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INVESTIGATION OF THE ANTIMICROBIAL PROPERTIES OF N,N-BIS(BENZYLIDENE)-o-PHENYLENEDIAMINE ZINC ACETATE COMPLEX

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Abstract: Schiff bases and their transition metal complexes represent a class of compounds of significant biological and industrial importance. The primary objective of this study is to investigate the antimicrobial, anticorrosion, and anti-wear properties of the N,N-Bis(benzylidene)-o-phenylenediamine ligand—synthesized from benzaldehyde and o-phenylenediamine—along with its zinc-acetate complex in cutting fluids, fuels, and lubricating oils. The structure of the synthesized compounds was confirmed by IR spectroscopy, revealing characteristic absorption bands for the azomethine C=N group at 1620 cm^{-1} for the ligand and 1663 cm^{-1} for the zinc-acetate complex. The antimicrobial and fungicidal activities of the compounds were evaluated using the well-diffusion method in accordance with GOST 9.052-88 and GOST 9.023-74 standards against Mycobacterium phlei, Pseudomonas aeruginosa bacteria, and Aspergillus niger, Cladosporium resinae fungi. The results demonstrated that the zinc-acetate complex at a concentration of 0.5% exhibits high fungicidal activity against Cladosporium resinae in cutting fluids and gasoline, with inhibition zones of 2.2–2.2 cm and 3.8–3.9 cm.

Keywords: Schiff bases, zinc complex, antimicrobial biocide, cutting fluids.

Annotatsiya: Shiff asoslari va ularning o‘tish metalli komplekslari yuqori biologik va sanoat ahamiyatiga ega bo‘lgan birikmalar sinfidir. Ushbu tadqiqotning asosiy maqsadi benzaldegid va o-fenilendiamin asosida sintez qilingan N,N'-Bis(benziliden)-o-fenilendiamin ligandi hamda uning rux-atsetat kompleksining sovutuvchi-kesuvchi suyuqliklarda (SKS), yoqilg‘i va moylash materiallarida mikroblarga qarshi, korroziyaga qarshi va yeyilishga qarshi xossalarini o‘rganishdan iborat. Sintez qilingan birikmalarning tuzilishi IQ spektroskopiyasi yordamida tasdiqlangan bo‘lib, azometin C=N guruhining yutilish chiziqlari ligandi uchun 1620 sm^{-1} da, rux-atsetat kompleksi uchun esa 1663 sm^{-1} chastotada kuzatilgan. Birikmalarning mikroblarga qarshi va fungitsid faolligi GOST 9.052-88 va GOST 9.023-74 standartlariga muvofiq diffuziya zonasi usuli yordamida *Mycobacterium phlei*, *Pseudomonas aeruginosa* bakteriyalari hamda *Aspergillus niger*, *Cladosporium resinae* zamburug‘lariga qarshi aniqlangan. Tadqiqotlar shuni ko‘rsatdiki, rux-atsetat kompleksi 0.5% konsentratsiyada sovutuvchi-kesuvchi suyuqliklar va benzin yoqilg‘isida Cladosporium resinae zamburug‘iga qarshi yuqori fungitsid faollik ko‘rsatadi (infeksiyani bostirish zonalari mos ravishda 2.2-2.2 sm va 3.8-3.9 sm).

Аннотация: Основания Шиффа и их переходные металлокомплексы представляют собой класс соединений, имеющих высокую биологическую и промышленную значимость. Основной целью исследования является изучение антимикробных, антикоррозионных и противоизносных свойств лиганда N,N-Бис(бензилиден)-о-фенилендиамина, синтезированного на основе бензальдегида и о-фенилендиамина, а также его цинк-ацетатного комплекса в смазочно-охлаждающих жидкостях (СОЖ), топливах и смазочных маслах.

