QO‘QON DAVLAT PEDAGOGIKA INSTITUTI ILMIY XABARLARI
(2026-yil 6-son)

TABIIY FANLAR

NATURAL SCIENCES

https://doi.org/10.70728/a.series.tab.v08.i06.109

UDK 546.742:547.79:615.31

COMPREHENSIVE IN SILICO EVALUATION OF THE PHYSICOCHEMICAL PROPERTIES, PHARMACOKINETIC PROFILE, AND DRUG-LIKENESS OF A NEWLY SYNTHESIZED DICHLOROBIS(6-METHOXY-1,3-BENZOTHIAZOL-2-AMINE)COBALT(II) COMPLEX

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Annotatsiya. Mazkur tadqiqotda yangi sintez qilingan dichlorobis(6-methoxy-1,3-benzothiazol-2-amine)cobalt(II) kompleksining fizik-kimyoviy xossalari, farmakokinetik profili, dori vositasiga o'xshashlik (drug-likeness) hamda medicinal chemistry ko'rsatkichlari SwissADME onlayn platformasi yordamida in silico usulda kompleks baholandi. Molekulyar tavsiflar, lipofillik, suvda eruvchanlik, ADME parametrlari, farmakokinetik xususiyatlar va dori vositasiga o'xshashlik mezonlariga muvofiqligi tizimli ravishda tahlil qilindi. Tadqiq etilgan kompleks o'rtacha lipofillik, qulay strukturaviy xususiyatlar hamda PAINS va Brenk ogohlantirishlarining mavjud emasligi bilan tavsiflandi. Suvda eruvchanlikning pastligi, oshqozon-ichak traktida so'rilishning cheklanganligi va ayrim empirik drug-likeness mezonlari bo'yicha kichik chetlanishlar aniqlangan bo'lsa-da, ushbu natijalar o'tish metallari koordinatsion birikmalarining o'ziga xos fizik-kimyoviy xususiyatlari bilan izohlanadi. Olingan natijalar tadqiq

etilgan kobalt(II) kompleksining farmatsevtik istiqbolini nazariy jihatdan baholash hamda keyingi in vitro, in vivo va molekulyar docking tadqiqotlari uchun ilmiy asos yaratadi.

Kalit so'zlar: benzotiazol hosilalari, kobalt(II) kompleksi, SwissADME, in silico tahlil, fizik-kimyoviy xossalar, farmakokinetik profil, drug-likeness, medicinal chemistry, ADME, biofoydalanuvchanlik.

Abstract. The physicochemical properties, pharmacokinetic profile, drug-likeness, and medicinal chemistry characteristics of the newly synthesized dichlorobis(6-methoxy-1,3-benzothiazol-2-amine)cobalt(II) complex were comprehensively evaluated using the SwissADME online platform through an in silico approach. Molecular descriptors, lipophilicity, water solubility, ADME parameters, pharmacokinetic behavior, and compliance with widely accepted drug-likeness criteria were systematically analyzed. The investigated complex exhibited physicochemical characteristics compatible with further pharmaceutical investigation, including moderate lipophilicity, favorable structural properties, and the absence of PAINS and Brenk alerts. Although limited aqueous solubility, low gastrointestinal absorption, and minor violations of several empirical drug-likeness filters were predicted, these findings are consistent with the intrinsic properties of transition metal coordination compounds. The obtained results provide valuable theoretical insight into the pharmaceutical potential of the investigated cobalt(II) complex and establish a scientific basis for subsequent in vitro, in vivo, and molecular docking studies.

Keywords: benzothiazole derivatives, cobalt(II) complex, SwissADME, in silico analysis, physicochemical properties, pharmacokinetic profile, drug-likeness, medicinal chemistry, ADME, bioavailability.

