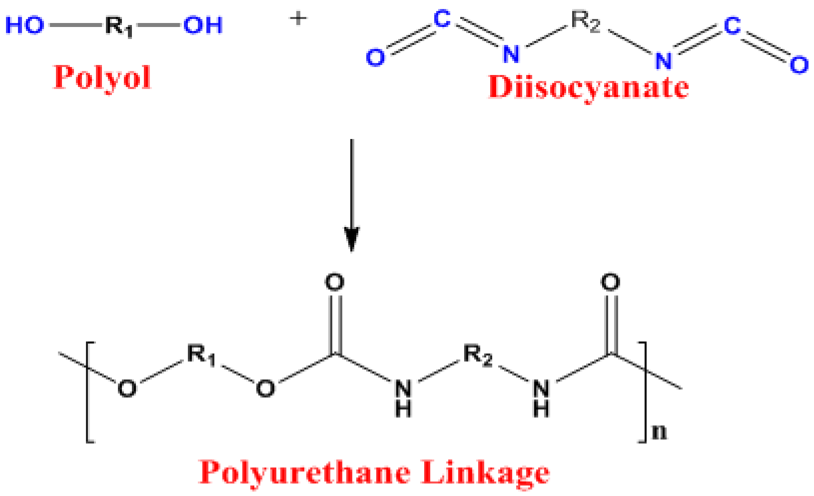

Figure 1: Reaction between diol and diisocyanate to form polyurethane [7].

2. Problems associated with coatings

Coatings have many advantages and are applied to many surfaces for many reasons. However, problems arise from their exploration, synthesis, application, and usage over time. Some of which will be discussed in this section of the paper.

2.1 Environmental degradation

Continuously exploring petroleum and using its resins for coatings has generated environmental concerns because of this feedstock's non-renewability, non-biodegradability, and attendant pollution [8, 9, 10]. Polyurethanes derived from petroleum feedstock have produced foams, adhesives, coatings, elastomers, thermoplastics, and thermosets [11, 10]. However, its continuous use has created severe environmentalconcerns [12].The worldwide adverse effects of petroleum exploration on the environment are graphically depicted inFigures 2 to 5. This pollution includesan uncensored generation of carbon dioxide (CO_2) gas, black carbon soot, heat, and oil spills.

Figure 2: Mauritius oil spill picture by Peter Mwai. [72]

Figure 3: Nigerian oil spills by Wasilat Azeez. [73]

Figure 4: Turtle with petroleum by Predrag1. [74]

Figure 5: Gas flaring Picture by Ed Kashi. [75]

2.2 Corrosion

According toOng et al. (2021), corrosion is a natural process that destroys metal due to its reaction with corrosive environmental agents such as water and moisture [2]. Dealing with corrosion is a global phenomenon that bears heavily on the world economy; hence finding a cost-reducing, efficient, and environmentally compliant means of combating the menace is of concern to policymakers, industrialists, and researchers [13, 14].Usingan organic coating to fight or inhibit corrosion has limited efficiency because it is permeable to water and oxygen due to its hydrophilic nature [15].

2.3 Bacteria activities

It is common to see coated surfaces covered with fungi or even packaged foods with heavy microbial loads.Polymers from renewable sources are naturally hydrophilic, so if the coating is applied in a humid environment, there will be an increase in microbial and fungi activities. There is, therefore,a growing demand for coatings that will enhance the coated surfaces and ensure sterility, especially in hospitals and food industries, by increasing hydrophobicity [16]. Microorganisms grow on the surface without incorporating antimicrobial functionality into the coating system[2].

3. Progress

When evaluating a coating material, it is crucial to consider its ability to adhere to the substrate in water.Naik et al. (2014)said, "Without adhesion, a coating is merely a film on a surface like a plastic wrap over a plate. Coating with poor adhesion to the substrate will give less service life." A coating's performance is judged by its characteristic adhesion to the metal substrate directly or indirectly via a primer [17]. According toLyon et al. (2017), "adhesion is performance," which means that (wet) adhesion and performance are directly related or proportional to each other [18].Wang et al. (2020)synthesised waterborne nano-hybrid hyperbranched acrylic emulsion in a wet adhesion test. They also demonstrated that the coating remained smooth after ten days of soaking. There was no drop-off, exhibiting excellent corrosion-protection and water-resistant coating properties on the metal substrates [12]. However,Yousefi et al. [19] noticed that the adhesion strength of waterborne polyurethane (PU) nanocomposite only increases with up to 3wt% of ZrO_2 and then begins to drop [19].

