E-ISSN No : 2581-6195 | Volume : 2 | Issue : 1 | Jan-Feb 2019

SURFACE ACTIVE, PERFORMANCE AND BIOLOGICAL PROPERTIES OF MONOETHANOLAMIDE BASED NON-IONIC GEMINI SURFACTANTS

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ABSTRACT

Gemini surfactants can be viewed as two conventional surfactants connected via a spacer at the level of the polar head groups. Surface active, performance and biological properties of monoethanolamide based Gemini surfactant were investigated. The head group of the Gemini surfactant consist of ethanol amide connected to a 1,2,7,8-diepoxyoctane. The alkyl tails have been varied in terms of tail length. The surface activities of the synthesized surfactant were determined using surface tensiometry. Within the same homologues series, expected decrease in critical micelle concentration (cmc) with the increase in hydrophobicity was observed. However, the deviation in cmc value from regularity was observed when number of carbon atom in the hydrophobic chain exceeded a certain number. The foam production & stability were studied by measuring the volume of foam production after 30 sec and 300 sec at different concentration. The wetting power and emulsifying power were studied. The dispersion power of Gemini surfactants was quite good. Contact angle with respect to different solid probe were measured. Biodegradability and Antimicrobial property were studied. The synthesized surfactants were showed good antimicrobial activities against the tested microorganisms.

KEYWORDS: Gemini Surfactant, Surface Activities, Performance Properties, Contact Angle Measurements, Biological Properties

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HOW TO CITE THIS ARTICLE:
Ishwar T. Gawali, & Ghayas A. Usmani (2019). Surface Active, Performance and Biological Properties of Monoethanolamide Based Non-ionic Gemini Surfactants , International Educational Journal of Science and Engineering (IEJSE), Vol: 2, Issue: 1, 26-32

1. INTRODUCTION

Surfactants are amphiphilic molecule consisting of both hydrophilic and hydrophobic regions. These substances are known to play a vital role many in process of interest in both fundamental and applied sciences. One important properties of surfactant is the formation of colloidal-sized cluster in solution, known as micelle. Today, new surfactants should be milder, safer and efficient with a minimal impact on the environment. Environmental awareness and protection have led to the development of more environmentally benign surfactant. There is trend toward replacing petrochemicals by renewable raw materials [1-2].

Gemini surfactants are a newer type of surfactants capable of forming self assemblies having two amphiphiles in molecules, chemically bonded through a spacer group. They are more surface active by order of magnitude than conventional surfactants. This newer type of surfactants has attracted considerable interest since it became evident that these compounds have a very low critical micelles concentration and much greater efficiency in reducing surface tension than expected [3-4]. Due to their high molecular weight, skin penetration of Gemini surfactant is expected to be low, which is one of the desirable properties of a surfactant to be used in body care products such as soaps, shampoos and cosmetics. However, the main factor that has prevented the use of Gemini surfactants in practical applications is their higher cost [5-6].

There are several research publications on Gemini surfactants and their potential applications. Aratani et. al. have synthesized Gemini surfactants from tartaric acid and studied properties. Anno Wagennaar et. al. have synthesized non-ionic reduced-sugar based bola amphiphiles and Gemini surfactants with an α, ω-diamino-(oxa) alkyl spacer. Wenjian Zhang et. al. synthesized non-ionic Gemini surfactant Di-Glycerol 2, 9-Dihexyldecanedioate and studied the physico-chemical and performance properties [4, 5-6].

In previous research paper [7], we have described the synthesis, characterization and anticorrosion properties of ethanol amide based non-ionic Gemini surfactants. The general structure of synthesized gemini surfactant is shown in fig.1. In this paper, various surface active properties of synthesized surfactant such as surface tension, critical micelle concentration, effectiveness, surface excess concentration etc. were determined. The performance properties such as foaming power and stability, emulsifying ability, wetting power, dispersion capability were studied in details. We have also described biological

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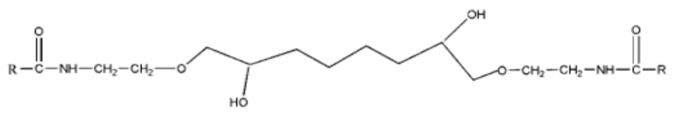
properties such as antimicrobial activity and biodegradability.