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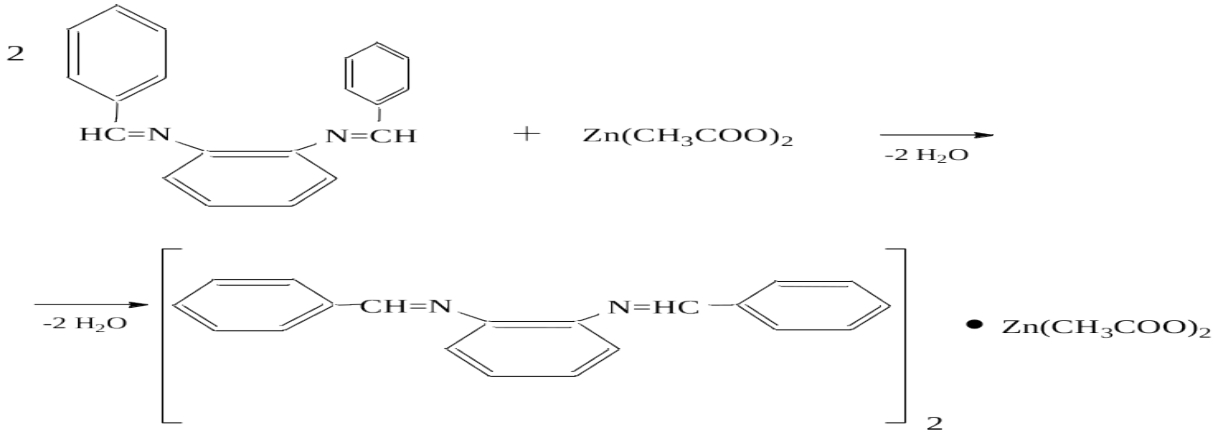
Структура синтезированных соединений подтверждена методом ИК-спектроскопии: полосы поглощения азометиновой группы (C=N) наблюдаются при частоте 1620 $см^{-1}$ для лиганда и 1663 $см^{-1}$ для цинк-ацетатного комплекса. Антимикробная и фунгицидная активность соединений определялась методом диффузии в лунки в соответствии со стандартами ГОСТ 9.052-88 и ГОСТ 9.023-74 в отношении бактерий Mycobacterium phlei, Pseudomonas aeruginosa и грибов Aspergillus niger, Cladosporium resinae. Исследования показали, что цинк-ацетатный комплекс при концентрации 0.5% проявляет высокую фунгицидную активность против гриба *Cladosporium resinae* в СОЖ и бензине (зоны угнетения составляют соответственно 2.2–2.2 см и 3.8–3.9 см).

Introduction

Recent studies indicate that transition metal complexes incorporating Schiff bases possess unique physicochemical properties with significant potential in pharmaceutical, biological, and industrial fields. Due to the presence of the azomethine group (–C=N–) alongside active heteroatoms (nitrogen, oxygen, sulfur), these compounds readily adsorb onto metal surfaces, forming protective films that provide high efficacy in protecting carbon steel from corrosion in aggressive environments. Furthermore, owing to the synergistic effect between metal ions (such as zinc) and organic ligands, these complexes display enhanced antimicrobial and fungicidal activities, making them effective biocide additives for industrial fluids and fuels.

Methods

The ligand N,N-Bis(benzylidene)-o-phenylenediamine was synthesized via the condensation of benzaldehyde and o-phenylenediamine in a 2:1 molar ratio. It represents a dark brown crystalline compound with a melting point of $T_{mp} = 90^0C$. The subsequent interaction of this Schiff base with zinc acetate salt yielded the corresponding zinc-acetate complex.



The antimicrobial and fungicidal performances were evaluated via the well-diffusion method in accordance with GOST 9.052-88 and GOST 9.023-74 standards.