Аннотация. В настоящем исследовании методом in silico с использованием онлайн-платформы SwissADME проведена комплексная оценка физико-химических свойств, фармакокинетического профиля, показателей лекарственноподобия (drug-likeness) и параметров medicinal chemistry нового синтезированного комплекса дихлоробис(6-метокси-1,3-бензотиазол-2-амин)кобальта(II). Выполнен систематический анализ молекулярных дескрипторов, липофильности, растворимости в воде, параметров ADME, фармакокинетических характеристик и соответствия критериям лекарственноподобия. Исследуемый комплекс характеризуется умеренной липофильностью, благоприятными структурными свойствами, а также отсутствием предупреждений PAINS и Brenk. Несмотря на низкую растворимость в воде, ограниченную желудочно-кишечную абсорбцию и незначительные отклонения по отдельным эмпирическим критериям drug-likeness, полученные результаты соответствуют характерным физико-химическим особенностям координационных соединений переходных металлов. Полученные данные позволяют предварительно оценить фармацевтический потенциал исследуемого комплекса кобальта(II) и служат научной основой для проведения дальнейших исследований in vitro, in vivo и молекулярного докинга.

Ключевые слова: производные бензотиазола, комплекс кобальта(II), SwissADME, in silico анализ, физико-химические свойства, фармакокинетический профиль, drug-likeness, medicinal chemistry, ADME, биодоступность.

INTRODUCTION. Benzothiazole derivatives constitute an important class of nitrogen- and sulfur-containing heterocyclic compounds that have attracted considerable attention owing to their broad spectrum of biological activities and remarkable coordination ability toward transition metal ions. In recent years, metal complexes incorporating benzothiazole-based ligands have been extensively investigated because coordination with metal ions can significantly modify the physicochemical characteristics of the parent ligands and enhance their biological potential. Numerous studies have demonstrated that cobalt(II) complexes of benzothiazole derivatives exhibit promising antibacterial, antifungal, antioxidant, anticancer, and enzyme inhibitory activities, making them attractive candidates for pharmaceutical and medicinal chemistry research.

The early evaluation of physicochemical properties and pharmacokinetic behavior has become an essential step in modern drug discovery and development. In addition to experimental biological investigations, computational approaches provide a rapid, reliable, and cost-effective strategy for predicting the absorption, distribution, metabolism, and excretion (ADME) characteristics of newly synthesized compounds. These predictions facilitate the identification of promising drug candidates before extensive biological and pharmacological studies, thereby reducing both research time and development costs.

SwissADME is one of the most widely used freely accessible web-based platforms for the comprehensive evaluation of molecular physicochemical properties, pharmacokinetic parameters, drug-likeness, and medicinal chemistry characteristics. The platform integrates several validated predictive models, including the Lipinski, Ghose, Veber, Egan, and Muegge filters, as well as the bioavailability radar and BOILED-Egg models, enabling a comprehensive assessment of the pharmaceutical potential of newly synthesized compounds.

The present study aims to perform a comprehensive in silico evaluation of the physicochemical properties, pharmacokinetic profile, and drug-likeness of a newly synthesized dichlorobis(6-methoxy-1,3-benzothiazol-2-amine)cobalt(II) complex using the SwissADME platform. The obtained results provide valuable insights into the pharmaceutical potential of this coordination compound and establish a theoretical basis for its further biological and pharmacological investigation.

2. LITERATURE REVIEW

2.1. Benzothiazole derivatives in medicinal chemistry

Benzothiazole derivatives represent one of the most important classes of fused nitrogen- and sulfur-containing heterocyclic compounds in medicinal chemistry [1]. Owing to their rigid aromatic structure, high chemical stability, and favorable electronic properties, these compounds

have been extensively investigated as pharmacologically active molecules [2]. The benzothiazole nucleus readily accommodates a variety of functional substituents, allowing systematic structural modification to optimize biological activity and physicochemical characteristics. Consequently, benzothiazole derivatives have attracted considerable interest as promising scaffolds for the development of new therapeutic agents [3, 4].