Ethanolamide Based Non-ionic Gemini Surfactant

Figure 1: General Structure of ethanol amide based non-ionic Gemini surfactant

Here, R= C11H23 [Lauryl ethanolamide based Gemini surfactant (GSLMDO)], R=C13H27, [Myristyl ethanolamide based Gemini surfactant (GSMMDO)], R= C15H31, [Palmityl ethanolamide based Gemini surfactant (GSPMDO)], R= C17H33 [Oleyl ethanolamide based Gemini surfactant (GSOMDO)].

2. MATERIALS AND METHODS

2.1 Material

Non-ionic gemini surfactants were prepared from methods developed previously [7]. The Light Paraffin, cyclohexane and sodium stearate were purchased from Sigma Aldrich. Cotton seed oil and coconut oil were purchased from local market. All the other chemicals and solvent used were analytical grade. Double distilled water was used.

2.2 Evaluation of Surfactant Properties

2.2.1 Surface Tension

Surface tension was determined by using kruss K12 Tensiometer with the Wilhelmy plate technique at 300C. The instrument was calibrated using double distilled water [8]. The average value of three measurements of the surface tension data was used.

2.2.2 Foaming Ability

Foaming power and stability of aqueous solution of Gemini surfactant of different concentrations were studied according to DIN-53902-1 method [9]. For the measurement, 200 ml of the aqueous solution of Gemini surfactant was poured into a graduated 1 liter measuring cylinder. The solution was manually beaten with a frequency of 60 beats per minute. The volume of the foam produced was measured after 30 seconds (foaming ability) and after 300 seconds (foam stability). Each of which was repeated three times and the average value was used for estimating the foam ability and foam stability of the surfactant.

2.2.3 Emulsifying Ability

The stability of emulsion containing cationic surfactants at different concentrations was determined for the systems of cyclohexane/water, coconut oil/water, cotton seed oil/water and liquid paraffin/water at room temperature (32^{o}C). The five 100mL stoppered graduated measuring cylinders were charged with 20 ml of aqueous solutions (0.1 ± 0.01 wt %) of the surfactants. Then in every cylinder 20 ml of cyclohexane, coconut oil/water, cotton seed oil/water and liquid paraffin were poured separately through the side of its wall. The cylinders were turned upside down for a total of five times at a rate of five turns per 1 min. Then the cylinders were left to stand. The time required to separate 20 ml of aqueous solution in every cylinder was recorded [10].

2.2.4 Wetting Ability

The wetting ability of the different concentrations of surfactants solution in distilled water onto canvas was determined using the canvas disc method [11]. The time for a canvas wafer from immersion to starting to sink in the surfactant solution was measured. This was repeated five times and the average time was defined as the wetting time. Then the curve of wetting time against surfactant concentrations was drawn.

2.2.5 Dispersing Capability

First aqueous solution of the surfactant (0.25 ± 0.01 wt%) were prepared. Secondly 5 mL of aqueous solution of sodium stearate (0.5 ± 0.01 wt %) and 10 mL of hard water were mixed in a 100-mL stoppered graduated measuring cylinder. Then a certain amounts of the aqueous solution of surfactant were added to the cylinder. The cylinder was turned upside down for a total of 20 times at a rate of 1 turn per 30s. Increasing the dosage of aqueous solution of surfactants gradually until the coagulation in the cylinder had disappeared and the measuring cylinder mixture was translucent. At that time the added amount of surfactant solution was recorded and this was repeated three times and average value was defined as V_1 [12].

$$\textbf{Lime} - \textbf{Soap Dispersion Requirement (LSDR)} = \frac{V1X0.25X100}{V2X0.5}$$

Where V1 is the amount of surfactant solution (mL) and V2 is the amount of sodium stearate solution (5 mL).

2.2.6 Contact Angle Measurement The dynamic contact angles of glass slides, steel slides & teflon slides against diluted surfactant solution (1mMol/L) were determined by using contact angle measuring instrument.