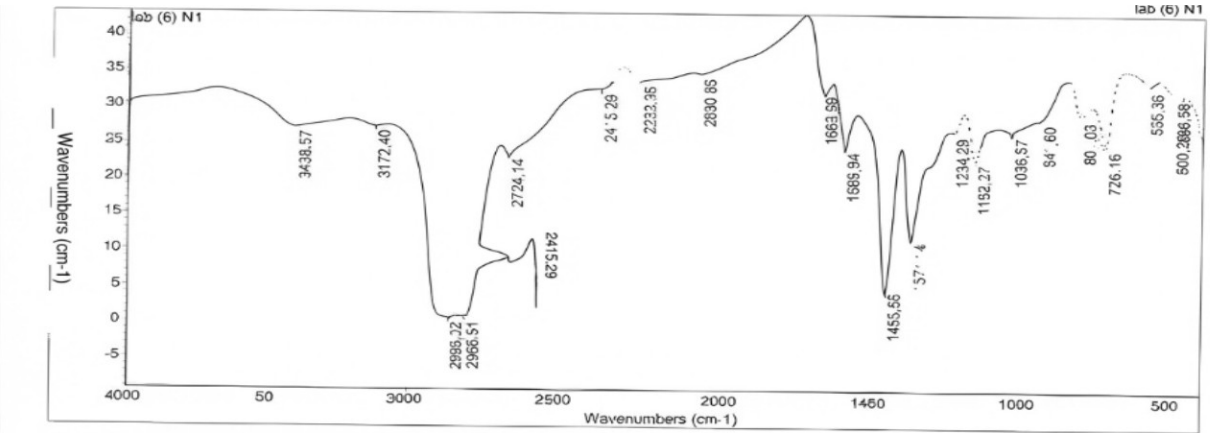


Figure 1. IR spectrum of the N,N-bis(benzylidene)-o-phenylenediamine zinc acetate complex

The intense absorption band observed at 1663.99cm $^{-1}$ corresponds to the stretching vibrations of the azomethine group C=N characteristic of the Schiff base. The shift in the frequency of this band compared to the initial ligand is one of the key indicators proving that the nitrogen atom is coordinated with the metal ion.

The antimicrobial properties of the synthesized compounds were evaluated using the well-diffusion method in accordance with GOST 9.052-88 and GOST 9.023-74 standards. The Schiff base derived from benzaldehyde and o-phenylenediamine yielded favorable results in lubricating-cooling fluids (LCFs**)** and fuel systems, specifically targeting *Cladosporium resinae*. Testing was conducted at a concentration of 0.5% in both media. The resulting derivative (at a 2:2 ratio) exhibited prominent fungicidal properties, displaying inhibition zones of 2.8–2.8 cm in lubricating-cooling fluids and 3.5–3.8 cm in fuel.

The antimicrobial performance of the evaluated organic compounds in fuel and lubricating-cooling fluids (LCFs) is summarized in Table 1:

Table 1. Antimicrobial activity of the studied compounds in lubricating-cooling fluids (LCFs) and fuel

№	compound	Diameter of the micro-organism destruction zone, cm					
		LCF			Fuel		
		Concentration%	Bacteria (*Mycobacterium phlei*, *Pseudomonas aeruginosa*)	Fungus (*Aspergillus niger*)	Concentration%	Bacteria (*Pseudomonas aeruginosa*)	Fungus (*Cladosporium resinae)*
1	Benzylidene-o-phenylenediamine zinc acetate complex salt	1,0	+++	2,2-2,2	0,5	2,3-2,4	3,8-3,9
2	Benzylidene-o-phenylenediamine	1,0	+++	2,0-2,0	0,5	2,3-2,4	2,4-2,4

The shift of the C=N absorption band in the IR spectra from 1620cm^{-1} (in the free ligand) to 1663 cm^{-1} (in the complex) explicitly confirms successful coordination between the nitrogen atom and the zinc center. Biological evaluations demonstrate that the 0.5% zinc-acetate complex exhibits remarkable fungicidal properties against *Cladosporium resinae*, particularly in fuel systems (showing

an inhibition zone of 3.8–3.9 cm). This enhanced efficacy stems from the synergistic interplay between the metal ion and the organic ligand. Additionally, the presence of active heteroatoms facilitates the formation of a protective adsorption layer on metal interfaces, efficiently lowering corrosion rates and sediment accumulation in MC-20 lubricating oil.

The N,N-Bis(benzylidene)-o-phenylenediamine ligand and its zinc-acetate complex were successfully synthesized and structurally validated via IR spectroscopy through characteristic azomethine C=N band shifts. Biological assays confirmed that the zinc-acetate complex serves as an exceptional antimicrobial and fungicidal biocide, showing high potency against *Cladosporium resinae*. The synthesized derivatives demonstrate strong anticorrosion and antioxidant performance in MC-20 lubricating oil by significantly mitigating metal corrosion and sediment creation.

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