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TECHNOLOGY FOR OBTAINING ANTICORROSIVE COATINGS BASED ON LOCAL RAW MATERIAL

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ABSTRACT

This article examines the technological principles of producing anticorrosive coatings from locally available mineral and organic raw materials. The study is based on a compositional approach in which the protective performance of the coating is formed through the interaction of four functional blocks: binder, filler, inhibitive pigment, and processing regime. Special attention is given to kaolin, bentonite, basalt flour, locally sourced phosphate-containing components, and film-forming systems compatible with industrial coating practice. The purpose of the article is to systematize the scientific basis of using domestic resources in protective coating formulations, propose a rational process flow, and identify the main factors controlling barrier and active corrosion protection. The materials-and-methods section describes raw material preparation, fraction control, surface pretreatment, dispersing sequence, curing, and the main evaluation criteria for coating quality. The results indicate that local lamellar and dispersed minerals can reduce porosity, lengthen the diffusion path of water and ions, improve packing density, and support the stabilization of inhibitive species at the metal/coating interface. At the same time, the final efficiency of the coating depends not only on the choice of raw materials, but also on drying, particle size distribution, wetting, mixing intensity, and substrate cleanliness. The discussion shows that local raw materials are technologically meaningful only when their chemistry and granulometry are standardized; otherwise, low cost may be offset by unstable coating performance. The article concludes that anticorrosive systems based on local resources can provide both import substitution and a realistic route toward regionally adapted protective materials for machinery, construction steel, pipelines, and infrastructure components.

Keywords: anticorrosive coating, local raw materials, kaolin, bentonite, basalt flour, phosphate pigment, epoxy system, barrier protection, metal surface, coating technology.

АННОТАЦИЯ

В данной статье рассматриваются технологические принципы производства антикоррозионных покрытий из местного минерального и органического сырья. Исследование основано на композиционном подходе, при котором защитные свойства покрытия формируются за счет взаимодействия четырех функциональных блоков: связующего, наполнителя, ингибирующего пигмента и режима обработки. Особое внимание уделяется каолину, бентониту, базальтовой муке, местным фосфатсодержащим компонентам и пленкообразующим системам, совместимым с промышленной практикой нанесения покрытий. Цель статьи – систематизировать научные основы использования отечественных ресурсов в рецептурах защитных покрытий, предложить рациональную технологическую схему и определить основные факторы, контролирующие барьерную и активную защиту от коррозии. В разделе «Материалы и методы» описаны подготовка сырья, контроль фракций, предварительная обработка поверхности, последовательность диспергирования, отверждение и основные критерии оценки качества покрытия. Результаты показывают, что местные слоистые и дисперсные минералы могут снижать пористость, удлинять путь диффузии воды и ионов, улучшать плотность упаковки и способствовать стабилизации ингибирующих веществ на границе раздела металл/покрытие. В то же время конечная эффективность покрытия зависит не только от выбора сырья, но и от сушки, гранулометрического состава, смачивания, интенсивности перемешивания и чистоты подложки. В статье показано, что местное сырье имеет технологическое значение только в том случае, если его химический состав и гранулометрия стандартизированы; в противном случае низкая стоимость может быть компенсирована нестабильной эффективностью покрытия. В заключение статьи утверждается, что антикоррозионные системы на основе местных ресурсов могут обеспечить как импортозамещение, так и реалистичный путь к созданию регионально адаптированных защитных материалов для машин, строительной стали, трубопроводов и компонентов инфраструктуры.

Ключевые слова: антикоррозионное покрытие, местное сырье, каолин, бентонит, базальтовая мука, фосфатный пигмент, эпоксидная система, барьерная защита, металлическая поверхность, технология нанесения покрытия.

INTRODUCTION

Corrosion remains one of the most persistent causes of material loss in metallurgy, construction, transport engineering, and industrial infrastructure. When metal structures are exposed to moisture, dissolved salts, industrial gases, or cyclic temperature changes, the degradation process affects not only appearance but also reliability, safety, and operating cost. Because of this, protective coatings continue to be one of the most economically practical strategies for corrosion control.

Conventional coating systems often rely on imported binders, specialized pigments, and expensive functional fillers. Such dependence increases formulation cost and makes production vulnerable to supply disruptions, currency fluctuations, and unstable logistics. For countries and regions with a strong mineral resource base, this creates a clear scientific and technological incentive to replace part of the imported components with local raw materials without sacrificing performance.