2.2.7 Biodegradability Study Biodegradability of the synthesized surfactants was examined by Die-away test in river water [13-14]. Sample taken were filtered through No. 1 whatman filter paper before measuring the surface tension. Surface tension measurement was made on each sample during degradation test. Biodegradation, % of the test substance was calculated using the following formula:

$$\mathbf{D} = \frac{\gamma t - \gamma 0}{\gamma bt - \gamma 0} \, x100$$

Where:

D is percentage of biodegradation of the test compound,
γt is the surface tension at time‘t’,
γ0 is the surface tension at time ‘0’ (the initial surface tension),
γbt is the surface tension of blank experiment at time t.

2.2.8 Antimicrobial Study

The synthesized compounds were screened for their antimicrobial activity against gram positive bacteria Staphylococcus aureus NCIM 2079, Bacillus subtilis NCIM 2250 and gram negative bacteria Escherichia coli NCIM 2109, Pseudomonas aeruginosa NCIM 2036 by using agar diffusion method. Stock solution [1000 microgram per ml] of each compound was prepared in DMSO. Assay carried out by taking concentration 100 microgram per disk with size 6mm. Hi-media antibiotics disk prepared by using Ciprofloxacin (10 microgram/disk) & Amphotericin-B (100 units/disk) moistened with water used as standard. Microbiological media used for bacteria was nutrient agar (Hi-media) with composition (gL-1) sodium chloride 5.0; beef extract 10.0; peptone 10.0 (pH 7.2) [15].

3. RESULT AND DISCUSSION

3.1 Surface Activity

Surfactant form aggregates of molecules called micelles, which are formed when the concentration of surfactant solute in the bulk of the solution exceed a limiting value, called critical micelle concentration (CMC), which is the fundamental characteristic of each solute-solvent system. If the interfacial properties of a surfactant solution are plotted as a function of the concentration of the solution, the interfacial properties usually vary linearly with the concentration up to the CMC, at which point there is a break in the curve as shown in fig. 2.

The surface tension of water (72 mN/m at 25OC) is normally reduced to a value 30-40 mN/m at a cmc of surfactant. Gemini surfactant is generally superior over conventional surfactant in term of surface activity. This is due to the distortion of water by hydrophobic groups. In Gemini surfactant two hydrophobic groups in single molecules are more disruptive than individual chain in conventional surfactant. The result in the table 1 showed that all the synthesized Gemini surfactant have small values of CMC particularly GSLMDO (0.1444 mMol/L).

Surfactants Name	CMC x 10^{-3} (mol/L)	γCMC (mN/m)	πCMC (mN/m)	Γmax x 10^{-11} (mol cm^{-2})	Amin (nm^2)	C_{20} x 10^{-3} (mol/L)	$_pC_{20}$ (mol/L)	cmc/C_{20}	ΔG_{mic} (KJ/mol)	ΔGads (KJ/mol)
GSLMDO	0.1444	27.84	43.95	21.63	76.66	0.0104	4.981	13.84	-22.33	-28.90
GSMMDO	0.2002	29.55	42.24	21.42	77.49	0.0144	4.838	13.84	-21.45	-28.07
GSPDMO	0.2786	30.91	40.88	22.18	74.84	0.0201	4.696	13.84	-20.62	-27.24
GSOMDO	0.3869	31.92	39.87	22.64	73.30	0.0279	4.553	13.84	-19.79	-26.41

Table 1. Surface actives properties of the synthesized non-ionic Gemini surfactants at 30°C.

As alkyl chain length increases, CMC increase and surface tension also increases. As shown in table 1 surface tension values depend on the hydrophobic chain length. Increasing the alkyl chain length of the Gemini surfactant increases the surface tension considerably due the hydrophobic effect of the alkyl chain [12-13]. Effectiveness is determined by the difference between interfacial tension values at CMC (γ_{CMC}) and the interfacial tension values measured for pure water (γ_0) at the appropriate temperature. The most effective surfactant gives the greatest lowering of surface tension for given CMC. From table 1 it is concluded that GSLMDO (43.95 mN/m) gave the most effectiveness and GSMMDO (42.24 mN/m) gave moderate effectiveness as compared to GSPMDO (40.88 mN/m) and GSOMDO (39.87 mN/m).