3.1 United Nations' Sustainable Development Goal (SDG)

The United Nations has formulated policies to regulate activities of meeting worldwide demand for coatings, especially in the fight against environmental degradation, corrosion, and microbial activities, in a responsible manner in line with the United Nations' sustainable development goal (SDG) 12 [20].This is a laudable development, taking particular notice of target 12.2, which talks about achieving sustainable management and efficient use of natural resources, and target 12.4, which talks about the responsible management of chemicals and waste through environmentally sound management of chemicals and all wastes throughout their life cycle. Therefore, exploring seed oils as renewable resources in the polymeric coating will stop the continuous exploitation of expensive, non-renewable petrochemicals that leave environmental material footprints. The material footprint is the quantity of material extraction required to meet a country's consumption.

Seed oils are suitable for preparing coating materials and answer the clarion call of the United Nations' sustainable development goal (SDG) 13, which says we must take urgent action to combat climate change and its impacts[21].

UN Definition "By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water, and soil in order to minimise their adverse impacts on human health and the environment"[22]

3.2 Organic materials as sustainable alternatives

The fear of depletion of petroleum reserves and growing concern about climate change have generated overarching desires for products with little or no carbon footprint as alternatives to petroleum acrylic resins. The search also includes ecological balance and sustainable development [17, 23, 7], using recycled materials, and lowering volatile organic compound(VOC) emissions [24]. VOC refers to gases emitted from products or processes which enable rigid acrylic polymers to form films at ambient temperature [25]. These gases could either be harmful or react with other gases to further pollute the air and harm the people or the ecosystem. Paints, paint strippers, aerosol sprays, and solvents are popular sources of these VOCs. Hence, the need to formulate coatings that reduce or eliminate solvents' use and develop environmentally friendly coating processes. To this end, Liu et al. [10] have prepared UV-curable hybrid coatings that have zero VOC content, which corroborates whatKhatoon et al. [23] affirmed that researchers are moving toward utilising green and sustainable resources to substitute petroleum-based polyols (ethylene and propylene oxides) and diisocyanates [10, 23]. Therefore, developing organic coatings from renewable sources presents viable alternatives to using chemicals from petroleum sources that are not eco-friendly [26, 27, 25].

There are two major categories of renewable polymers: naturally existing biopolymers and synthetic biopolymers [12]. Examples of naturally existing biopolymers are protein, starch, cellulose, hemicellulose, Chitin (the main component of the exoskeletonof insects and crustaceans), and lignin. While examples of synthetic biopolymers are those derived from molecular biomass of different things like plant oils, fatty acids, amino acids, terpenes, and rosin acids [28].Out of the many alternative sources of renewable materials, vegetable oils are the most explored due to their sustainability and availability from various plant sources. They are biodegradable and have low toxicity [29]. Vegetable oils consist mainly of triglycerides, making them a potential for polymerisation due to carbon-carbon double bonds. According toLu &Larock [30], the properties of vegetable oil triglycerides that determine the vegetable oil's chemical and physical properties are the length of the chain and the degree of unsaturation of the fatty acids [30].The word **'oil'** describes triglycerides that are liquid at ordinary temperatures and are not soluble in water. Triglycerides are products of an esterification reaction between three molecules of fatty acids and one molecule of glycerol. They occur naturally and could also be synthesised.

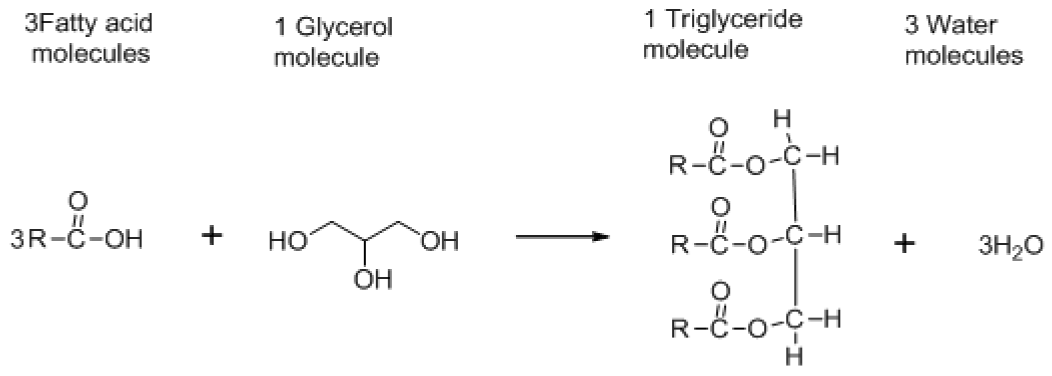

Figure 6: Esterification reaction

Table 1: Some common fatty acids [76]