Numerous studies have demonstrated that benzothiazole derivatives possess a broad spectrum of biological activities, including antibacterial, antifungal, antiviral, antioxidant, anti-inflammatory, antitubercular, antidiabetic, and anticancer effects[2]. Their biological performance largely depends on the electronic properties of the heterocyclic system and the nature of substituent groups attached to the benzothiazole ring[4, 5]. Among the reported derivatives, amino- and methoxy-substituted compounds exhibit particularly promising pharmacological properties because these substituents improve hydrogen-bonding capability, molecular recognition, and interactions with biological receptors [6].

Structure–activity relationship (SAR) studies have revealed that substitution at the C-2 position primarily affects receptor binding and biological potency. In contrast, modifications at the C-5 and C-6 positions mainly regulate molecular lipophilicity, polarity, and metabolic behavior [7]. Therefore, rational substitution of the benzothiazole nucleus is an effective strategy for designing biologically active compounds with improved pharmacokinetic properties and drug-like characteristics [8].

2.2. Benzothiazole metal complexes as potential bioactive molecules

The coordination of benzothiazole derivatives with transition metal ions has emerged as an effective strategy for improving both physicochemical and biological properties of the parent ligands [9]. Complexation with biologically relevant metal ions such as Co(II), Cu(II), Ni(II), and Zn(II) frequently enhances molecular stability, modifies electronic distribution, increases lipophilicity, and facilitates transport across biological membranes [10]. According to Tweedy's chelation theory, coordination decreases the polarity of the central metal ion through partial sharing of positive charge with donor atoms, thereby increasing the overall lipophilic character of the complex and promoting stronger interactions with biological targets [11, 12, 13].

Numerous cobalt(II) benzothiazole complexes have demonstrated enhanced antibacterial, antifungal, antioxidant, and cytotoxic activities compared with their corresponding free ligands [13]. These improvements are generally attributed to changes in molecular geometry, redox properties, DNA-binding affinity, protein interactions, and cellular uptake resulting from metal coordination [14]. Consequently, cobalt(II) coordination compounds have become attractive candidates for medicinal inorganic chemistry and pharmaceutical research [15].

2.3. In silico evaluation of coordination compounds using SwissADME

The growing application of computational chemistry has significantly accelerated the early evaluation of newly synthesized bioactive compounds. Before biological experiments, the prediction of physicochemical descriptors and pharmacokinetic parameters allows rapid

identification of compounds possessing favorable pharmaceutical characteristics while reducing experimental time and cost [16,17]. In particular, molecular descriptors such as molecular weight, lipophilicity (LogP), topological polar surface area (TPSA), hydrogen-bonding capacity, aqueous solubility, and molecular flexibility are closely associated with oral bioavailability and overall drug-likeness [18, 19].

SwissADME has become one of the most widely used web-based platforms for predicting physicochemical properties, ADME parameters, drug-likeness, and medicinal chemistry descriptors of small molecules. The platform integrates validated predictive models, including Lipinski, Ghose, Veber, Egan, and Muegge filters, together with Bioavailability Radar and BOILED-Egg models, providing a comprehensive assessment of pharmaceutical potential [20]. These computational tools enable prediction of gastrointestinal absorption, blood–brain barrier permeability, cytochrome P450 inhibition, P-glycoprotein interaction, aqueous solubility, and synthetic accessibility before experimental pharmacological evaluation [21, 22].

Although numerous benzothiazole-based coordination compounds have been synthesized and biologically investigated, comprehensive in silico evaluation of amino- and methoxy-substituted cobalt(II) benzothiazole complexes remains relatively limited. Therefore, systematic investigation of the physicochemical properties, pharmacokinetic profile, and drug-likeness of the newly synthesized novel dichlorobis(6-methoxy-1,3-benzothiazol-2-amine)cobalt(II) complex using the SwissADME platform is scientifically justified and provides valuable theoretical information for future biological studies.

3. RESEARCH METHODOLOGY

The present study employed an in silico approach to evaluate the physicochemical properties, pharmacokinetic profile, drug-likeness, and medicinal chemistry characteristics of the newly synthesized dichlorobis(6-methoxy-1,3-benzothiazol-2-amine)cobalt(II) complex ($C_{16}H_{16}Cl_2CoN_4O_2S_2$).