The efficiency of surfactant is the value of logarithm of the surfactant concentration C_{20} at which the surface tension of water is reduced by 20 mNm-1 [13]. The $_pC_{20}$ (-log C_{20}) value measures the efficiency of adsorption of surfactant at the air/water interface. From the values of $_pC_{20}$ of compounds listed in table 1 it was showed that the efficiency of adsorption is not significantly affected by the chain length of the hydrophobic alkyl group. Minimum surface area per molecule at air/water interface (Amin) is calculated from surface excess concentration values (Γmax), by using Gibbs adsorption isotherm equation [16]. As shown in table 1, A_{min} values were observed to increase and Γmax values observed to decrease when alkyl chain length of Gemini surfactants increased from C_{12} to C_{18}. The maximum surface excess, Γmax, describes the accumulation of surfactant molecules at the air-water interface.

The free energies of micellization (ΔGmic) and free energies of micellization adsorption (ΔGads) have negative sign indicating that the two processes are spontaneous. The values of ΔGads is slightly higher than ΔGmic. The more negativity of ΔGads values indicates the adsorptive tendency of these surfactants than micellization tendency. The driving force of micelle formation is the repulsion occurring between the hydrophobic chains and the polar medium. The chemical structure of these molecules is the main factor influencing their thermodynamic aspects. The equivalence between adsorption and micellization tendencies qualifies these surfactants as being applicable in the interfacial applications including emulsification, corrosion inhibition and biocidal application [17-18].

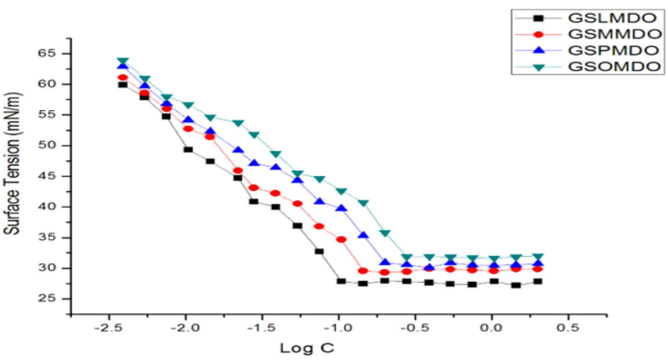


Figure 2: Variation of surface tension versus concentration on semi log scale of ethanolamide based Gemini surfactants

3.2 Performance Properties

Among the performance properties we have studied the foaming power and stability, emulsifying capability, wetting ability and dispersion power of ethanolamide based Gemini surfactants at different concentrations.

3.2.1 Foaming Power and Stability

The most widely appreciated property of surface active substances in aqueous solution is their ability to promote the formation of foam and bubbles. The gas is dispersed in the liquid to form the foam which is a thermodynamically unstable system. Surfactants can reduce the interfacial tension between the gas and liquid to form stabilized foam. These behaviors could be attributed to the physical nature and bubble formation. The results obtained for synthesized Gemini surfactant shows low quality foam production. The nature of the foam produced from synthesized surfactant has thicker nature with small bubbles throughout the experimental period. The result of foaming power and foaming stability is summarized in table 2.

Sr. No	Conc. (gm/100ml)	Foaming power (ml)				Foaming stability (ml)			
		Gsl Mdo	Gsm Mdo	Gsp Mdo	Gso Mdo	Gsl Mdo	Gsm Mdo	Gsp Mdo	Gso Mdo
1	0.1	70	54	30	18	64	47	24	16
2	0.2	107	94	60	29	99	89	56	27
3	0.3	174	148	98	55	157	124	82	41
4	0.4	240	211	125	89	192	183	110	78

The main factor that can affect the formability and stability of surfactants are the interfacial tension and the properties of interfacial film. When generating foam of same total surface area, lower surface tension system needs less work. This means that lower surface tension is good for the foam production, but it is also good for foam burst (foam unstable). The stability of foam is mainly depends on the drain speed and intensity of the interfacial film, and also on the solution viscosity [19]. The foam producing ability of all these prepared compounds was less. However, the entire compound exhibited a decrease in foam height after five minute. Table 2 shows that by increasing fatty chain length from 12 to18, foam stability become stronger. The foaming power and stability of GSLMDO is higher than the other synthesized Gemini surfactants. The Variation of foaming power and stability with concentration of synthesized surfactants are shown in fig. 3. a, b. It showed that foaming power and stability is depending on concentration of synthesized surfactant and it increases with concentration.

