

Formulation & Production of Emulsion Paint Using Local Pigments and Extenders

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Abstract: *This study explores the multifaceted roles of key components in modern emulsion paint formulations, with a focus on water as the central solvent and carrier medium. Water-based paints, known for their eco-friendliness and reduced volatile organic compounds (VOCs), rely on water not only as a solvent but also as a film-forming facilitator and viscosity modifier. The research further evaluates the functional contributions of key additives such as polyvinyl acetate (PVA), sodium hexametaphosphate (SHMP), calcium carbonate, Tylose (hydroxyethyl cellulose), defoamers (e. g., silicon dioxide), ammonia solution, and alternative ingredients like egg yolk and formalin. Each additive plays a distinct role in enhancing the paint's performance-ranging from binder formation, dispersion, rheology control, and emulsion stabilization to microbial resistance and surface finish. Emphasis is placed on formulating sustainable, cost-effective, and high-performance coatings. The study also outlines the manufacturing process and evaluates the physical properties of the final paint product, which exhibited a viscosity of 5400 cP, a pH of 10.5, and a specific gravity of less than 0.828, confirming suitability for practical applications.*

Keywords: emulsion paint formulation, water-based paint, paint additives, eco-friendly coatings, paint performance properties

1. Introduction

Paint remains a remarkably adaptable material that continues to shape our world, bridging history, technology, and culture. In today's context, its relevance spans far beyond artistic and decorative uses, becoming integral to modern industries, sustainable development, and advanced manufacturing processes. From smart coatings that respond to environmental changes to eco-friendly formulations designed for a greener planet, paint has evolved to meet the complex demands of the 21st century [1]. Fundamentally, paint is a liquid, semi-solid, or solid substance applied to surfaces for protective, decorative, or functional purposes. Its core components-pigments, binders, solvents, and additives-remain essential. Pigments deliver color, binders ensure cohesion, solvents facilitate application, and additives tailor properties such as UV resistance, antimicrobial action, or enhanced durability. Historically, civilizations like the Egyptians and Romans used natural materials to create rudimentary paints, marking the earliest fusion of creativity and utility [2]. The Renaissance transformed paint into a fine art medium, with figures like Leonardo da Vinci pioneering oil-based techniques that allowed for richer color and depth. The industrial age and advances in chemistry brought about synthetic pigments and polymer-based binders, dramatically expanding the range and resilience of paints. This period laid the groundwork for the development of coatings used in everything from skyscrapers to spacecraft. Today, paint plays a vital role across diverse sectors [3]. In homes, it contributes to interior aesthetics and surface protection. In industries such as automotive, aerospace, marine, and electronics, it ensures safety, improves performance, and extends the life of products through corrosion resistance, thermal regulation, and even signal reflection or absorption [4]. Sustainability has become a central concern in modern paint development. Water-based

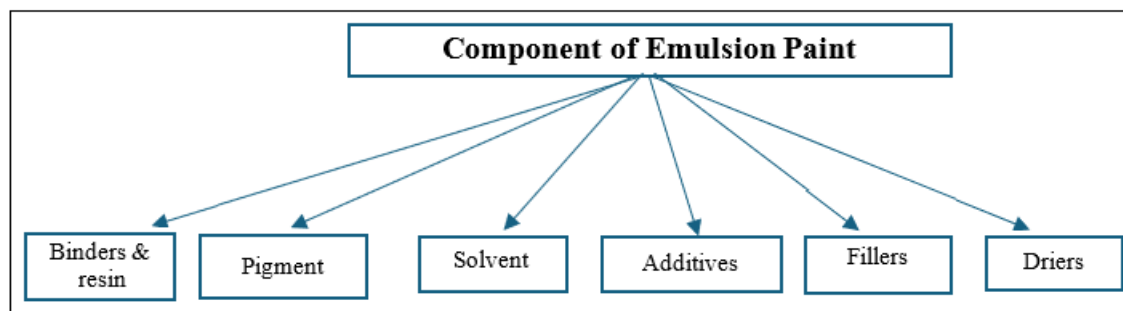
paints, including acrylic and latex, dominate the consumer market due to their low environmental impact, ease of use, and rapid drying. Meanwhile, innovations in bio-based resins, low-VOC formulations, and recyclable packaging reflect the industry's commitment to environmental stewardship. Specialty coatings now address specific challenges: anti-bacterial paints in healthcare settings, fire-retardant coatings in construction, and conductive paints in electronics. With the emergence of smart materials and nanotechnology, future paints may be capable of self-healing, energy harvesting, or even environmental monitoring. In essence, paint continues to evolve, not only preserving its historical significance but also adapting to the demands of a rapidly changing, technologically advanced, and environmentally conscious world.