Common Name	**Formular**	**Scientific Name**
Stearic acid	$CH_3(CH_2)_{16}COOH$	Octadecanoic acid
Palmitic acid	$CH_3(CH_2)_{14}COOH$	Hexadecanoic acid
Oleic acid	$CH_3(CH_2)_7CH=CH(CH_2)_7COOH$	9-Octadecanoic acid
Vaccenic acid	$CH_3(CH_2)_5CH=CH(CH_2)_9COOH$	11-Octadecanoic acid

Linoleic acid in linseed oil	$CH_3(CH_2)_4CH=CH-CH_2CH=CH(CH_2)_7COOH$	9, I2-linoleic acid (non-conjugated bonds)
Linoleic acid in hydrated castor oil	$CH_3(CH_2)_4CH_2CH=CH-CH=CH(CH_2)_7COOH$	9, 11-linoleic acid (Conjugated bonds)
Linolenic acid	$CH3CH_{2-}CH=CH-CH_2-CH=CH-CH_{2-}CH=CH(CH_2)_7COOH$	9,12,15-octadecatrienoic acid
Eleostearic acid (tung oil)	$CH3(CH_2)_3CH=CH-CH=CH-CH=CH(CH_2)_7COOH$	9,11,13-octadecatrienoic acid
Ricinoleic acid		12-Hydroxy-9-octadecenoic acid

Waterborne coatings from polyurethane are also alternatives to solvent-borne coatings. However, they present severe mechanical and thermal stability challenges like extreme temperature and humidity.Ospina et al. [31] submerged PU films in water at 80^{o}C in accelerated ageing studies and discovered that polyols with higher molecular weights are more susceptible to hydrolytic degradation. They exhibit less adhesion to the substrates than those PU coatings from shorter polyols. Oils and clays, substitutes for synthetic binders, also present durability problems. Castor oil waterborne polyurethane (CWPU) has a lot of characteristics, such as low VOC content, renewability, biodegradability, and excellent biocompatibility. Still, they make coatings that are generally poor in water resistance.Ong *et al.* [2] enumerated some weaknesses of renewable coating, including poor chemical and solvent resistance, degradation under sunlight or ultraviolet (UV) light, and pores in the coating layers through which corrosive agents pass to the substrate [2].

Therefore, the need to solve these problems has led researchers to incorporate nanoparticles into the coating materials.Dhoke et al. [4] enumerated that nanosized materials can be incorporated into the polymer to overcome the weaknesses and improve the coatings' performance[4]. According to Kaya et al. [32], introducing nanomaterials into the polymer matrices resulted in the formation of sophisticated polymers from renewable sources

[32].These products can compete favourably with petroleum polymers without negatively impacting the environment.

3.3 Nanoparticles to the rescue

Nano is from the Greek word "*nános*," which means dwarf [33]. In today's universal usage, nano means one billionth of a metre ($1x10^{-9}$ m) [34]. Nanomaterials exhibit multifunctional properties that are distinctively different from the properties of bulk materials [33]. Nanoparticles are materials with at least one dimension, 100 nm or less [35, 36, 37]. This is like dividing one millimetre into one million places or dividing a strand of hair into ten thousand. The volume-to-mass ratio is enormous, and this characteristic presents nanomaterials for applications in many fields, such as sciences, technology, engineering, and medicine. The large surface area of nanomaterials and their interaction with polymers is robust, giving rise to improved properties [11].

Nanomaterials are classified into three categories (i) zero-dimensional, which are also called nanoparticles (ii) one-dimensional, also known as nanorods or nanotubes; and (iii) two-dimensional, also known as nanoplates or nanosheets [37]

3.3.1 Synthesis of nanoparticles

Methods of synthesising nanoparticles are broadly classified into two basic categories [35, 33, 39, 36]. They are:

3.3.1.1 Top-down approach

This approach employs a destructive method, breaking down appropriate bulk material into fine particles using chemical or mechanical methods like grinding, sputtering, laser ablation, and milling to produce the intended nanostructured material.

3.3.1.2 Bottom-up approach

This approach synthesises nanoparticles from relatively minor substances like atoms and molecules. This approach includes sol gen, laser pyrolysis, sedimentation, biological processes, etc.