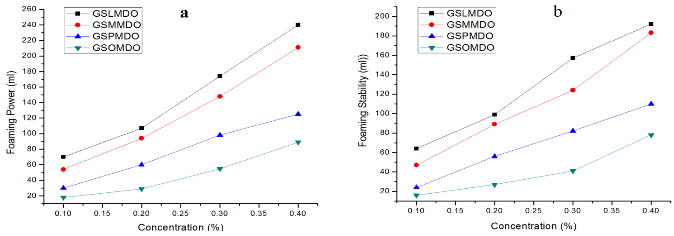


Figure 3: a, b Variation of foaming power and stability with concentration of ethanolamide based Gemini surfactants.

3.2.2 Emulsifying Ability

Surfactant can promote the formation of emulsion and improve its stability. The emulsification is realized by the effect of adsorption and it forms a layer of adsorptive film at the interface of dispersed droplets, which can prevent or delay collision among droplets and may cause gathering and condensation. The adsorption effect of the oil-water surface in the emulsion o/w is determined by the degree to which hydrophobic groups damage the structure of water phase and with the increase in the length of the hydrophobic chain, the adsorption effect decreases.

Table 3 shows the results of the emulsifying abilities of the surfactants in the systems of cyclohexanane/ water, cotton seed oil/water, coconut oil/water and liquid paraffin/ water at room temperature (320C). As shown here, the emulsifying ability of GSOMDO is the best among the four surfactants and the relatively segregation time for GSOMDO is more than 300 seconds except for cotton seed oil. The emulsion stability depends on the strength and stability of the interfacial film [20]. The hydrophobic group can be arranged closely to the oil–water interface, thus increasing the molecular density of interface adsorption and enhancing molecular interaction. So the interfacial film becomes stronger and the emulsion becomes more stable.. The GSMMDO has good emulsifying ability for cyclohexane water system.

Sr. No.	Surfactant Name	Relatively Stratification Time in second			
		Cyclohexane / water	Coconut oil / water	Cottonseed Oil / Water	Liquid Paraffin Oil /Water
1	GSLMDO	540	630	87	210
2	GSMMDO	920	370	36	41
3	GSPMDO	340	290	480	180
4	GSOMDO	660	310	108	514

Table 3: Emulsifying property of surfactants (gm/100 ml) at Cyclohexane / water, Coconut oil / water, Cottonseed Oil / Water, Liquid Paraffin / Water system at 300 C.

3.2.3 Wetting Ability

The wetting behaviors of the synthesized product using the canvas disc method were studied. The time required to sink the canvas disc in surfactant solution is measured as wetting time. The minimum is the time required for sinking the disc, higher is the wetting power of surfactant [21]. The result of wetting time of ethanolamide based non-ionic Gemini surfactants as shown in table 4. As shown here, the wetting abilities of these four surfactants follow the order: for GSLMDO > GSMMDO

> GSPMDO > GSOMDO. The Gemini surfactant adsorption quantity on canvas surface is much larger than the single corresponding surfactants. The number of molecules of Gemini surfactants with shorter hydrophobic alkyl chains arranged at the interface is more than that of the Gemini surfactant with longer hydrophobic alkyl chains. This shows that Gemini surfactant with shorter hydrophobic alkyl chains have stronger wetting power than Gemini surfactant with longer hydrophobic alkyl chains. Thus wetting ability of GSLMDO is better than GSMMDO, GSPMDO and GSOMDO.

Sr. No	Concentration (gm/100 ml)	Wetting Time in Second for surfactants			
		GSLMDO	GSMMDO	GSPMDO	GSOMDO
1	0.1	635	750	870	917
2	0.2	355	459	583	640
3	0.3	240	270	420	533
4	0.4	130	190	272	321

A surfactant can adsorb at the solid–liquid and liquid–gas interface when it is added to the solution. The adsorption leads to the solid surface wetting due to the hydration of surfactant. The more surfactant adsorbs onto the solid surface, the stronger is the wetting ability. An aqueous solution of a surfactant can wet a solid surface due to the adsorption and hydration of the surfactant. The variations of wetting times versus surfactant concentration are shown in fig. 4.

