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Studies on DNA Interaction, Biological Activities of Surfactant-Cobalt(III)-Phendione Complexes

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ABSTRACT

The mixed ligand surfactant-cobalt(III)-phendione complexes of the type *cis*-$[Co(phendione)_2(DA)Cl](ClO_4)_2$ and *cis*-$[Co(phendione)_2(DA)_2](ClO_4)_3$ (Phendione = 1,10-Phenanthroline-5,6-dione, DA = Dodecylamine) were synthesized and characterized. The interaction between surfactant-cobalt(III)-phendione complexes and calf thymus DNA in aqueous solution was investigated by spectroscopic methods, viscosity, and electrophoresis measurements. Results suggest that the complexes bind to DNA via intercalation binding. The cytotoxicity of the surfactant-cobalt(III)-phendione complexes has been evaluated by MTT assay. Surfactant-cobalt(III)-phendione complexes were tested for antibacterial and antifungal activities having good activities.

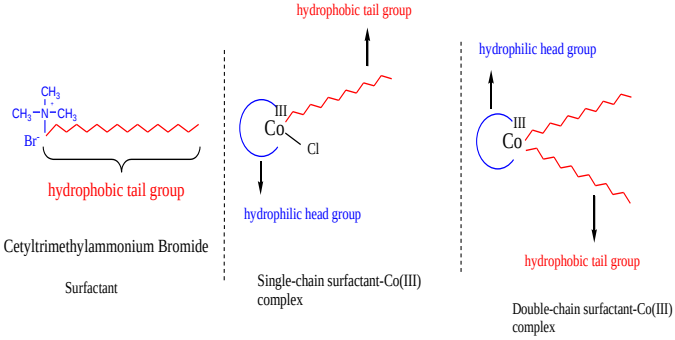
1. Introduction

The interaction of transition metal polypyridyl complexes with DNA has received considerable attention during the past decade [1]. These interests stemmed from developing attractive candidates as DNA secondary structure probes and photocleavage reagents [2]. In these complexes, the ligands or metal may be varied in an easily controlled way to facilitate the individual application. But most studies focus on the interaction of those complexes containing the fully planar ligand, and the reports on the complexes containing ligand with substituent's are relatively limited [3-5].

The metal complexes can interact non-covalently with DNA by intercalation, groove binding, or external electrostatic binding. Among the factors governing the binding modes, it appears that the most significant is the molecular shape. Those complexes that best fit against the DNA helical structure display the highest binding affinity. Many useful applications of these complexes require that the complex bind to DNA through an intercalative mode with the ligand intercalating into the adjacent base pairs of DNA [6]. The DNA binding studies have been focused on complexes of Ru(II) and, to a far lesser extent, on other metal complexes. Ji et al. noted that much attention has been paid to the complexes containing symmetric aromatic ligands such as 1,10-phenanthroline and its derivatives, investigations of complexes with asymmetric ligands as DNA-binding reagents have been relatively few. In fact, some of these complexes are also exhibit interesting properties upon binding to DNA [7-9].

Barton et al. initiated the binding studies of transition metal complexes with nucleic acids and reported that the *cis*-$[Ru(phen)_2Cl_2]$ (phen = 1,10-phenanthroline) binds covalently to DNA and exhibits enantiomeric selectivity different from that seen on intercalation [10]. The high level of recognition of DNA conformation by these chiral inorganic complexes suggested the powerful application of stereo specificity in DNA drug design. The features common to these complexes are that the molecule has a high affinity for double-stranded DNA and that the molecule also binds a redox-active metal ion cofactor. The ligands or the metal in these complexes can be varied in an easily controlled manner to facilitate an individual application. All the studies reveal that modification of the metal or ligands would lead to subtle or substantial changes in the binding modes, location and affinity [11], giving changes to explore various valuable conformation or site-specific DNA probes and potential chemotherapeutical agents.