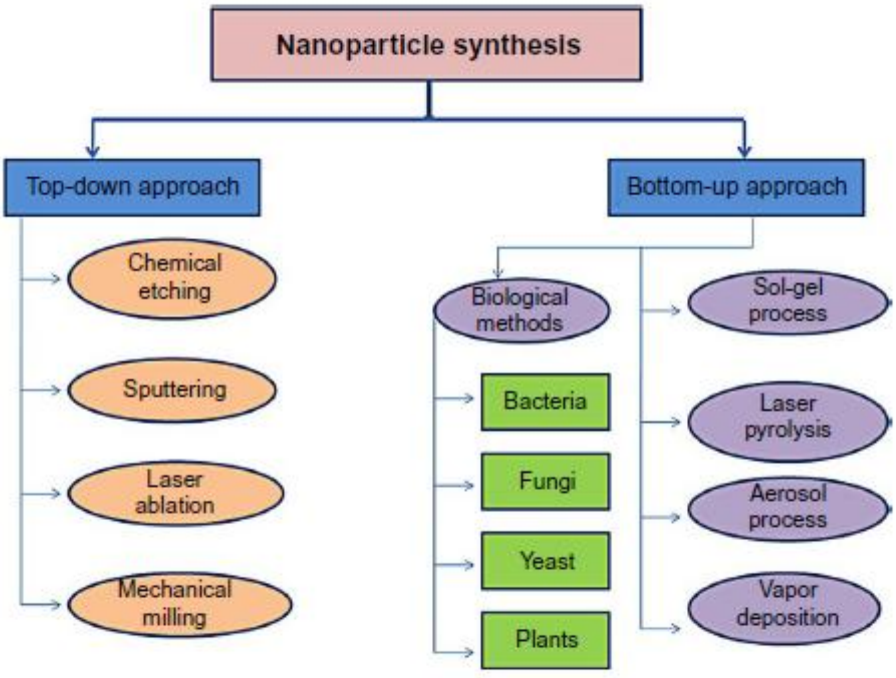

Figure 7: Processes for synthesising nanoparticles [36].

3.3.2 Uniqueness of nanomaterials

Nanoparticles now form an essential part of raw materials used to manufacture products. These include scratchproof glasses, crack-resistant paints, anti-graffiti coatings for walls, transparent sunscreens, stain-repellent fabrics, and ceramic coatings for solar cells. The volume-to-mass ratio and tensile of nanomaterials contribute to more robust, lighter, cleaner, and "smarter" surfaces and systems. At the nanoscale, the properties of particles may vary significantly from the bulk material [39]. These multifunctional characteristics make them helpful in developing coatings and other commercial products [40]. For example, titanium oxide (TiO_2) nanoparticles have the same chemical composition as the bulk white titanium oxide materials, but the nanosized titanium oxide is transparent, making it soundlike sunscreen.Antimony-tin oxide nanoparticles are also incorporated into coatings to make them scratch-resistant and offer transparent protection against ultraviolet radiation, characteristics absent in bulk-sized materials [41]. The type of coatings provided by the nanomaterials depends on the polymer matrix's size, shape, and concentration [7]. Nanosized materials come with unique challenges, such as aggregation and agglomeration, and are not visible to the naked eye[42].However, incorporating nanomaterials into coatings has far-reaching implications, such as improving polymers' electrical, magnetic, mechanical, and thermal properties [43].

3.3.3 Modification of nanomaterials

Nanosized materials have a challenge of agglomeration because of the presence of Van der Waals forces; hence, they stick together to form lumps [42, 23, 44]. They also tend to agglomerate due to enormous surface energy and strong polarity [45].These characteristics must be dealt with by modifying the surface and thus making the surface available for use in various other applications [38]. The interfacial interaction of the nanoparticle within the polymer matrix is improved when the nanoparticle surfaces are modified, thus enhancing miscibility [46].

The surfaces of nanomaterials are modified to avoid insufficient dispersion [45]. Because if nanomaterial surfaces are not modified, they will inhibit instead of enhancing polymer nanocomposites' properties [46].Nanosized materials could be modified and functionalised through several methods, such as surfactant-assisted modification, polymer grafting, and silane grafting [48]. According to Mu et al. [44], modification of graphene significantly improves graphene dispersion in polymer coatings resulting in a better barrier effect in corrosion prevention [44].Agglomeration usually leads to poor distribution of the nanomaterials in the polymer composite. Sometimes, it is so severe that the inorganic nanomaterial's simple mechanical mixing and agitation may not effectively fix it [48]. According to Kango *et al.* [49], the hydroxyl (OH) group covering the surface of inorganic nanoparticles can be functionalised with many modification agents, such as silane compounds. They reported using 3-methacryloxypropl trimethoxy silane and concluded that the OH and the silane groups behaved differently in an organic medium[49].According to Dall et al.(2021),"the structure and chemistry of the nanomaterial seriously affect its dispersion in the polymer matrix". That is whyGhasemlou et al. [50] proposed surface modification of nanocellulose to broaden the range of polymer matrices in which nanocellulose can be incorporated [48, 50].