The idea of using local resources in protective coatings should not be reduced to a purely economic measure. In a properly designed formulation, locally available minerals can perform distinct physicochemical functions. Lamellar particles may increase tortuosity and strengthen the barrier effect. Fine dispersed mineral fractions may improve packing density and reduce the permeability of the cured film. Certain phosphate-containing compounds may provide an inhibitive effect at the metal/coating interface. Organic modifiers derived from regional industrial streams may further adjust rheology, adhesion, and film formation.

However, a weak formulation strategy is to assume that any inexpensive mineral powder will automatically work as a corrosion-protective filler. That assumption is false. The protective efficiency of a coating depends on particle morphology, chemical purity, oil absorption, moisture content, compatibility with the binder, and the stability of the cured microstructure. Local raw materials are useful only when their role in the system is technically justified and their preparation is controlled.

The purpose of this article is therefore to present a structured IMRAD-style discussion of the technology for obtaining anticorrosive coatings based on local raw materials. The paper focuses on the functional role of kaolin, bentonite, basalt flour, and phosphate-containing ingredients; proposes a technological sequence for raw material preparation and coating manufacture; and discusses the main factors that determine the protective performance of the final film.

MATERIALS AND METHODS

The conceptual basis of the work is a composite coating approach. Instead of treating the formulation as a simple mixture of resin and pigment, the system is viewed as an interaction of four coordinated functional subsystems: the film-forming binder, the mineral filler block, the inhibitive block, and the technological processing block. The binder is responsible for adhesion, continuity, and chemical resistance; the mineral block builds barrier microstructure; the inhibitive block slows electrochemical activity; and the processing block controls dispersion, film homogeneity, and curing quality.

Among the local raw materials, kaolin was considered as a plate-like aluminosilicate filler capable of increasing the diffusion path for aggressive media. Bentonite was included as a layered mineral with high surface activity, which may act both as a rheology modifier and as a carrier phase for inhibitive species. Basalt flour was selected as a hard and chemically stable dispersed filler that can improve packing density and mechanical resistance. Phosphate-containing local components were treated as candidate inhibitive pigments for active protection at the metal/coating boundary. As binder systems, epoxy and epoxy-modified compositions were taken as the baseline due to their practical relevance in corrosion protection.

Raw material preparation was divided into three mandatory stages: drying, grinding, and fractioning. Drying is essential because residual moisture in mineral fillers leads to agglomeration, porosity, unstable viscosity, and poor adhesion. Grinding determines the active surface area and the packing behavior of the particles. Fractioning makes it possible to narrow the particle size distribution and to avoid a formulation in which large particles create weak points inside the film. In technological terms, ignoring any of these three stages undermines the performance of the coating before the formulation even reaches the mixing vessel.

The substrate preparation procedure was treated as an integral part of the technology rather than a secondary operation. Metal samples must be mechanically cleaned from rust scale, degreased to remove oils and contaminants, dust-free before coating, and, where required, chemically pretreated or primed. A technically strong coating cannot compensate for poor substrate cleanliness. In fact, one of the most common industrial failure modes is not chemical weakness of the coating itself but underfilm corrosion initiated by inadequate surface preparation.

The coating composition was prepared in a sequential mixing regime. First, the binder was homogenized with wetting and dispersing additives. Second, the inhibitive pigment and the finer mineral fractions were introduced gradually under controlled stirring. Third, the coarser or higher-density filler fractions were added to optimize packing without provoking sedimentation. Finally, the system was adjusted to the required application viscosity and filtered if necessary. The curing regime was selected according to the binder chemistry and targeted film thickness.

The main evaluation criteria included viscosity, solids content, application stability, adhesion to metal, impact resistance, flexibility, water uptake, and expected behavior in saline or humid media. The discussion in this article is therefore methodological and technological: it identifies the controlling variables and their functional relationships rather than reporting a narrow single-batch laboratory experiment.

Table 1. Functional structure of the proposed anticorrosive coating system

Component block	Typical local raw material	Primary function	Technological note
Barrier filler block	Kaolin, basalt flour	Reduces porosity and increases diffusion path	Requires drying and fraction control
Layered/rheology block	Bentonite	Improves suspension stability and can retain active species	Needs careful dosage to avoid excessive viscosity

Active inhibitive block	Phosphate-containing component	Forms protective products at the metal interface	Most effective when well dispersed
Film-forming block	Epoxy or modified resin system	Ensures adhesion, cohesion, and chemical resistance	Curing regime strongly affects final performance

RESULTS AND DISCUSSION

The analysis shows that the effectiveness of anticorrosive coatings based on local raw materials is primarily governed by the density and continuity of the internal microstructure. Kaolin and basalt flour contribute most strongly to the barrier mechanism. When their particle size and distribution are properly controlled, they occupy free volume inside the film and force water, oxygen, and ions to pass through a longer and more complex route. This reduces the rate at which aggressive media reach the metal substrate.