Paint comes in various types, each formulated for specific purposes, surfaces, and application methods. Here are some common types of paint: Water-Based Paints: Latex Paint, Acrylic Paint. Oil-Based Paints: Alkyd Paint, Enamel Paint, Primer Paint, Epoxy Paint, Heat-Resistant Paint, Anti-Graffiti Paint, Spray Paint, Chalkboard Paint. Specialty Finishes: Textured Paint, Metallic Paint,

Low-VOC and Eco-Friendly Paints:

These paints contain fewer volatile organic compounds (VOCs), reducing their impact on indoor air quality and the environment. They're often water-based and come in various finishes and colors. Understanding the specific characteristics, surfaces, and environments where each type of paint performs best is crucial for achieving desired results in painting projects. Factors like durability, drying time, finish, and environmental impact should also be considered when choosing the appropriate paint type.

Component of emulsion paint:



Additives:

- **Thickeners:** These additives help in controlling the viscosity of the paint, making it easier to apply and preventing excessive dripping.
- **Stabilizers:** Stabilizers help to maintain the paint's consistency and prevent it from separating or settling.
- **Defoamers:** Defoaming agents are used to reduce the formation of foam during paint production and application.
- **Biocides and Preservatives:** These additives are included to prevent the growth of bacteria, mold, or fungi within the paint, extending its shelf life.
- **Antifreeze agents:** They help prevent the paint from freezing during storage in low temperatures.

Emulsion paints are versatile and can be formulated in various ways to achieve different finishes (matte, eggshell, satin, or semi-gloss), durability levels, and environmental considerations. The balance and combination of these components determine the performance, appearance, and functionality of the paint for specific applications.

2. Material and Methods

Raw materials:

Water, Sodium metahexa phosphate, Hibiscus flower, Calcium carbonate, PVA (poly vinyl acetate), monomer, Ammonium solution, Formalin, Egg yolk, Tylose, Deformer.

Composition of component

Sr. no	Name of component	Quantity
1.	Water	500 ml
2.	Sodium metahexa phosphate	TBS
3.	Titanium dioxide	25 gm
4.	Calcium carbonate	600 gm
5.	PVA (monomer)	40 gm
6.	Ammonia solution	6 ml
7.	formalin	6 ml
8.	Thinner	6 ml
9.	Deformer	3 ml
10.	Egg yolk	30 gm
11.	Hibiscus flower	5 gm

Reactor Specifications

Continuous Stirred Tank Reactor (CSTR), Capacity: 5 liters, Material of Construction: Stainless Steel (SS 316 preferred for corrosion resistance), 0–4000 RPM (variable speed control for shear adjustment), Control Panel: Digital or manual switch (On/Off) with optional RPM and temperature display.

This bench-scale setup is optimized for academic research, formulation testing, and parameter optimization. It allows real-time observation of emulsion formation, stability testing, and the study of variables such as surfactant concentration, mixing speed, temperature, and phase ratio. While this setup omits large-scale automation and advanced instrumentation (e. g., in-line viscosity, turbidity, or droplet size sensors), it offers the flexibility required for controlled experimentation and repeatability in a laboratory environment. Emulsion manufacturing systems can vary greatly depending on the type (O/W, W/O, multiple emulsions), the end-use (pharmaceutical, cosmetic, food, or chemical), and scalability needs. Therefore, the system can be easily modified to align with specific experimental goals or industry requirements.



3. Result and Discussion

1) Role of Water (H₂O) in Emulsion Paints

Water is a fundamental component in emulsion paints, commonly referred to as water-based paints. Its multifunctional role is essential to both the formulation and practical application of these paints, making it a cornerstone of contemporary coating technologies: Primary Solvent, Viscosity Modifier (Thinning Agent) The viscosity of water-based paint can be precisely adjusted by adding water, enhancing flow properties and application efficiency [5]. This is particularly beneficial for tools like brushes, rollers, or spray systems, allowing for smoother finishes with less effort.

- a) **Dispersion Medium for Pigments and Binders:** Water acts as a carrier for both pigments and polymeric binders, ensuring even distribution throughout the formulation. This promotes color consistency, uniform film formation, and optimal surface coverage during application.
- b) **Evaporation and Film Formation:** As the paint dries, water evaporates from the applied layer, enabling the coalescence of binder particles. This transition from liquid to solid forms a continuous film that adheres firmly to the substrate, providing durability and aesthetic appeal. The faster evaporation rate of water-compared to organic solvents-leads to quicker drying times and increased productivity.
- c) **Sustainability and Indoor Air Quality:** Water-based paints are significantly lower in Volatile Organic Compounds (VOCs), contributing to healthier indoor environments and reduced environmental impact. As global regulations tighten around solvent emissions, water's role in eco-friendly paint systems has become increasingly vital.
- d) **Ease of Clean up:** Tools and surfaces used with emulsion paints can be easily cleaned using just water, eliminating the need for harsh chemical solvents. This adds to user convenience and further supports the sustainability of water-based systems.