Generally, Cobalt(III) complexes show antitumor activities *in vivo* [12, 13] and, hence recently, the interaction of cobalt complexes with DNA has attracted much attention [14-16]. Shimakoshi et al. have shown that a dicobalt complex was more efficient in cleaving DNA compared to an equivalent monomeric complex [17]. Metal complexes binding nucleic acid are currently investigated because of their utility as DNA structural probes, DNA foot printing and sequence-specific cleavage agents and potential anticancer drug [18-20]. Binding of small molecules with DNA has been studied extensively since DNA is the material of inherence and controls the structure and function of cells [21]. In this respect ruthenium (II) complexes have attracted a great deal of attention due to their strong DNA-binding and potential anticancer [22, 23]. In fact, the activity of many anticancer, antimalarial and antibacterical agents finds its origin in intercalative interactions with DNA. Many researchers have focused on the DNA-binding mechanism of Ru(II) complexes with DNA. The previous studies showed that Ru(II) complexes could bind DNA in a non-covalent interactions fashion such as electrostatic binding, grooving binding and intercalation. In recent years, the antitumor activity of Ru(II) complex has been investigated extensively [24, 25].



Scheme 1 Structure of surfactant and surfactant-Cobalt(III)-phendione complexes

Metallosurfactants are a special type of surfactant, where a coordination complex (containing a central metal ion with surrounding ligands coordinated to the metal) acts as the surfactant (Scheme 1). Like

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any other well-known surfactant, e.g. cetyltrimethyl ammonium bromide (CTAB), these surfactant–metal complexes also form micelles at a specific concentration called critical micelle concentration (CMC) in aqueous solution. In recent times, there are some reports from various research groups on metallosurfactants of a various nature and their micelle forming properties [26]. We were interested in the synthesis and micelle-forming properties of surfactant-Co(III) complexes containing lipophilic ligands for a long time [27-30].

In this report we explore the DNA binding properties, cytotoxicity and antimicrobioal studies of two new surfactant-cobalt(III)-phendione complexes *cis*-$[Co(phendione)_2(DA)Cl](ClO_4)_2$ and *cis*-$[Co(phendione)_2(DA)_2](ClO_4)_3$ (Phendione = 1,10-Phenanthroline-5,6-dione, DA = Dodecylamine). The mode of DNA binding of the surfactant-cobalt(III)-phendione complexes has been studied by using absorption spectral titration, competitive DNA binding studies and viscosity measurements. The cytotoxicity activities of the complexes have been also investigated. The spectroscopic titration and viscosity changes of calf thymus DNA (CT-DNA) show these complexes interact with DNA through intercalative mode. The cytotoxicity of the complexes has been studied by screening the surfactant-cobalt(III)-phendione complexes against human breast cancer (MCF-7) cell line. It exhibits the highest anticancer activity against human breast cancer cell lines with its potency being higher than that of *cis*-platin.

2. Experimental Methods

2.1 Materials and Methods

All the reagents were analytical grade (Sigma-Aldrich and Merck). Calf thymus DNA was obtained from Sigma-Aldrich and used as such. The spectroscopic titration was carried out in the buffer (50 mM NaCl–5 mM Tris–HCl, pH 7.1) at room temperature. A solution of calf thymus DNA in the buffer gave a ratio of UV absorbance 1.8–1.9:1 at 260 and 280 nm, indicating that the DNA was sufficiently free of protein [31]. Milli-Q water was used to prepare the solutions. Absorption spectra were recorded on a UV–VIS–NIR Cary 300 Spectrophotometer using cuvettes of 1 cm path length, and emission spectra were recorded on a JASCO FP 770 spectrofluorimeter. Cancer cell was obtained from National Center for Cell Science (NCCS), Pune, India. The bacteria and fungus species were obtained from National Chemical Laboratory (NCL), Pune, India. Ciprofloxacin and fluconazole discs were purchased from HiMedia Laboratories Pvt. Ltd., India.

2.2 Synthesis of Surfactants-Cobalt(III)-Phendione Complexes

The single chain surfactant-cobalt(III)-phendione complex (1) *cis*-$[Co(phendione)_2(DA)Cl](ClO_4)_2$ and double-chain surfactant-cobalt(III)-phendione complex (2) *cis*-$[Co(phendione)_2(DA)_2](ClO_4)_3$ (Phendione = 1,10-Phenanthroline-5,6-dione, DA = Dodecylamine) were synthesized and characterized by elemental analysis, UV–Vis, Infra-red and NMR spectroscopy methods. The critical micelle concentration (CMC) values of these complexes in aqueous solution were obtained from conductance measurements [32].

