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"Waterborne Paints with Biocidal Properties"

Abstract

Relevance of the Research Topic

The current level of technological advancement in waterborne paints and coatings (WPCs) allows for a transition from traditional solvent-based systems—characterized by environmental and fire hazards—to safer water-dispersed coatings. However, the widespread adoption of WPCs is limited by their susceptibility to microbiological contamination, which can occur due to insufficient industrial hygiene at various stages of production or the use of bio-sensitive components.

A critical issue remains the need to protect surfaces in residential, industrial, and medical facilities from microorganisms that degrade the durability, performance, and decorative properties of coatings. The metabolic byproducts of these organisms can worsen sanitary conditions and pose serious health risks. Modern studies highlight the similarity of colonization mechanisms of solid substrates by bio-organisms in both aquatic and airborne environments, making the development of bioresistant materials a universal and highly demanded objective. In this context, the development of waterborne paints with biocidal properties that ensure long-term surface protection while maintaining environmental safety is a relevant and practically significant task.

Current State of Research

The topic of waterborne paints with biocidal properties is in an active stage of study and development. The literature presents research on the composition, mechanism of action, and effectiveness of biocidal additives in paints and coatings. Various methods of introducing antimicrobial components have been developed, and studies have been conducted on the impact of biocides on the performance properties of paints and coatings, with an emphasis on developing environmentally friendly and effective antimicrobial additives. However, issues related to the long-term stability of biocidal effects, compatibility of various components, and their environmental impact require further investigation and practical validation.

Objects of the Study

The study focuses on:

- Aqueous dispersions of polyvinyl acetate (PVA) and styrene-acrylic polymers, and waterborne paints based on these dispersions.
- As biocidal additives, the following polycations were studied: polydiallyldimethylammonium chloride (PDADMAC), a copolymer of methacryloylguanidine and polydiallyldimethylammonium chloride

(MGGH/DADMAC), and polyhexamethylene guanidine hydrochloride (PHMG-HC).

Purpose of the Study

The aim of this work is: To develop waterborne paints with biocidal properties that effectively protect painted surfaces from microbial colonization, including fungi, bacteria, and mold. Particular attention is paid to the selection of biocidal polyelectrolytes that combine high efficiency with environmental safety while maintaining the performance properties of the paint.

To achieve this goal, the following objectives were addressed:

1. The effectiveness of cationic polyelectrolytes—PDADMAC, PHMG-HC, and the MGGH/DADMAC copolymer—was studied as biocidal agents for preventing microbial growth in water-dispersed coatings and paints.
2. The effect of polyelectrolytes on the compatibility and stability of waterborne paints based on styrene-acrylic and PVA dispersions, as well as on the properties of the coatings, was evaluated.
3. Composite biocidal additives (CBAs) containing PHMG-HC immobilized on an inorganic carrier (montmorillonite) were synthesized.
4. The influence of CBAs on microbial suppression, paint stability, and coating properties was determined.

Methodology and Research Methods, Reliability of Results

The following methods were used in the study:

- Thermogravimetric analysis (Netzsch STA 2500 Regulus);
- X-ray diffraction analysis (Rigaku RU-200 Rotaflex diffractometer);
- X-ray fluorescence elemental analysis (Thermo Scientific ARL PERFORM'X XRF Spectrometer);
- pH-metry (I-160 MI laboratory ionometer);
- Biofouling assessment method developed by the S.N. Vinogradsky Institute of Microbiology of the Russian Academy of Sciences;
- Mold resistance testing in accordance with GOST 9.050–2021;
- Standardized methods for evaluating paint and coating properties.

The use of modern research methods and the absence of contradictions with the literature confirm the reliability of the obtained results.

Key Findings to Be Defended:

1. Formulations of waterborne paints with biocidal properties have been developed that effectively protect coatings and painted surfaces from biological degradation.
2. The composition of biocidal additives was optimized to provide long-lasting antimicrobial effects without adversely affecting the technological and performance characteristics of the paint.
3. The impact of biocidal components on the stability of waterborne paints was investigated. Compatibility with the polymer base and the stability of the dispersion system throughout storage were confirmed.
4. Tests confirmed the high antimicrobial activity of the paints against a broad range of microorganisms.
5. It was substantiated that the use of the proposed paints meets modern environmental safety requirements, including the minimization of volatile organic compounds (VOCs) and the absence of toxic effects on humans and the environment.
6. The developed biocidal waterborne paints are recommended for use in high-humidity environments (bathrooms, kitchens, basements) as well as for exterior applications in conditions with a high likelihood of microbial contamination.