The molecular structure of the complex was previously determined by single-crystal X-ray diffraction analysis. The corresponding SMILES notation was generated from the crystallographic structure using ChemDraw software and submitted to the SwissADME web server (http://www.swissadme.ch) for computational analysis.

SwissADME was used to predict physicochemical descriptors, lipophilicity, water solubility, pharmacokinetic parameters, drug-likeness, and medicinal chemistry properties. Physicochemical parameters included molecular weight, molecular formula, hydrogen-bond donors and acceptors, rotatable bonds, molar refractivity, and topological polar surface area (TPSA). Pharmacokinetic analysis comprised gastrointestinal absorption, blood–brain barrier permeability, P-glycoprotein interaction, cytochrome P450 inhibition, and skin permeability. Drug-likeness was assessed using the Lipinski, Ghose, Veber, Egan, and Muegge rules. Medicinal chemistry evaluation included PAINS alerts, Brenk alerts, lead-likeness, bioavailability score, and synthetic accessibility.

The obtained results were comparatively analyzed and interpreted using published literature on benzothiazole derivatives and cobalt(II) coordination compounds to assess the pharmaceutical potential of the investigated complex.

4. RESULTS AND DISCUSSION

4.1. Physicochemical properties

The physicochemical properties of the investigated dichlorobis(6-methoxy-1,3-benzothiazol-2-amine)cobalt(II) complex predicted by the SwissADME platform are summarized in Table 1. These molecular descriptors provide essential information regarding the structural characteristics of the complex and serve as the basis for evaluating its pharmacokinetic behavior and pharmaceutical potential.

Table 1

Physicochemical properties of the investigated cobalt(II) complex

Parameter	Value
Molecular formula	$C_{16}H_{16}Cl_2CoN_4O_2S_2$
Molecular weight (g/mol)	*490.29*
Heavy atoms	*27*
Aromatic heavy atoms	*18*
Fraction Csp³	*0.12*
Rotatable bonds	*4*
H-bond acceptors	*2*
H-bond donors	*2*
Molar refractivity	*112.74*
TPSA (Å²)	*136.84*

The investigated cobalt(II) complex possesses a molecular weight of 490.29 g/mol, which remains below the 500 g/mol threshold established by Lipinski's Rule of Five. Although the incorporation of two methoxy substituents increases the molecular mass compared with the parent benzothiazole framework, the complex still satisfies the molecular weight criterion generally associated with drug-like compounds.

The complex contains 27 heavy atoms, including 18 aromatic heavy atoms, indicating that the molecular framework is predominantly composed of aromatic benzothiazole rings. This aromatic character contributes to structural rigidity and may enhance π–π stacking interactions with biological macromolecules.

The calculated fraction Csp³ value of 0.12 indicates a highly conjugated aromatic system with limited aliphatic character, which is typical of benzothiazole-based coordination compounds. In addition, the presence of four rotatable bonds suggests moderate conformational flexibility resulting from the methoxy substituents, while maintaining an overall rigid coordination framework.

SwissADME predicted two hydrogen-bond acceptors and two hydrogen-bond donors, reflecting the contribution of the methoxy oxygen atoms and amino groups to intermolecular

interactions. These functional groups are expected to facilitate hydrogen bonding with biological targets and may contribute to molecular recognition during ligand–receptor interactions.

The molar refractivity of 112.74 indicates relatively high molecular polarizability, which is consistent with the presence of aromatic rings, sulfur atoms, chlorine atoms, oxygen atoms, and the cobalt(II) center. Such electronic characteristics may influence intermolecular interactions and biological activity.

The topological polar surface area (TPSA) of 136.84 Å² indicates relatively high molecular polarity. Although this value approaches the upper limit generally considered favorable for passive membrane permeation, it remains below the commonly accepted threshold of 140 Å². Consequently, the complex is expected to exhibit limited passive gastrointestinal absorption while maintaining adequate polarity for interaction with biological macromolecules.