Bentonite should not be treated as a cheap filler with a decorative auxiliary role. Its layered structure allows it to function as a technologically active phase. In small and controlled amounts, it can improve suspension stability and limit rapid sedimentation of denser particles. In more advanced formulations, it may also serve as a carrier or reservoir for inhibitive components. The trade-off is obvious: if the bentonite content is too high or insufficiently activated, viscosity rises sharply, dispersion becomes difficult, and the applied film may contain structural defects. That is a classic example of why local raw materials must be engineered, not merely added.

The incorporation of phosphate-containing inhibitive ingredients is one of the most important elements of the proposed technology. A purely barrier coating may perform well as long as the film remains intact, but once the coating is scratched or microdefects appear, corrosive electrolytes can quickly reach the substrate. Inhibitive pigments provide a second line of defense by promoting the formation of low-solubility protective products at the metal surface and slowing electrochemical reactions in the defect zone. This combined barrier-plus-active mechanism is much more robust than relying on passive sealing alone.

Binder selection determines whether the potential of the mineral phase is actually realized. Epoxy-based systems are attractive because they generally provide strong adhesion, low permeability, and comparatively high chemical resistance. Yet even a good binder can fail when the filler surface is wet, contaminated, or poorly compatible with the resin matrix. The critical lesson is that coating performance emerges from interfacial compatibility. A cheap filler that disrupts wetting or creates agglomerates may damage the system more than it helps. Therefore, the formulation must be optimized around dispersion behavior rather than around filler content alone.

Surface preparation also emerged as a decisive technological factor. In industrial practice, coating failures are often misdiagnosed as formulation failures while the actual cause is poor substrate pretreatment. Residual rust, grease, and dust weaken adhesion, create local electrochemical cells, and accelerate underfilm corrosion. For this reason, the technology for obtaining an anticorrosive coating cannot be reduced to recipe design. It must be understood as a complete process chain including substrate conditioning, composition preparation, application, and curing.

From an economic perspective, local raw materials offer a meaningful route toward reducing the dependence on imported functional fillers and part of the pigment package. This can lower production cost and make coating technologies more accessible for regional infrastructure, agricultural machinery, reservoirs, pipelines, and structural steel components. But there is a nontrivial risk: if the supply chain of local minerals does not include quality control for moisture, granulometry, and chemical composition, the apparent cost advantage may disappear through batch-to-batch instability and premature coating failure.

Another important result of the analysis is that locally based anticorrosive coatings should not be designed as one universal formula for every service condition. A formulation intended for humid atmosphere, saline exposure, buried metal, or mechanically stressed surfaces should not be expected to share identical filler ratios and curing regimes. The rational strategy is to build a platform technology in which the same local raw material base is adapted to different environments through changes in binder chemistry, inhibitive loading, particle ratio, and final film thickness.

Overall, the proposed approach demonstrates that local raw materials can play a serious technological role in anticorrosive coating design when they are introduced according to function, processed to a stable quality, and integrated into a coherent coating architecture. The weakest version of the idea would be to present local materials as inherently beneficial merely because they are available. The defensible version is narrower and stronger: local materials are useful when their mineralogy, morphology, and processing route are aligned with the corrosion-protection mechanism of the final coating system.

CONCLUSION

1. Local mineral and organic resources can form a viable raw material base for anticorrosive coatings when each component is assigned a clear barrier, inhibitive, rheological, or film-forming function.

2. Kaolin, bentonite, basalt flour, and phosphate-containing ingredients are technologically relevant not because they are inexpensive, but because they can contribute to diffusion control, microstructural densification, and active corrosion inhibition.

3. The effectiveness of the final coating depends on a complete process chain that includes drying and fractioning of raw materials, proper sequential dispersion, rigorous substrate preparation, and a controlled curing regime.

4. Economic advantages from the use of local raw materials are realistic only under conditions of standardized quality control; otherwise, formulation instability becomes the dominant failure mode.

5. Future work should focus on laboratory and pilot-scale validation, salt-spray and humidity testing, optimization of particle-size ratios, and long-term field performance under region-specific service conditions.

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