2.3 DNA Binding Experiments

The DNA concentration per nucleotide was determined adopting absorption spectroscopy using the known molar extinction coefficient value of 6600 $M^{-1}cm^{-1}$ at 260 nm [33]. Concentrated stock solutions of surfactant-cobalt(III)-phendione complexes were prepared by dissolving them in a 5 mM Tris-HCl– 50 mM NaCl buffer at pH 7.1 and diluting suitably with the corresponding buffer to required concentrations for all the experiments. Absorption titrations were performed by using a fixed surfactant–cobalt(III)-phendione complex concentration to which increments of the DNA stock solution were added. Surfactant-cobalt(III)-phendione solutions were 20 μM in concentration and calf thymus DNA was added to give a ratio 8:1 [DNA]/[Complex]. The surfactant–cobalt(III)-phendione complex–DNA solutions were incubated for 10 min before the absorption spectra were recorded.

For fluorescence experiments, DNA was pretreated with ethidium bromide (EB) for 30 min. The surfactant–cobalt(III) complexes were then added to this mixture and the effect on the emission intensity was measured. The samples were excited at 450 nm and emission was observed between 500 and 750 nm. These experiments were carried out in 50 mM NaCl, 5 mM Tris– HCl at pH 7.1 in aqueous media.

Viscosity experiments were carried on an Ubbelohde viscometer, immersed in a thermostatic water-bath maintained at 29.0 ± 0.1 °C. CT-DNA samples approximately 200 base pairs in average length were prepared by sonication in order to minimize complexities arising from DNA flexibility [34]. Data were presented as $(\eta/\eta_0)^{1/3}$ versus binding ratio [35], where η is the viscosity of CT- DNA in the presence of the complex, and η_0 is the viscosity of DNA alone. The relative viscosity was calculated according to the relation $\eta = (t - t^0)/t^0$, where t^0 is the flow time for the buffer and t is the observed flow time for DNA in the presence and absence of the complex. Flow time was measured with a digital stopwatch and each sample was measured three times and the average flow time was used.

2.4 Cytotoxicity Assay

MTT assay was carried out as described previously [36]. The surfactant–cobalt(III)-phendione complexes 1 and 2 in the concentration range of 0.05–50 μg/mL, dissolved in DMSO were added to the wells 24 h after seeding of 5×10^3 cells per well in 200 μL of fresh culture medium. DMSO was used as the vehicle control. After 24 and 48 h, 20 μL of MTT solution [5 mg/mL in phosphate-buffered saline (PBS)] was added to each well and the plates were wrapped with aluminum foil and incubated for 4 h at 37 °C. The purple formazan product formed was dissolved by addition of 100 μL of 100% DMSO to each well. The absorbance was monitored at 570 nm (measurement) and 630 nm (reference) using a 96 well plate reader (Bio-Rad, Hercules,CA, USA). The stock solutions of the metal complexes were prepared in DMSO and in all the experiments the percentage of DMSO was maintained in the range of 0.1–1%. DMSO by itself was found to benon-toxic to the cells till 1% concentration. Data were collected for four replicates each and used to calculate the mean. The percentage inhibition was calculated from this data using the formula:

$$IC_{50} = \frac{\text{Mean OD of untreated cells (control)} - \text{Mean OD of treated cells}}{\text{Mean OD of untreated cells (control)}} \times 100$$

The IC_{50} value was determined as the concentration of the complex that is required to reduce the absorbance to half that of the control.