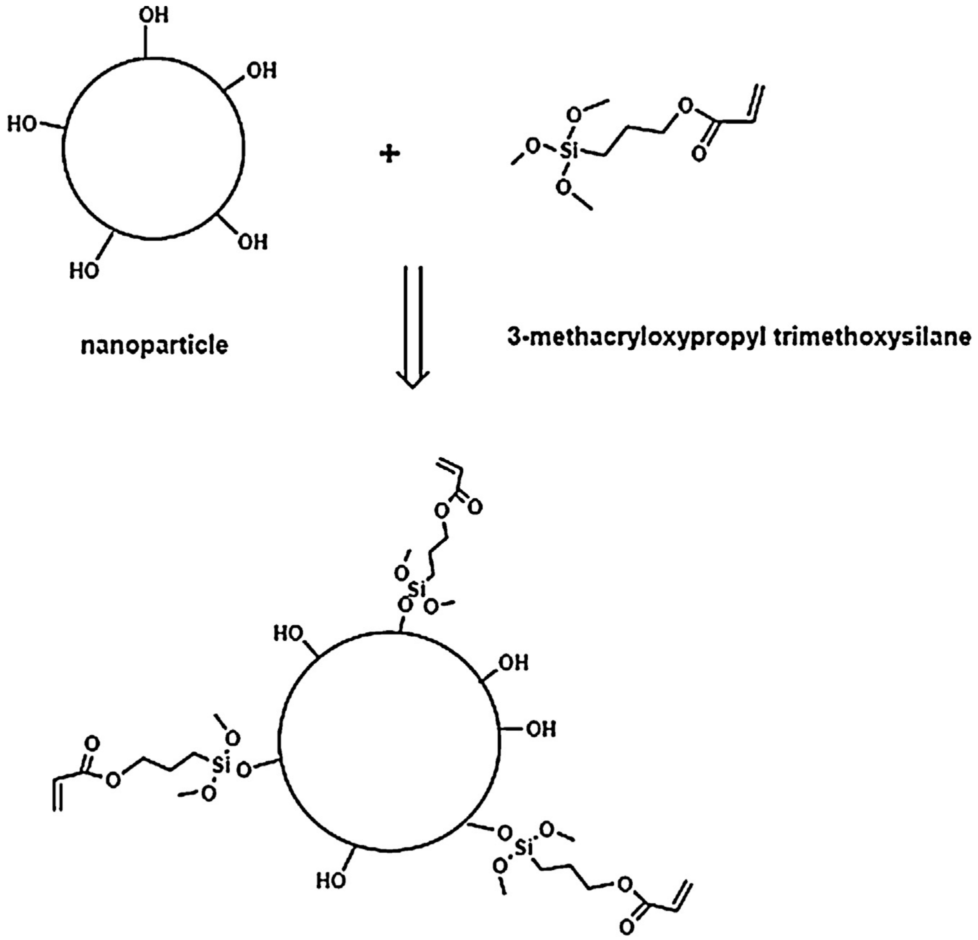

Figure 8: Modification of a nanoparticle with 3-methacryloxypropyl trimethoxysilane[49].

3.4Effects of nanomaterials on coating

Incorporating nanomaterials into the polymer matrix of organic coating has a tremendous impact on improving the identified shortcomings of organic coatings with no nanomaterials [32]. Some of these improved characteristics are discussed below.

3.4.1 Corrosion resistance

Siyanbola et al. [26, 40], using a salt spray test, demonstrated an increase in corrosion resistance when siloxane-modified-ZnO nanomaterial is present in the polyurethane polymer matrix.Jeyasubramanian et al. [51] prepared an alkyd coating containing nano iron (III) oxide (Fe_2O_3). Although iron (III) oxide has been previously used as a catalyst, solar energy harvester, and gas sensor, it is now an effective anticorrosive agent in coatings [26, 40, 51].Using a salt spray test,Wazarkar&Sabnis [52] and Shen et al. [53] also demonstrated that coatings increase barrier properties at the surface of the substrate by preventing electrochemical reactions that would have caused corrosion. They showed that coatings' anticorrosion properties depend on the crosslinker's chemical structure, functionality, and the hard and rigid moieties present in the polymer backbone [52, 53].

