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DEVELOPMENT OF A REAGENT FOR SNOW AND ICE REMOVAL

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Abstract
This paper examines the development of a liquid de-icing reagent based on calcium and magnesium nitrates obtained from dolomite and urea. It discusses the limitations of conventional salt-containing mixtures, reviews existing technologies for producing nitrate–urea formulations, and describes the main stages of preparing the proposed liquid composition. The study employed nitric-acid processing of dolomite, formulation with urea, pH monitoring, and volumetric and titrimetric chemical analyses. The reagent was tested under subzero conditions, including road trials at the Kamchik Pass. According to recommendations of the Uzavtoyul Research Institute, the liquid formulation may be used to remove road ice at temperatures down to -32 °C. Technical specifications TSh 00203068-24:2014 were registered for the NKMM product. The findings support the practical potential of a liquid nitrate–urea de-icing formulation; detailed environmental safety and comparative performance assessments remain necessary.

Keywords: Deicing reagent; snow and ice removal; dolomite; calcium nitrate; magnesium nitrate; urea; liquid formulation; winter road maintenance.



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INTRODUCTION

In the Republic of Uzbekistan, quartz sand mixed with technical-grade sodium chloride, as well as ash from fuel combustion at thermal power plants, is commonly used to combat ice formation on road surfaces. However, salt-based mixtures may adversely affect the environment and road pavements and are corrosive to metal structures and reinforced concrete [1].

De-icing agents should meet several requirements: lower the freezing point of water below anticipated minimum ambient temperatures; exhibit hydrophilic properties and melt snow and ice rapidly; avoid deterioration of road pavements; minimize harmful effects on human health, roadside vegetation, metals, rubber, and leather products; be nonflammable, nonexplosive, and of low toxicity; and have low application rates and a uniform particle-size distribution where applicable.

REVIEW OF EXISTING TECHNOLOGIES

A previously described process [2] produces a composition based on complex compounds of calcium and magnesium nitrates with urea, represented by the general formula $Ca(NO_3)_2 \cdot Mg(NO_3)_2 \cdot 8CO(NH_2)_2$, for use as a de-icing reagent. The process involves mixing calcium nitrate, obtained by treating quicklime with nitric acid at a concentration of 53–55 wt.%, with a magnesium-containing reagent (preferably magnesium nitrate or magnesite) and urea added to a neutral solution of calcium and magnesium nitrates. A surfactant is then added, followed by drying. When needed, the nitrate solution is neutralized with lime milk. Neonol is proposed as the preferred surfactant at 1–5 wt.%, and the recommended mixing temperature is 50–90 °C.

The disadvantages of this approach include the use of a 32–33% magnesium nitrate solution, which introduces a substantial amount of water, increases energy

consumption during granulation and drying, and reduces equipment productivity. The use of individual nitrate reagents rather than suitable industrial by-products also increases production costs.

The closest process in terms of technical principle and expected outcome involves complex calcium and magnesium compounds with the general formula (1.0–1.9)·$Ca(NO_3)_2$·$Mg(NO_3)_2$·$8CO(NH_2)_2$ [3]. Calcium-, magnesium-, and nitrate-containing feedstock is prepared by treating calcined dolomite flour with dilute nitric acid. The CaO/MgO mass ratio of the feedstock is 1.39–1.9, and the solid-to-liquid ratio is 1:(4.2–4.7). The resulting material is mixed with urea and the surfactant Neonol and contains 0.1–1.01 wt.% of a corrosion inhibitor, preferably selected from hexamethylenetetramine, salts of fatty acids and sulfamic acid, or alkylamide-substituted derivatives of tall-oil acids.

The limitations of this process arise from its reliance on calcined dolomite flour with a narrow CaO/MgO mass-ratio range (1.39–1.9) and a high combined CaO + MgO content exceeding 95 wt.%. These requirements restrict the available raw-material base and complicate industrial implementation. More readily available dolomite flour contains approximately 65–95 wt.% CaO + MgO, with a CaO/MgO mass ratio varying from 1.5 to 4.0.

Environmental protection and public health remain important concerns in both international and domestic research on winter road maintenance [4]. The large-scale use of technical salt in the 1970s–1990s caused serious environmental and hygienic problems in Moscow and other major Russian cities. Reported consequences included corrosion of metal structures, vehicles, and engineering networks, damage to foundations, and partial loss of lawns and green spaces [5, 6]. During the period of its application, residents also reported skin irritation and exacerbation of allergic conditions.

De-icing reagents are available in liquid, solid, granular, and sand–salt mixture forms. Despite differences in chemical composition and physical characteristics, they are used to facilitate the melting of ice and snow by depressing the freezing point of the aqueous phase.

RESEARCH OBJECTIVE AND METHODS

The objective of this study was to develop a liquid de-icing reagent based on calcium nitrate, magnesium nitrate, and urea and to evaluate its operational characteristics.

The experimental work employed conventional nitric-acid processing of dolomite raw materials, preparation of urea-containing formulations, pH monitoring, and determination of elemental and chemical compositions of mixtures and solutions using volumetric and titrimetric analytical techniques.

PRODUCTION PROCESS

The proposed process for manufacturing the liquid de-icing agent consists of the following stages:

- Preparation of the raw materials;
- Dissolution of ground dolomite in nitric acid;
- Separation of the solution from the insoluble residue;
- Evaporation (concentration) of the solution;
- Addition of urea to the concentrated solution.

RESULTS AND CONCLUSION

A liquid de-icing formulation was developed using calcium and magnesium nitrates obtained from dolomite and urea. The formulation remained operational at subzero temperatures, and industrial-scale road trials were conducted at the

Kamchik Pass. According to recommendations of the Uzavtoyul Research Institute, the liquid reagent can be used to remove ice from road surfaces at temperatures down to -32 °C.

A technical and economic assessment of the use of the NKMM de-icing reagent on roads at the Kamchik Pass was performed. A regulatory technical document for the product, TSh 00203068-24:2014, was registered. The source text does not provide numerical details of the economic evaluation, and no additional quantitative results are asserted here.

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