2.5 Antimicrobial Screening

The *in vitro* antimicrobial screening of the surfactant-cobalt(III)-phendione complexes were tested for its effect on certain human pathogenic bacteria and fungus by Kirby–Bauer disc diffusion technique [37]. The disc diffusion method is highly effective for rapidly growing microorganisms and the activities of the test complexes are expressed by measuring the diameter of the zone of inhibition [38]. The surfactant-cobalt(III)-phendione complexes were stored dry at room temperature and dissolved in DMSO. Both the Gram positive (*Staphylococcus aureus*, *Bacillus subtilis*) and Gram negative (*Escherichia coli*, *P. vulgaris*) bacteria were grown in nutrient agar medium and incubated at 37 °C for 48 h followed by frequent subculture to fresh medium and were used as test bacteria. The fungi *Trichoderma sp*, *Aspergillus niger* and *Candida albicans* grown as Sabouraud dextrose agar medium were incubated at 27 °C for 72 h followed by periodic sub culturing to fresh medium and were used as test fungus. Then the petriplates were inoculated with a loop full of bacterial and fungal culture and spread throughout the petriplates uniformly with a sterile glass spreader. To each disc the test samples (10 ppm) and reference ciprofloxacin (1 μg/disc for bacteria) or clotrimazole (10 μg/disc for fungus) was added with a sterile micropipette. The plates were then incubated at 35 ± 2 °C for 24–48 h and 27 ± 1 °C for bacteria and fungus, respectively. Plates with disc containing respective solvents served as control. Inhibition was recorded by measuring the diameter of the inhibitory zone after the period of incubation. All the experiments were repeated thrice and the average values are presented.

3. Results and Discussion

3.1 DNA Binding Studies

3.1.1 Electronic Absorption Spectral Studies

Electronic absorption spectroscopy is an effective method of examining the mode and extent of binding of a metal complex with DNA [39-42]. The binding behavior of surfactant–cobalt(III)-phendione complexes to DNA helix has been followed through absorption spectral titrations. The typical absorption of the complex 1, *cis*-$[Co(phen)_2(DA)Cl](ClO_4)_2$, spectral traces of 5 with increasing concentration of CT-DNA are shown in the absence and in the presence of CT-DNA, are shown in Fig. 1. With increasing concentration of calf thymus DNA, the absorption bands of the complexes were affected, resulting in the tendency of hyperchromism and a slight blue shift. As the extent of hypochromism is commonly associated with the strength of DNA interaction. The surfactant–cobalt(III)-phendione complexes can bind to the DNA in different binding modes on the basis of their structure and charge and type of ligands. Since our surfactant–cobalt(III)-phendione complexes contain methylene groups of long

aliphatic amine (dodecylamine), these complexes can bind to DNA by van der Waals interactions between the methylene groups and the thymine methyl groups of DNA [43]. Also, since DNA possesses several hydrogen bonding sites in the minor as well as major grooves, and the surfactant–cobalt(III)-phendione complexes contain –NH-groups, there could be hydrogen bonding between the complexes and the base pairs in DNA [44-47]. In complex 1 and 2, contains phendione ligand, it would provide an aromatic moiety extending from the metal center through which overlapping would occur with the base pairs of DNA by intercalation. The higher blue-shifts (2–8 nm) observed for complexes 1 and 2 suggest that the coordinated phendione in them are inserted into the DNA base pairs leading to the intercalative interaction of the complexes with DNA. However, the hyperchromism effects observed in the present study in respect of both the complexes suggest that there is a strong hydrophobic association between the hydrocarbon chain of the surfactant and the hydrophobic interior of DNA. In order to compare the binding strengths of the complexes, the intrinsic binding constant, K_b, was determined using the equation [48],

$$[DNA]/(\varepsilon_a-\varepsilon_f) = [DNA]/(\varepsilon_b-\varepsilon_f) + 1/K_b(\varepsilon_b-\varepsilon_f)$$

where [DNA] is the concentration of DNA in base pairs, ε_a, ε_f and ε_b correspond to $A_{obsd}/[Co]$, the extinction coefficient of the free surfactant-cobalt complex and the extinction coefficient of the surfactant-complex in the fully bound form, respectively, In plot of $[DNA]/(\varepsilon_a-\varepsilon_f)$ versus [DNA], K_b is given by the ratio of slop to the intercept. The intrinsic binding constant, K_b of the complexes can be obtained from the decay of the absorbance. The intrinsic binding constants for the surfactant–cobalt(III)-phendione complexes 1 and 2 are shown in Table 1. The table shows that the binding constant of complex 2 is higher than complex 1. Due to the presence of two alkyl chain ligand and higher hydrophobicity, the complex 2, *cis*-$[Co(phendione)_2DA_2](ClO_4)_3$, binds with DNA more strongly than complex 1, *cis*-$[Co(phendione)_2(DA)Cl](ClO_4)_2$.