Dhoke et al. [4] said that the excellent bond strength of Si-O-Si gives the polymer an excellent anticorrosion property. According toMishra et al. [11], there is a strong interfacial adhesion between the substrate and the ZnO coatings. This interfacial adhesion is because of the surface geometry of ZnO, which does not allow the NH groups of urethanes to make hydrogen bonds with the CO groups of the hard segment. When the interfacial adhesion is strong, it protects the substrate against corrosion [11, 54]. Adhesion is the most crucial property of organic coatings, without which other properties become useless and worthless.Lingner Moura et al. [13]and Ammar et al. [55]synthsised a fully organic coating system using epoxidised soybean oil and found corrosion-resistant properties [13, 56]. The salt spray test shown by Soleimani et al. [56] indicated that adding silica leads to increased anti-corrosionproperties up to 3 wt%, after which there is a decline in the anticorrosion property [56]. Chen et al. [57], using modified poly dimethyl siloxane (PDMS) with self-healing properties as coatings on cold-rolled steel and dipping it in 3.5% NaCl for ten days, discovered that no corrosion occurred on the steel of the self-healing property. This protective ability against corrosion that the healable silicone exhibited could be used for marine metal protection.

Search for high-performance epoxy coating for concrete led Chi et al. [59] to develop high-strength and low VOC epoxy coating that can permeate concrete and crosslink at high temperaturesto form a root-like coating/concrete composite. This complex then protects the concrete [59].Perrin et al. [60] studied the corrosion behaviour of coatings when dipped in a 3.5% NaCl solution and discovered that incorporating triethylenetetramine (TETA) into the polymer matrix improved anticorrosion. Wang et al. [10] also found that waterborne nano-hybrid hyperbranched acrylic emulsion exhibited excellent corrosion inhibition capability after 1000 hours of salt spray with 3.5% NaCl. Khatoon et al. [12] discovered that non-isocyanate polyurethanes (NIPU) have a non-porous structure, exhibiting long-time corrosion protection even in aggressively corrosive media [10, 12].

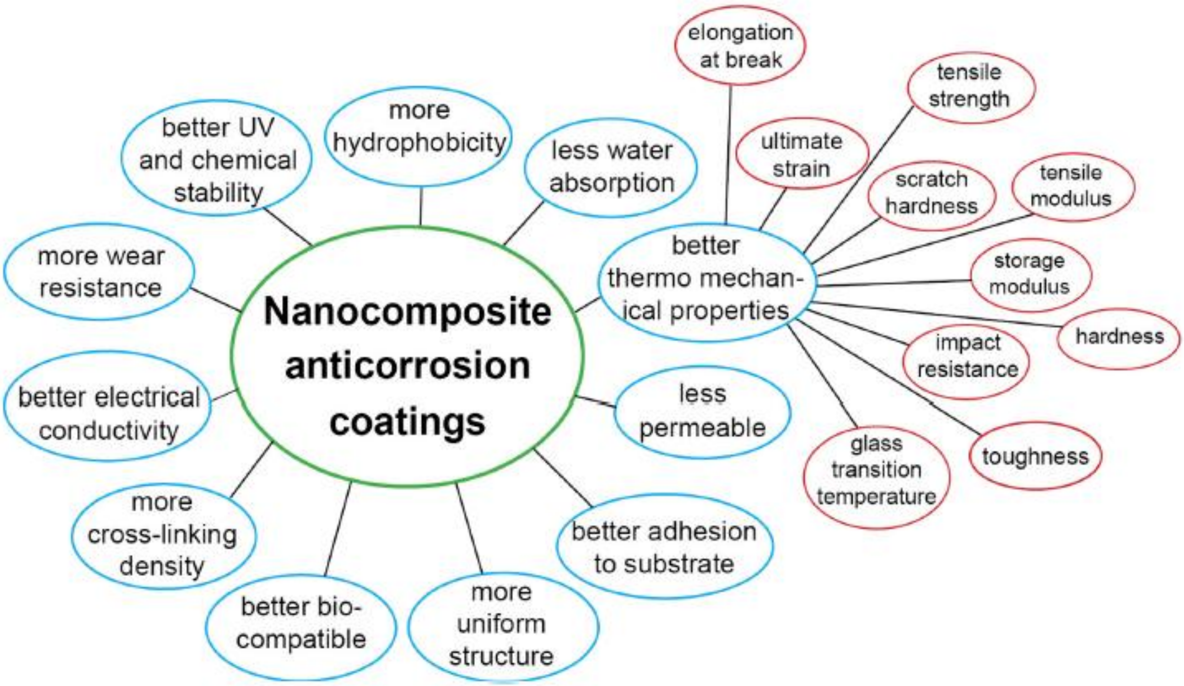

Figure 9: Effects of nanomaterial integration on nanocomposite organic coatings[15].