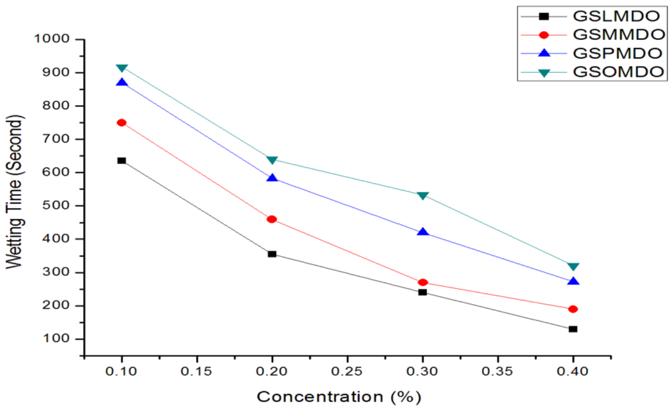


Figure 4: Variation of wetting time with concentration of synthesized non-ionic gemini surfactants (1mMol/L) at 30^{0}C.

3.2.4 Dispersing Capability

A surfactant possesses the ability to disperse the agglomerative solid particle and this is called dispersibility. Generally, dispersibility is measured by its lime-soap dispersion ability. Table 5 shows the results of lime-soap dispersion abilities of GSLMDO, GSMMDO, GSPMDO and GSOMDO. The smaller the LSDR %, the better is the dispersibility. From table 5 it is concluded that GSLMDO has better lime-soap dispersion ability than those of the others. The reason is that the number of molecules of Gemini surfactants with shorter hydrophobic alkyl chains arranged at the interface is more than that of the Gemini surfactant with longer hydrophobic alkyl chains and forms a large steric hindrance. As shown here, the dispersion ability of synthesized surfactants follow the order: GSLMDO > GSMMDO > GSPMDO>GSOMDO.

Sample	GSLMDO	GSMMDO	GSPMDO	GSOMDO
LSDR (%)	22	27	30	39

Table 5: Lime-soap dispersion ability of synthesized non-ionic Gemini surfactants at 32 0C.

3.2.5 Contact Angle Measurement

The dynamic contact angles of Glass slides, Steel slides, Teflon slides against diluted surfactants solution (1mMol/L) were determined as shown in table 6. These values of contact angle were lower for steel and Teflon than those obtained for pure water but higher for glass probes. Smaller the contact angle better is the wetting power [22-23]. Table shows that synthesized Gemini surfactant having wetting property for steel and Teflon but not for glass at 1mMol/L concentration. The GSLMDO shows more wetting property for steel and Teflon probe than other synthesized Gemini surfactant. It may be due to the presence of shorter alkyl chain than other synthesized surfactant.

Sr. No.	Sample Name	Contact Angle with respect to		
		Glass Probe	Steel Probe	Teflon Probe
1	Water	30°	75°	98°
1	GSLMDO	480	440	610
2	GSMMDO	440	610	700
3	GSPMDO	450	620	670
4	GSOMDO	500	650	700

Table 6: The contact angle measurement of ethanolamide based non-ionic Gemini surfactants with respect to different solid probes.

3.3 Biological Properties

3.3.1 Biodegradability

Alkanolamides, discovered in 1937, gradually found acceptance in a number of specialty applications. By the 1950's, practically all of the light and heavy duty detergents, shampoos and specialty detergent formulations contained alkanolamides [24-25]. Because of the extensive use, their ability to biodegrade is very critical. Therefore it was interesting to study biodegradation of surfactant derived from monethanolamide. In this study, the biodegradability of these surfactants was evaluated by surface tension measurement in 28 days. The results are shown in table 7.