Table 1 The binding constants (K_b) of surfactant-cobalt(III) complexes with CT-DNA

Complexes	K_b x 10^4 ($mol^{-1}dm^3$)	K_{sv}
cis-$[Co(phendione)_2(DA)Cl](ClO_4)_2$	1.71	0.028
cis-$[Co(phendione)_2(DA)_2](ClO_4)_3$	2.35	0.035

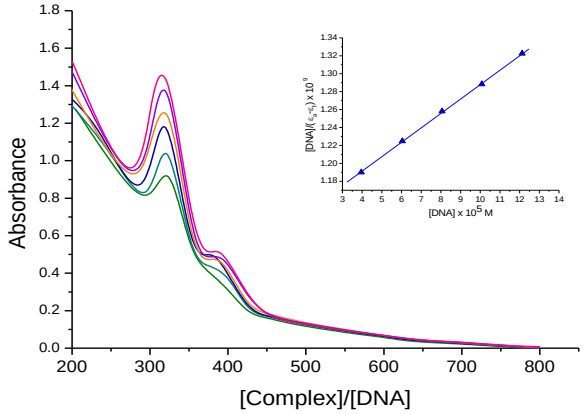

Fig. 1 Absorption spectrum of in the *cis*-$[Co(phendione)_2(DA)Cl](ClO_4)_2$(1 x 10 μM) in the absence and presence of CT DNA. Inset: Plot of $[DNA]/(\varepsilon_a-\varepsilon_f)$ x 10^9 M *vs* [DNA] x 10^5 M

3.1.2 Competitive Binding Studies

No luminescence was observed for the two surfactant-cobalt(III) complexes at room temperature in aqueous solution or any organic solvent examined or in the presented of calf thymus DNA. So the binding of surfactant-Co(III) complexes and DNA cannot be directly presented in the emission spectra. In order to investigate the mode of binding of the surfactant–cobalt(III)-phendione complexes to DNA, the competitive binding experiment using ethidium bromide (EB) was carried out. Ethidium bromide (EB) is one of the most sensitive fluorescent probes that can bind to DNA [49-51]. The ethidium ion demonstrates a dramatic increase in fluorescence efficiency when it intercalates into the DNA. The extent of fluorescence quenching of EB bound to DNA is used to determine the binding of a second molecule to DNA. Bhattacharya and Mandal [52] have reported that the addition of cationic surfactants to EB–DNA complex can result in quenching of the fluorescence due to displacement of EB by the surfactants. Zhao et al. [53] found that the fluorescence quenching of EB–DNA by the Gemini surfactant may be due to the replacement of the DNA intercalator, i.e., EB. The emission spectra of EB bound to DNA in the absence and the presence of the surfactant–cobalt(III)-phendione complexes 1 is given in Fig. 2. The addition of the surfactant-cobalt(III)-phendione complex to DNA pretreated with EB caused appreciable reduction in the emission intensity, indicating that the replacement of the EB fluorophore by the surfactant-cobalt(III)-phendione complex results in a decrease of the binding constant of ethidium bromide to DNA. According to the classical Stern–Volmer equation [54]:

$$I_0/I = 1+ K_{sv}r$$

where I_0 and I are the fluorescence intensities in the absence and the presence of complex, respectively. K_{sv} is a linear Stern–Volmer quenching constant and r is the radio of the total concentration of complex to that of DNA.

The fluorescence quenching of EB bound to DNA by the surfactant–cobalt(III)-phendione complexes 1 is shown in Fig. 2. The quenching plots illustrate that the quenching of EB bound to DNA by the surfactant–cobalt(III)-phendione complexes are in good agreement with the linear Stern–Volmer equation, which also indicates that the complexes bind to DNA. In the plot of I_0/I versus [Complex]/[DNA], K_{sv} is given by the ratio of the slope to intercept. The K_{sv} values for our surfactant–cobalt(III)-phendione complexes 1 and 2 are 0.028 and 0.035, respectively. These data suggest that the interaction of surfactant–cobalt(III)-phendione complex 2 with DNA is stronger than complex 1, which is consistent with the spectral results described above.