4.2. Lipophilicity

The lipophilicity of the investigated dichlorobis(6-methoxy-1,3-benzothiazol-2-amine)cobalt(II) complex was predicted using five independent computational models implemented in the SwissADME platform. The calculated values are summarized in Table 2.

Table 2

Predicted lipophilicity parameters of the investigated cobalt(II) complex

Model	Log Po/w
iLOGP	*Temporarily unavailable*
XLOGP3	*6.04*
WLOGP	*5.17*
MLOGP	*2.28*
SILICOS-IT	*−0.29*
Consensus LogP	*3.30*

Lipophilicity is one of the key molecular descriptors affecting membrane permeability, aqueous solubility, tissue distribution, and overall pharmacokinetic behavior. SwissADME estimates lipophilicity using several independent prediction models based on different mathematical algorithms. Therefore, some variation among individual LogP values is expected. To reduce model-dependent bias, the platform reports the Consensus LogP, which is generally regarded as the most representative estimate of molecular lipophilicity.

The investigated cobalt(II) complex exhibited a Consensus LogP value of 3.30, indicating moderate lipophilicity. This value suggests a favorable balance between hydrophilic and lipophilic properties, which is desirable for compounds intended for biological applications. Compared with highly lipophilic molecules, the present complex is expected to exhibit improved aqueous compatibility while retaining sufficient hydrophobicity to facilitate membrane interactions.

Among the individual prediction methods, XLOGP3 (6.04) and WLOGP (5.17) predicted relatively high lipophilicity, whereas MLOGP (2.28) indicated moderate lipophilic behavior. The SILICOS-IT model predicted a slightly hydrophilic character (−0.29), reflecting differences in

the computational approaches used by individual algorithms. Such discrepancies are frequently observed for coordination compounds because most predictive models have been developed primarily using datasets of organic molecules rather than transition metal complexes.

The incorporation of methoxy substituents into the benzothiazole framework appears to improve the hydrophilic–lipophilic balance of the investigated complex, leading to a lower Consensus LogP compared with structurally related hydrophobic coordination compounds. This result is consistent with the increased polarity (TPSA = 136.84 Å²) observed in the physicochemical analysis and provides a reasonable explanation for the subsequent pharmacokinetic predictions.

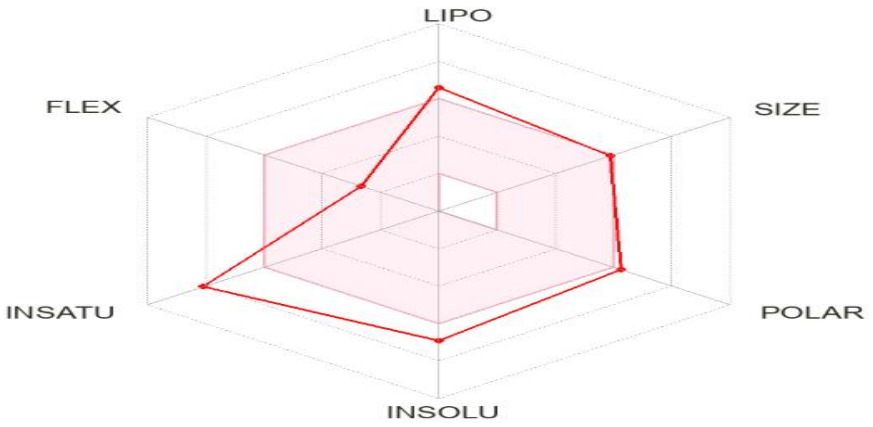

Figure 1. SwissADME bioavailability radar of the investigated dichlorobis(6-methoxy-1,3-benzothiazol-2-amine)cobalt(II) complex.

The SwissADME bioavailability radar (Figure 1) provides a visual summary of the six principal physicochemical descriptors associated with oral drug-likeness, namely lipophilicity (LIPO), molecular size (SIZE), polarity (POLAR), solubility (INSOLU), saturation (INSATU), and molecular flexibility (FLEX). As illustrated in Figure 1, most of the predicted parameters are located close to or within the optimal pink region, indicating an overall balanced physicochemical profile. Slight deviations observed for saturation and solubility are consistent with the highly aromatic structure and coordination environment of the cobalt(II) complex and are commonly encountered in transition metal coordination compounds.