3.4.2 Antimicrobial activities

A functional antimicrobial coating can prevent the growth of microorganisms on the coating surface.One central area where nanocomposites are being applied is in the area of bacteria and fungi control. Silver nanoparticles (AgNP) are used in coatings, water treatment, and biotechnology as antibacterial and antifungal agents.Incorporating silver oxide (AgO) into coatings also enhanced the bactericidal effect of the nanocomposites.Coatings made from polydimethylsiloxane with silver nanoparticles (PDMS/AgNPs) demonstrate high antimicrobial activity against *Escherichia coli* and *Staphylococcus aureus*[2, 34, 53, 61]. According to Nguyen et al. [62], TiO_2/Ag nanohybrid-based polyethylene (PE) nanocomposite displayed a potent antibacterial efficiency against *Staphylococcus aureus* and *Escherichia coli*. They concluded that the composite's antibacterial activity was primarily due to the presence of silver nanoparticles (AgNPs).

The incorporation of the functionalised nanomaterial improved antimicrobial properties. This further confirms the earlier finding by Siyanbola et al. [26] that the presence of 3-aminopropyltrimethoxysilane (APTMS) modified ZnO in the polyurethane matrix prepared from *Thevetia peruviana* seed oil (TPSO) leads to thermal stability and antibacterial activity. This confirms that the hybrid films possess significant *Escherichia coli* and *Staphylococcus aureus* resistance. Also, according toSiyanbola et al. [51], including ZnO nanomaterial in coating formulation gives these nanocomposites noticeable antimicrobial activity against

Escherichia coli, *Klebsiella pneumonia*, *Staphylococcus aureus*, and *Aspergillus niger*. Li et al. [64]found out that coatings incorporated with ZnO have excellent antibacterial properties and that their efficiency increases as the concentration of ZnO increases in the polymer.La et al. [65] incorporated ZnO nanoparticles into an edible coating to enhance the shelf-life and quality of bananas (*Musa acuminata*L.) [51, 62, 63, 64, 65].

Zhang et al. [66] demonstrated that coating jet fuel tank surfaces with aluminium substrate polymers protects them from microbial contamination. It is 99.999% effective against *Escherichia coli*, *Staphylococcus aureus*, *Bacillus subtilis*, and *Yarrowialipolytica.*

Microbial infection poses a significant threat to human existence worldwide. Chen et al. [57] observed that although an antibacterial surface can kill bacteria or prevent initial adhesion, the surface is poorly biocompatible and easily degraded. Therefore, they prepared a polyurethane-acrylate (PUA) composite film, a biocompatible antibacterial-adhesion coating with broad-spectrum activity.

3.4.3 Durability

Durability is the ability of the coated surface to withstand wear, deterioration, or damage upon use over time or exposure to weathering elements [31, 67]. According to Chen et al. [57], silicone-epoxy coating shows high resistance to chemicals and weathering elements. AndtoMemon et al. [66], incorporating carbon fibres, nanodiamonds, and graphene enhances the durability of polymeric coatings due to increased mechanical properties [58, 66].

3.4.4 Optical Properties and Ultraviolet (UV) Resistance

When light (photo) incidents or falls on any surface, the light could be reflected, refracted, absorbed, or scattered. These properties are referred to as optical properties. The optical properties describe the object's clarity, gloss, dullness, or turbidity [68]. The extent to which a nanomaterial will withstand weathering depends on its optical properties [69].Dhoke et al. [4] affirmed that adding ZnO nanoparticles prevents the polymer composite from photo-degradation. Siyanbola et al. [26] explored the polymer composite matrix's inorganic nanoparticle/organic material ratio. They found that the coatings retain their photographic transparency and are unaffected by the percentage within the polymer matrix. Also, Dhoke et al. [4]demonstrated that upon exposure to salt spray and other harsh conditions like UV radiations, the gloss value of the coatings containing ZnO nanomaterial did not reduce as drastically as that of the neat coating[4, 26].Qiang et al. [27] prepared a luminescent nanocomposite of waterborne Polyurethane (WPU)/carbon quantum dots (CQDs) and discovered that the fabricated nanocomposite film showed excellent transparency and photoluminescence properties. They also noticed that the photoluminescence intensity of CQDs-WPU nanocomposite increased as the dosage of CQDs increased[27].