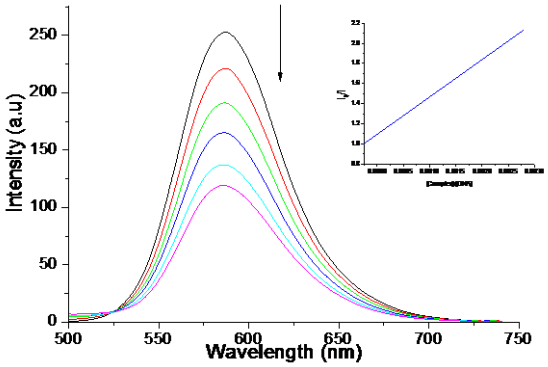

Fig. 2 Emission spectra of Ethidium bromide bound to DNA in the absence and presence of cis-$[Co(phendione)_2(DA)Cl](ClO_4)_2$. Arrow shows the absorbance changes upon increasing DNA concentration. Inset: Plat of relative integrated emission intensity

3.2 Viscosity Measurements

Measurement of the viscosity of CT DNA after treatment with varying concentrations of complexes provides reliable evidence for the DNA binding mode. Thus intercalation of complexes with DNA and groove binding increases the length of DNA [55] and hence enhances the DNA viscosity whereas the complexes that bind to the DNA surface do not alter the length of the DNA helix due to kinking or bending [56]. The values of the relative specific viscosity (η/η_0), where η and η_0 are the specific viscosities of DNA in the presence and absence of the complexes, are plotted against [Complex]/ [DNA].

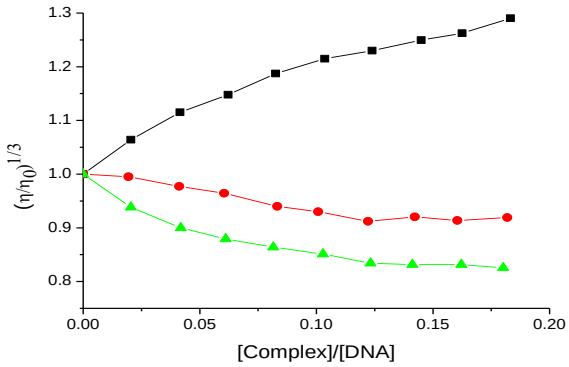

Fig. 3 Effect of increasing amounts of ethidium(■), *cis*-$[Co(phendione)_2(DA)Cl](ClO_4)_2$ (●), *cis*-$[Co(phendione)_2(DA)_2](ClO_4)_3$ (▲) on the relative specific viscosity of CT DNA at 28.0 (± 0.1) °C, [CT-DNA] = 0.5 mM

The effects of the surfactant–cobalt(III)-phendione complexes 1, 2 and EB on the viscosity of DNA are shown in Fig. 3. The intercalator EB significantly increased the relative specific viscosity of DNA as expected for the lengthening of the DNA double helix resultant from well-characterized intercalation. In contrast, the binding of surfactant–cobalt(III)-phendione complex 1 to DNA decreased the relative specific viscosity of DNA while the complex 2 exerted slight increase of DNA

viscosity. This is probably related to the molecular structure of the complex. In the complex 2 the phendione ring is somewhat sterically hindered from planarity and partially intercalated with DNA. The complex would act as a "wedge" to pry apart one side of a base pair stack but not fully separate the stack as required by the classical intercalation model. So it is likely that the observed slight increase in relative viscosity in the case of complex 2 is due to intercalative interaction. Based on the viscosity results, it is inferred that the surfactant–cobalt(III)-phendione complexes could bind to DNA by external contact (surface binding) or groove binding.