Compounds containing shorter hydrophobic tail are slightly more extensively degraded than those with longer hydrophobic tail [26]. The data collected in table 7 indicated that GSLMDO surfactant have the highest biodegradability i.e. 67.97%. The biodegradability of GSMMDO, GSPMDO, GSOMDO were about 66.11%, 64.89% and 63.87% respectively. The results obtained for the compounds GSMMDO, GSPMDO, GSOMDO demonstrated that their biodegrading rates are little slower than GSLMDO. Generally "ready biodegradability" is a legislative concept applied to compounds reaching 60% biodegrading within 28 day [27]. All the synthesized Gemini surfactants had biodegradability above the pass level of 60%. Therefore the biodegradation results allowed classification of tested compounds as readily biodegradable. It is important to note that there is no simple correlation between antimicrobial activity and biodegradation. The high antimicrobial activity of the biocide against specific strains does not always correspond to its low biodegradability.

Sample	GSLMDO	GSMMDO	GSPMDO	GSOMDO
Biodegradability (%)	67.97	66.11	64.89	63.87

Table 7: Biodegradability of synthesized non-ionic Gemini surfactants (0.1%) at 32°C.

3.4.1 Antimicrobial Activity

The antimicrobial activity of ethanolamide based gemini surfactants was screened against gram-positive bacteria Bacillis subtilis & Staphylococcus aureus and gram-negative bacteria Pseudomonas aeruginosa & Escherichia coli. It was found that prepared surfactants possessed antimicrobial activities and the difference in their activities depend on the length of hydrophobic chains. The optimal length of alkyl chain has been noted to be twelve carbon atoms, which exhibit the maximum inhibition zone. These results are in agreement with a result obtained previously. This indicates that the optimal activity toward a variety of bacterial species for surfactants occurs with an alkyl chain between ten and fourteen carbon atoms. These results are in agreement with results reported elsewhere [28-32]. The presence of the alkyl hydrophobic chains in the biocide structure increases the adsorption of these biocides to the cellular membranes of the microorganism. The length of the alkyl chain of the surfactants is thought to contribute to the extent of this membrane disruption [33-34]. Table 8 summarizes the results of the diffusion agar technique in term of inhibition zone diameter, mm.

The efficiency of biocides under investigation can be attributed to the interaction between the hydrophobic chains and the external cellular membrane of the bacteria. The interaction is increased by increasing the adsorption tendency of these biocide molecules, which is occurred as a result of the chain length presence. The GSLMDO showed the maximum inhibition zone diameter 12, 10, 7 and 8 mm against Bacillis subtilis, Staphylococcus aureus, Pseudomonas aeruginosa & Escherichia coli respectively. The antibacterial activities of the surfactants can be depends on several factors including chemical structural factors and surface factors. The structural factors include the aliphatic hydrocarbon chains side, the spacer chain length and amide head groups. The surface factors include the effectiveness, efficiency, surface pressure and surface area. The most compatible hydrocarbon chain length with bacterial lipids is the dodecyl chain length.

Compounds Name	Gram Positive Bacteria		Gram Negative Bacteria	
	Bacillis subtilis	Staphylococcus aureus	Pseudomonas aeruginosa	Escherichia coli
GSLMDO	12	10	7	8
GSMMDO	11	8	6	7
GSPMDO	5	6	5	6
GSOMDO	4	5	4	5

Table 8: Antimicrobial activity of the ethanolamide based-nonionic surfactants against pathogenic bacteria. Compounds Inhibition zone diameter (mm/mg sample).

4. CONCLUSION

The monoethanolamide based Gemini surfactant have small values of CMC particularly GSLMDO (0.1444mMol/L) so that the quantity of synthesized Gemini surfactants required for application would be less in amount. The foam production was quite low. The GSLMDO has higher foaming power and stability than other Gemini surfactants. The emulsifying ability of GSOMDO is the more among the four surfactants and the relatively segregation time for GSOMDO is more than 300 seconds except for cotton seed oil. The wetting ability and lime soap dispersion ability of GSLMDO is better than GSMMDO, GSPMDO and GSOMDO. The dynamic contact angles measurement showed that synthesized Gemini surfactant having wetting property for steel and teflon but not for glass at 1mMol/L concentration. The GSLMDO shows more wetting property for steel and teflon probe than other synthesized Gemini surfactant. The experimental results have shown that ethanolamide based surfactants effective as antimicrobial agents. The biodegradation results allowed classification of these compounds as readily biodegradable.

5. ACKNOWLEDGMENT

Authors are thankful to the UGC (University Grants Commission of India), for providing the research grant for this research work [Project F. No. 41-373/2012 (SR)].

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