2) Sodium Hexa-metaphosphate ((NaPO₃)₆) in Emulsion Paints

Sodium Hexametaphosphate (SHMP) is a multifunctional additive widely used in modern emulsion (water-based) paint formulations. Its role extends across several critical performance and processing parameters, making it a valuable component in both commercial and industrial-grade paints:

- a) **Dispersing Agent:** SHMP acts as an effective dispersant, helping to prevent pigment agglomeration by breaking down clusters and keeping particles evenly distributed throughout the formulation. This ensures consistent color development, enhanced opacity, and improved overall finish quality.
- b) **Emulsion Stabilizer:** In water-based systems where pigments and polymer binders coexist in a dispersed phase, SHMP contributes to emulsion stability [6]. It helps inhibit phase separation, sedimentation, and flocculation, thereby prolonging shelf life and maintaining uniform consistency during storage and application.
- c) **pH Buffer and Control:** SHMP aids in regulating the pH of the paint formulation, which is crucial for maintaining the stability of dispersion systems and the performance of other additives. A balanced pH prevents

microbial growth, optimizes binder performance, and supports compatibility among formulation components.

- d) **Rheology Modification:** While not a primary rheology modifier, SHMP can influence flow and viscosity by interacting with other ingredients. It contributes to the ease of application, leveling, and film formation properties, ultimately improving the user experience and surface finish.
- e) **Water Softening Capability:** In regions where hard water is used during paint production or dilution, SHMP helps by sequestering calcium and magnesium ions, reducing water hardness. This prevents undesirable reactions with paint ingredients that could otherwise affect dispersion quality and stability.

Sodium Hexa-metaphosphate is a versatile auxiliary additive in modern emulsion paint technology. Its functions-ranging from pigment dispersion and emulsion stabilization to pH control and water softening-directly impact the paint's quality, durability, and processing efficiency. With increasing emphasis on formulation precision and long-term stability, SHMP remains a reliable and effective tool in the coatings industry.

3) Calcium Carbonate (CaCO₃) in Emulsion Paints

Calcium carbonate is one of the most widely used mineral additives in contemporary emulsion (water-based) paint formulations. Its versatility, availability, and cost-effectiveness make it a valuable component in achieving a balance between performance, aesthetics, and economic efficiency.

- a) **Functional Extender and Cost Optimizer:** Acting as a functional extender or filler, calcium carbonate increases the paint's volume without compromising core properties. This helps reduce the reliance on more expensive raw materials like pigments and binders, allowing manufacturers to offer cost-effective products while maintaining adequate performance.
- b) **Enhancement of Opacity and Whiteness:** Due to its high refractive index and fine particle size, calcium carbonate improves the paint's opacity by scattering light effectively. It supports brighter whites and enhances color strength by improving surface coverage-critical in achieving uniform finishes with fewer coats.
- c) **Rheological Contribution:** Calcium carbonate contributes to the paint's rheological behavior by influencing viscosity and flow characteristics. It improves application smoothness, anti-sag properties, and leveling-making it easier to apply by brush, roller, or spray without running or streaking.
- d) **Improved Film Properties:** When properly formulated, calcium carbonate reinforces the dried paint film by increasing abrasion resistance and surface hardness [7]. This adds durability, especially in interior and exterior wall coatings where wear resistance is important.
- e) **Gloss Control:** Depending on its particle size and concentration, calcium carbonate can be used to reduce the gloss level of the paint, helping to achieve flat or matte finishes. This is especially beneficial in architectural coatings where non-reflective surfaces are often preferred.
- f) **Sustainability and Environmental Compatibility:** Calcium carbonate plays a critical role in modern emulsion paint systems, enhancing performance, visual

appeal, and production efficiency. Its contribution to opacity, texture, mechanical strength, and cost control makes it an indispensable additive. However, careful formulation is essential to balance its benefits with potential effects on viscosity, adhesion, and long-term durability.

4) Polyvinyl Acetate (PVA) in Emulsion Paints:

Polyvinyl acetate (PVA) is a widely used synthetic polymer in modern emulsion (water-based) paints, primarily serving as a binder. Its chemical versatility and film-forming capabilities make it a cornerstone ingredient in architectural and decorative coatings, especially for interior applications.