3.3 Cytotoxicity Assay in Vitro

The cytotoxic activity of surfactant-cobalt(III)-phendione complexes against the MCF-7 human breast cancer cell line has been investigated in DMSO buffer solution in comparison with the widely used drug *cis*-platin under identical conditions by using the MTT assay. *Cis*-platin has been included as the control, and it shows high cytotoxicity, which is accordance with the literature reports [57]. The surfactant-cobalt(III)-phendione complexes are found to kill cancer cells more efficiently at 48 h incubation than at 24 h incubation clearly indicating that the cell killing activity is time-dependent. The cytotoxic ability of complex 2 is higher than complex 1, while that of *cis*-platin for both 24 and 48 h incubation. Also, the observed IC_{50} values shown in Table 2, revealing that cytotoxicity depends upon the mode and extent of interaction of the complexes with DNA and protein.

Table 2 demonstrates the IC_{50} values obtained from non-linear regression analysis of dose response data for the compounds tested. Both the complexes demonstrate lower in vitro cytotoxicity against selected tumor cell lines than cis-platin. The complex 2 *cis*-$[Co(phendione)_2(DA)_2](ClO_4)_3$ is more active against MCF-7 tumor cell lines, complex 1 *cis*-$[Co(phendione)_2(DA)Cl](ClO_4)_2$ shows much active against MCF-7 tumor cell lines. The IC_{50} values (Table 2), the median cytotoxic concentrations, were determined after 24 and 48 h of drug exposure. Generally, the longer the exposure time the more cytotoxic is the complexes with the 48 h exposure being more effective compared to the 24 h exposure.

Table 2 The IC_{50} values for surfactant-cobalt(III)-phendione complexes and *cis*-platin against human breast cancer cell - MCF-7

Complex	MCF-7	
	IC_{50} (24 h) / μM	IC_{50} (48 h) / μM
cis-$[Co(phendione)_2(DA)Cl](ClO_4)_2$	22.7 ± 1.9	16.3±1.4
cis-$[Co(phendione)_2(DA)_2](ClO_4)_3$	18.5±1.8	12.2 ± 1.6
Cis-platin	38.6 ± 1.5	27.5 ± 1.1

3.4 Microbial Assay

The surfactant–cobalt(III) complexes 1 and 2 were screened in vitro for their antimicrobial activity against certain human pathogenic bacterial and fungal species using disc diffusion method, and the results are summarized in Table 3. There was considerable antibacterial activity of the complexes against Gram-positive bacteria and the Gram-negative bacteria and fungai. This moderate activity may be due to an efficient diffusion of the metal complexes into the bacterial/ fungal cells and/or interaction with these organisms [58]. Out of the two surfactant-cobalt(III)-phendione complexes, the complex 2 exhibited better activity than complex 1. This may be due to the hydrophobic character of the complex 2, which can damage the bacterial/fungal cell wall. It may be concluded that our surfactant–cobalt(III)-phendione complexes are in general capable of inhibiting the growth of bacteria and fungi to a moderate extent.

Table 3 Antimicrobial activities of surfactant- cobalt(III)-phendione complexes

Surfactants	Diameter of zone inhibition (mm)						
	Antibacterial activity				Antifungal activity		
	E. coil	*S. aureus*	*P. vulgaris*	*B. subtillis*	*Trichoderma sp.*	*Aspergillusniger*	*C. albicans*
cis-$[Co(phendione)_2(DA)Cl](ClO_4)_2$	20	20	18	21	21	16	20
cis-$[Co(phendione)_2(DA)_2](ClO_4)_3$	14	17	11	15	14	10	15
Standard	24	21	19	23	22	17	21

Standard – Ciprofloxacin for bacteria and Clotrimazole for fungus.
Solvent – DMSO (showed nil effect against the microorganisms under test)

4. Conclusion

Two new surfactant-cobalt(III)-phendione complexes of *cis*-$[Co(phendione)_2(DA)Cl](ClO_4)_2$ and *cis*-$[Co(phendione)_2(DA)_2](ClO_4)_3$ have been synthesized and characterized. The DNA-binding of two surfactant-cobalt(III)-phendione complexes has also examined by absorption spectroscopy, luminescence spectroscopy, viscosity measurement and gel electrophoresis experiments. Results indicate that the two complexes can intercalate into DNA base pairs via intercalative ligand. Cytotoxicity assay shows that the two complexes displayed antitumor activity against tumor cells tested. Both the surfactant–cobalt(III)-phendione complexes showed moderate antimicrobial activity against Gram-positive and Gram-negative bacteria and fungi.

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