4.3. Water solubility

The aqueous solubility of the investigated dichlorobis(6-methoxy-1,3-benzothiazol-2-amine)cobalt(II) complex was predicted using three independent computational models implemented in the SwissADME platform. The calculated results are summarized in Table 3.

Table 3

Predicted water solubility of the investigated cobalt(II) complex

Model	***Log S***	***Solubility class***
ESOL	*−6.91*	*Poorly soluble*
Ali	*−8.69*	*Poorly soluble*
SILICOS-IT	*−5.23*	*Moderately soluble*

The water solubility of the investigated cobalt(II) complex was estimated using the ESOL, Ali, and SILICOS-IT predictive models. As expected, slight differences were observed among the individual methods because each model employs different computational algorithms for estimating aqueous solubility.

According to the ESOL model, the complex exhibited a Log S value of −6.91, corresponding to the poorly soluble class. A similar prediction was obtained using the Ali model (Log S = −8.69), which also classified the compound as poorly soluble. In contrast, the SILICOS-IT model predicted a somewhat higher solubility (Log S = −5.23) and categorized the complex as moderately soluble.

The generally limited aqueous solubility can be attributed to the aromatic benzothiazole framework, the coordination of the cobalt(II) center, and the relatively high molecular weight of the complex. Nevertheless, the presence of methoxy and amino substituents increases molecular polarity and hydrogen-bonding capability, which may partially compensate for the hydrophobic character of the aromatic system. This observation is consistent with the moderate Consensus LogP (3.30) and the relatively high TPSA (136.84 Å²) obtained in the physicochemical analysis.

Although the investigated complex is predicted to possess limited water solubility, this characteristic is frequently observed for transition metal coordination compounds and does not necessarily preclude biological activity. Appropriate pharmaceutical formulation strategies, such as the use of suitable solvents, nanocarriers, or encapsulation systems, may further improve the apparent aqueous solubility and biological performance of the compound.

4.4. Pharmacokinetic profile

The predicted pharmacokinetic properties of the investigated dichlorobis(6-methoxy-1,3-benzothiazol-2-amine)cobalt(II) complex obtained from the SwissADME platform are presented in Table 4. These parameters provide preliminary insight into the absorption, distribution, metabolism, and excretion (ADME) behavior of the compound.

Table 4

Predicted pharmacokinetic properties of the investigated cobalt(II) complex

Parameter	Prediction
GI absorption	*Low*
BBB permeant	*No*
P-gp substrate	*No*
CYP1A2 inhibitor	*Temporarily unavailable*
CYP2C19 inhibitor	*Temporarily unavailable*
CYP2C9 inhibitor	*Temporarily unavailable*
CYP2D6 inhibitor	*Temporarily unavailable*
CYP3A4 inhibitor	*Temporarily unavailable*
Log Kp (skin permeation)	*−5.00 cm/s*

The SwissADME prediction indicated low gastrointestinal (GI) absorption for the investigated cobalt(II) complex. This result is consistent with its relatively high molecular weight

(490.29 g/mol) and elevated topological polar surface area (TPSA = 136.84 Å²), both of which may reduce passive diffusion across the intestinal epithelium. Similar behavior has frequently been reported for transition metal coordination compounds possessing relatively high polarity.

The complex was predicted to be non-permeable to the blood–brain barrier (BBB), suggesting that it is unlikely to penetrate the central nervous system. This property may be advantageous for compounds intended for peripheral therapeutic applications because it could reduce the risk of undesirable neurological side effects.

SwissADME also predicted that the investigated compound is not a substrate of P-glycoprotein (P-gp). Since P-gp is an ATP-dependent efflux transporter responsible for limiting intracellular drug accumulation, the absence of P-gp substrate characteristics may favor intracellular retention of the complex after cellular uptake.