Ultraviolet (UV) resistance is the capacity of a polymer to withstand degradation after exposure to ultraviolet light. This form of degradation is also called photo-induced degradation. Photo-degradation occurs when epoxy and polyurethane coatings are exposed to ultraviolet (UV) light [2]. The ability of a nanocomposite polymer to be UV resistant depends mainly on its optical properties [69]. A polymer that has low UV resistance, therefore, will quickly deteriorate.ZnO nanomaterial is non-toxic and can block UV radiation; therefore, it is instrumental in cosmetics, textiles, and polymer coatings [4]. According to Naik et al. [17], the characteristic gloss retention of hyperbranched urethane alkyd (HBUA) coatings possesses cycloaliphatic urethane linkages that are UV-resistant in the polymer backbone.Jnido et al. [6] applied polyester/TiO_2 coatings on wood surfaces and discovered that the wood surface became UV-resistant moisture repellant, thus transforming it from hydrophilic to superhydrophobic,whileDas et al. [71] demonstrated that polyurethane/nano-silica (PU/NS) composite could shield UV radiations up to 300nm, beyond which it fails due to scattering phenomenon at the interface.

3.4.5 Chemical resistance

A substance is said to be chemically resistant if it can withstand a chemical attack. Strong or high chemical resistance makes the material remain unchanged after exposure. Such materials are highly resistant to corrosion [58].According to Siyanbola et al. [26], polyurethane exhibits good water and acid resistance which is why they are used in coatings. However, reinforcing such coatings with nanomaterial fillers gives higher toughness and strength and increases hydrophobicity. Wazarkar&Sabnis [52] demonstrated that polyurethane coatings exhibit remarkable resistance to acid and alkali after being immersed in 5%HCL and 5% NaOH solutions for 24 hours. The result shows no loss of gloss, film defect, etching, or softening of the film. The coatings also exhibited hydrolytic stability because when dipped in boiling water for 4 hours, no blisters, delamination, or loss of gloss were observed. Evaluating solvent resistance with methyl ethyl ketone (MEK) and xylene shows that polyurethane coatings can withstand xylene but show poor resistance with MEK. Raychura et al. [29] investigated the stain resistance property of PU coatings using beverages like coffee and tea. Stain resistance is the ability to withstand surface discolouration due to the hydrophilicity of the surface. They discovered that PU's ability to withstand stain-induced absorption is relatively high, and the stains could easily be washed off, making PU coating useful for household furniture [26, 29].

3.4.6 Others

The presence of inorganic nanoparticles in UV-curable coatings gives them flame-retardant and anti-fogging properties. A flame retardant is any substance that prevents or hinders the start of a fire and slows its (fire) growth. Waterborne polyurethane-zirconia (WBPU-ZrO_2) composite is environmentally friendly and has antistatic properties that prevent dust accumulation and electrical insulation [19, 23].

4. Prospects

Prospects here refer to future opportunities ahead of coating chemistry to enhance environmental health and reduce chemical footprints. The commitment of the United Nations to the funding of research in the area, setting the goal of zero gas flaring target by 2030, is a huge booster to the morale of environmentalists. There are lots of opportunities for interdisciplinary collaboration in the deployment of nanotechnology andprospects also for further research into coating chemistry, such as the development of Non-isocyanate polyurethane (NIPU), development of more eco-friendly processes in pursuit of responsible or green chemistry, use of nonedible oils as the source of triglycerides like oils from yellow oleanda (*Theveta peruviana*) and Castor (*Ricinus communis*) seeds.

This review would have achieved a lot if, beyond replacing petroleum resources with nano-improved renewable materials, we also paid close attention to the manufacturing processes and wastes generated throughout their lifecycle, especially as this will be in tandem with SDG 13

UN Definition "By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water, and soil in order to minimise their adverse impacts on human health and the environment."

5. Conclusion and Recommendation

Coatings will remain with us for a long time to come. Therefore, researching renewable materials' sustainability is critical for the coating industry's development, which must be sustained. Recent studies and technological advancesprove that the world is at risk due to increased greenhouse gas, ozone depletion, global warming, and environmental degradation. Commitment to responsible chemistry, therefore, must go beyond rhetoric. It must be backed by the political will to save our world from self-destructing. As research into coatings works is pushing the frontiers of green chemistry by employing renewable and biodegradable materials, this should be done without ignoring recycling some used materials and redesigning manufacturing processes to save our environment.

The use of vegetable oils is good, but if this competes with the food supply chain, we may create another food security problem while trying to solve one. This is why seed oils from *Thevetia peruviana,* also known as Yellow oleanda seed, and *Ricinus communis*seed, also known as castor seed which arenon-edible oils, come highly recommended by Siyanbola et al. [26, 50, 62, 70].

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