- a) **Primary Binder:** PVA acts as the primary film-forming binder in many emulsion paints. During application, water evaporates from the formulation, allowing PVA to coalesce into a continuous film. This film binds pigment particles together and secures them to the substrate, ensuring long-term adhesion and durability.
- b) **Enhanced Adhesion:** One of PVA's critical functions is improving paint adhesion across various substrates, including plaster, drywall, wood, and masonry. Its excellent bonding capacity helps minimize issues such as peeling, chalking, or flaking, even under variable indoor conditions.
- c) **Strong, Flexible Film Formation:** Upon drying, PVA forms a robust yet flexible film that contributes to the mechanical integrity of the coating. This enhances resistance to abrasion, minor impacts, and surface wear-critical factors in interior wall applications.
- d) **Improved Application and Workability:** PVA-based emulsion paints offer excellent workability. The paint spreads smoothly and evenly using brushes, rollers, or spray equipment, supporting consistent film thickness and improved surface coverage.
- e) **Reduction in Porosity:** By lowering the porosity of the paint film, PVA helps seal porous surfaces such as plaster and cement. This minimizes substrate absorption, improves surface uniformity, and can reduce the number of coats required.
- f) **Water Resistance and Washability:** While PVA is inherently water-soluble, once dried and coalesced into a film, it offers moderate water resistance [8]. This contributes to the washability of interior coatings-making surfaces easier to clean without degrading the film, especially when used in conjunction with crosslinking agents or modified polymers.

Polyvinyl acetate remains a key component in contemporary emulsion paint formulations due to its excellent binding, adhesion, film-forming, and cost-effective performance. While more advanced copolymers (such as vinyl acrylics or styrene-acrylics) are used for high-performance or exterior paints, PVA continues to be the preferred choice for interior coatings where smooth finish, ease of application, and affordability are paramount.

5) Ammonium solution

- a) **Alkalinity Regulation:** Ammonia solution can act as an alkalinity regulator in paints. It helps in controlling the alkalinity or acidity of the paint, which can affect the paint's properties, such as its drying time, stability, and adhesion.
- b) **Emulsion Stability:** In emulsion paints, ammonia

solution can contribute to the stability of the emulsion by helping to prevent coalescence or separation of the dispersed particles (such as pigments and binders). This aids in maintaining a well-mixed and stable paint formulation.

- c) **Viscosity Control:** Ammonium hydroxide can influence the viscosity of the paint. Depending on the formulation and concentration used, it may help in adjusting the viscosity of the paint to achieve desired application characteristics.
- d) **Enhancing Pigment Performance:** In some cases, ammonia solution can aid in enhancing the performance of certain pigments or additives in the paint formulation by improving their dispersion and compatibility [9].
- e) **Antimicrobial Properties:** Ammonium hydroxide, being a weak base, might also contribute to the paint's resistance to microbial growth, potentially acting as a preservative.

It's important to note that the use of ammonia solution in paint formulations should be carefully controlled and balanced to avoid adverse effects on paint properties or potential issues related to odor, toxicity, or compatibility with other ingredients. Manufacturers carefully consider the concentration and compatibility of ammonia solution to optimize its beneficial effects in emulsion paint formulations.

6) Formalin

Formalin, which is a solution of formaldehyde gas dissolved in water, is not commonly used in emulsion paint formulations due to its toxicity and health concerns. Formaldehyde is a volatile organic compound (VOC) that is known to have harmful effects on human health and the environment.

In the past, formaldehyde-based resins or solutions might have been used as preservatives or biocides in some paint formulations to inhibit microbial growth or as a crosslinking agent in certain specialty coatings.

However, due to increasing awareness of its health risks, regulations regarding formaldehyde emissions, and the availability of alternative additives, its use in paints has significantly diminished or been eliminated in many regions.

The potential health hazards associated with formaldehyde exposure, including respiratory issues, skin irritation, and carcinogenicity, have led to its restricted use or complete avoidance in consumer products, including paints.

Modern paint formulations prioritize safer alternatives and eco-friendly additives that achieve similar functionalities without posing health risks to individuals or the environment. Biocides or preservatives used in paint formulations today are often chosen from a range of less toxic or non-toxic alternatives to ensure product stability and prevent microbial contamination without relying on formaldehyde-based compounds.

Therefore, formalin or formaldehyde is not typically used in contemporary emulsion paint formulations due to its potential health hazards and regulatory restrictions. Instead, manufacturers focus on utilizing safer and more environmentally friendly additives in their paint products.