The prediction of inhibition toward the major cytochrome P450 isoenzymes (CYP1A2, CYP2C19, CYP2C9, CYP2D6, and CYP3A4) was reported as temporarily unavailable by the SwissADME platform. Therefore, no reliable conclusions regarding possible CYP-mediated metabolism or drug–drug interactions can be drawn from the present computational analysis. Further experimental studies or complementary computational tools would be required to evaluate these parameters.

The predicted skin permeability coefficient (Log Kp = −5.00 cm/s) indicates low transdermal permeability, suggesting limited diffusion through the skin. This finding is consistent with the relatively high polarity and molecular size of the investigated coordination compound.

Taken together, these pharmacokinetic predictions indicate that the investigated cobalt(II) complex exhibits ADME characteristics typical of coordination compounds and provides a useful theoretical basis for subsequent biological and pharmacological investigations.

4.5. Drug-likeness evaluation

The drug-likeness of the investigated dichlorobis(6-methoxy-1,3-benzothiazol-2-amine)cobalt(II) complex was assessed using the empirical filters implemented in the SwissADME platform. The predicted results are summarized in Table 5.

Table 5

Drug-likeness evaluation of the investigated cobalt(II) complex

Parameter	***Prediction***
Lipinski	*Yes (0 violations)*
Ghose	*No (1 violation: MW > 480)*
Veber	*Yes*
Egan	*No (1 violation: TPSA > 131.6 Å²)*
Muegge	*No (1 violation: XLOGP3 > 5)*
Bioavailability score	*0.55*

The investigated cobalt(II) complex fully satisfied Lipinski's Rule of Five, exhibiting no violations. Despite its relatively high molecular weight (490.29 g/mol), the value remains below

Lipinski's threshold of 500 g/mol, indicating that the compound retains favorable drug-like characteristics according to this widely accepted criterion.

The Ghose filter identified a single violation due to the molecular weight exceeding the recommended limit (MW > 480 Da). This deviation is not unexpected because coordination compounds generally possess larger molecular masses than conventional organic drug molecules owing to the presence of a central metal ion and coordinated ligands.

The complex also satisfied the Veber criterion, indicating that the combination of molecular flexibility and hydrogen-bonding properties remains compatible with acceptable oral bioavailability. Although the molecule contains four rotatable bonds and exhibits relatively high polarity, these parameters remain within the acceptable range defined by the Veber model.

According to the Egan filter, one violation was observed because the topological polar surface area (TPSA = 136.84 Å²) slightly exceeded the recommended limit of 131.6 Å². This result suggests that passive membrane permeation may be somewhat restricted, which is consistent with the predicted low gastrointestinal absorption obtained in the pharmacokinetic analysis.

The Muegge filter also reported a single violation due to the XLOGP3 value exceeding 5, indicating relatively high lipophilicity according to this particular prediction model. However, the Consensus LogP (3.30) remains within a range generally considered acceptable for drug-like molecules, suggesting that the overall lipophilic character of the complex is moderate.

The predicted bioavailability score of 0.55 indicates a moderate probability of oral bioavailability. Although this value does not guarantee successful clinical performance, it suggests that the investigated coordination compound possesses physicochemical characteristics compatible with further pharmaceutical and biological evaluation.

Taken together, the drug-likeness analysis demonstrates that the investigated cobalt(II) complex satisfies the majority of the commonly accepted empirical criteria for drug-like molecules. The observed violations are primarily associated with molecular size, polarity, and individual lipophilicity models, all of which are typical characteristics of transition metal coordination compounds rather than indicators of poor pharmaceutical potential.

4.6. Medicinal chemistry evaluation

The medicinal chemistry descriptors of the investigated dichlorobis(6-methoxy-1,3-benzothiazol-2-amine)cobalt(II) complex predicted by the SwissADME platform are summarized in Table 6. These parameters provide additional information regarding the structural quality of the molecule, its synthetic feasibility, and its suitability for further pharmaceutical development.