7) Egg yolk

Egg yolk has historically been used as a binding agent in paint formulations, particularly in traditional or historic painting techniques, such as egg tempera. However, its use in modern emulsion paints is extremely rare due to several limitations and the availability of more effective and stable synthetic binders.

In traditional egg tempera painting, egg yolk was mixed with pigments to create a paint medium. Egg yolk contains lecithin and proteins that act as natural emulsifiers and binders. When mixed with pigments, it forms a durable paint film with a matte finish.

However, there are significant drawbacks to using egg yolk in emulsion paints for modern applications:

- a) **Durability Issues:** Egg yolk-based paints are susceptible to moisture, temperature fluctuations, and damage from environmental factors, which can cause the paint film to degrade over time.
- b) **Limited Compatibility:** Egg yolk-based paints might not be compatible with other additives or synthetic binders commonly used in modern paint formulations. This could result in instability or inconsistent performance.
- c) **Storage and Shelf Life:** Egg-based paints have a relatively short shelf life compared to synthetic paints. They can spoil or become unusable if not stored properly.
- d) **Application Challenges:** Egg yolk-based paints can be challenging to apply and may require specific techniques and expertise.

Due to these limitations and the availability of more reliable synthetic binders, egg yolk is not a practical or commonly used ingredient in modern emulsion paint formulations. Contemporary paints rely on synthetic polymers such as acrylics, vinyl acrylics, polyvinyl acetate (PVA), and other advanced binders that offer improved durability, flexibility, adhesion, and performance across a wide range of applications and surfaces.

8) Tylose

Tylose, also known as hydroxyethyl cellulose (HEC), is a non-ionic cellulose ether that serves as a thickener, rheology modifier, and stabilizer in various applications, including emulsion paint formulations. Its use in emulsion paints provides several benefits:

- a) **Thickening Agent:** Tylose is used as a thickener to adjust the viscosity of the paint. It helps control the flow properties of the paint, preventing sagging or dripping during application and improving the paint's overall workability.
- b) **Improved Stability:** Tylose helps stabilize the paint emulsion by preventing settling or separation of pigments and other components. It assists in maintaining the homogeneity and consistency of the paint over time.

9) Defoamer (silicon Sio2)

In the context of emulsion paint, a defoamer or antifoaming agent is an additive used to control or prevent the formation of foam during the manufacturing process, application, or storage of the paint [10]. Foam can be produced due to the agitation of paint ingredients, the presence of surfactants, or other factors.

The primary purpose of a defoamer in emulsion paint is to:

- a) **Foam Control:** Defoamers help in suppressing or

eliminating foam formation that might occur during the production, mixing, or application of the paint. Excessive foam can negatively impact the paint application by causing uneven coverage, trapping air bubbles in the dried film, or affecting the appearance of the painted surface.

- b) Defoamers work by disrupting the foam bubbles, causing them to collapse or break, and preventing the formation of new bubbles. They typically contain surface-active agents or silicone-based compounds that reduce the surface tension of the paint, allowing trapped air bubbles to escape more easily.
- c) The manufacturing process of emulsion paint involves several stages, including formulation, mixing, grinding, and packaging. Here is a general procedure for manufacturing emulsion paint:
- d) **Quality Control and Adjustments:** The paint batch is tested for various properties such as viscosity, pH, color consistency, and stability. Adjustments are made if needed, like fine-tuning the color, viscosity, or adding more additives for desired characteristic.
- e) **Final Properties of the Emulsion Paint Sample:**
- f) **Viscosity:** 5400 centipoise, indicating a medium-to-high thickness suitable for uniform application and good surface coverage.
- g) **pH:** 10.5, reflecting a mildly alkaline formulation, which helps enhance paint stability and prevent microbial growth.
- h) **Specific Gravity:** Less than 0.828, suggesting a lightweight composition ideal for ease of handling and application, while also contributing to better spread ability on various substrates.

4. Conclusion

The research confirms that water is not merely a solvent but a vital enabler of functionality in emulsion paints-affecting dispersion, film formation, drying time, and overall environmental impact. Additives like PVA, SHMP, and calcium carbonate serve essential roles in optimizing adhesion, opacity, rheological behavior, and durability. PVA particularly enhances film strength and workability, while SHMP stabilizes emulsions and improves pigment dispersion. Calcium carbonate acts as an economical extender that improves mechanical strength and finish. Modern emulsion formulations avoid harmful additives like formalin, focusing instead on safer and more sustainable components. Final product characterization shows desirable viscosity, alkaline pH, and low specific gravity, indicating a stable and easy-to-apply formulation. Together, these findings underscore the potential of water-based paints to meet both performance demands and environmental standards, making them a preferred choice in contemporary coating technologies.

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