Table 6

Medicinal chemistry evaluation of the investigated cobalt(II) complex

Parameter	***Prediction***
PAINS	*0 alert*

Brenk	*0 alert*
Lead-likeness	*No (2 violations: MW > 350; XLOGP3 > 3.5)*
Synthetic accessibility	*3.74*

The investigated cobalt(II) complex exhibited no PAINS (Pan-Assay Interference Compounds) alerts, indicating that its molecular structure does not contain substructures commonly associated with false-positive biological responses in screening assays. This result suggests that any experimentally observed biological activity is less likely to arise from nonspecific assay interference.

Similarly, no Brenk alerts were detected, demonstrating the absence of chemically unfavorable structural fragments that are frequently associated with poor pharmacological performance, toxicity, or instability. The lack of both PAINS and Brenk alerts supports the structural reliability of the investigated coordination compound and highlights its suitability for further biological evaluation.

The lead-likeness assessment indicated two violations related to molecular weight (MW > 350 Da) and XLOGP3 (> 3.5). These deviations are expected for transition metal coordination compounds because the presence of a cobalt(II) center and two benzothiazole ligands inevitably increases molecular size and influences lipophilicity. Importantly, the lead-likeness filter was originally developed for relatively small organic lead compounds and therefore may not be fully applicable to coordination complexes.

The predicted synthetic accessibility score of 3.74 indicates that the investigated complex possesses moderate synthetic complexity. According to the SwissADME scale, compounds with values close to 1 are considered easy to synthesize, whereas values approaching 10 represent highly challenging synthetic targets. Therefore, the obtained value suggests that the cobalt(II) complex can be prepared using conventional coordination chemistry methods without excessive synthetic difficulty, which is in agreement with its successful laboratory synthesis.

Collectively, the medicinal chemistry assessment supports the suitability of the investigated cobalt(II) complex for further biological and pharmaceutical studies. Although the compound does not fully satisfy the lead-likeness criteria because of its molecular size and lipophilicity, these characteristics are typical of coordination compounds and should not be regarded as major obstacles to their potential therapeutic applications.

CONCLUSION

In the present study, the physicochemical properties, pharmacokinetic profile, drug-likeness, and medicinal chemistry characteristics of the newly synthesized dichlorobis(6-methoxy-1,3-benzothiazol-2-amine)cobalt(II) complex were comprehensively evaluated using the SwissADME web platform. The in silico analysis demonstrated that the complex possesses physicochemical properties compatible with further pharmaceutical investigation, including a molecular weight below the Lipinski threshold (490.29 g/mol), moderate lipophilicity

(Consensus LogP = 3.30), and a relatively high topological polar surface area (TPSA = 136.84 Å²).

The pharmacokinetic prediction indicated low gastrointestinal absorption, lack of blood–brain barrier permeability, and absence of P-glycoprotein substrate characteristics, suggesting that the complex is more suitable for peripheral biological applications than for central nervous system targeting. Although the compound exhibited limited aqueous solubility and several violations in the Ghose, Egan, and Muegge filters, these deviations are primarily associated with the intrinsic physicochemical properties of transition metal coordination compounds and do not necessarily limit their biological potential.

The medicinal chemistry evaluation further demonstrated the absence of PAINS and Brenk structural alerts together with a moderate synthetic accessibility score (3.74), indicating good structural reliability and feasible laboratory synthesis. These findings support the suitability of the investigated cobalt(II) complex for continued biological evaluation and future pharmaceutical research.

Overall, the present in silico investigation provides valuable theoretical insight into the pharmaceutical potential of the synthesized cobalt(II) complex and establishes a scientific basis for subsequent in vitro, in vivo, and molecular docking studies aimed at validating its biological activity and therapeutic applicability.

Acknowledgements. This research was carried out at the Laboratory of Complex Compounds of the Institute of Bioorganic Chemistry, Academy of Sciences of the Republic of Uzbekistan, and was financially supported by the Government of the Republic of Uzbekistan.

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