

REVIEW

Cationic Gemini Surfactants: A Review

Dipti SHUKLA and V.K. TYAGI*

*Department of Oil and Paint Technology, Harcourt Butler Technological Institute
(Kanpur-208002, INDIA)*

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Abstract: Recently new classes of gemini surfactants have emerged which are composed of two hydrophobic tails and two cationic head groups linked by spacer group i.e cationic gemini surfactants. Now a days, different types of cationic geminis have been synthesized. In comparison with corresponding single chain surfactants, these surfactants are more efficient in lowering surface tension and have much lower cmc. Due to their higher surface activity they have excellent properties of dispersion stabilization and soil cleanup. These compounds are widely used as an effective emulsifiers, dispersing and anti-foaming agents etc. Cationic gemini surfactants show good antimicrobial activities. Some of these geminis show good biodegradability too. This review paper deals with synthesis, properties, applications, and biodegradability of new cationic gemini surfactants.

Key words: gemini, bis-quaternary ammonium salt, microemulsion, dispersing and emulsifying properties

1 Introduction

In recent years, new classes of amphiphilic molecules have emerged and have attracted the attention of various industrial and academic research groups. One of these classes is the “gemini” or “dimeric” surfactants, which have two hydrophilic head groups and two hydrophobic groups per molecule, separated by a covalently bonded spacer (1). These surfactants have also been referred as “bipolar” or “bisquaternary ammonium” in case of cationic surfactants. The first reports on dimeric surfactants concerned bisquaternary ammonium halide surfactants. Their biological activity in aqueous solution was studied and micellar solutions of these surfactants were used to catalyze chemical reactions (2). Most studies, however reported on the surface tension of the aqueous solutions of dimeric surfactants for cmc determination and assessment of their capacity in the reducing the surface tension of water (3-5). These surfactants appear to be better in certain properties than

corresponding, and more conventional monomeric surfactants which are made up of one hydrophilic and one hydrophobic group which may include one or more alkyl chains. They tend to much lower cmc's, can produce lower tension than monomeric surfactants at the same molar mass concentration and have better wetting properties (6).

Cationic surfactants are used for number of stabilization problems and have found many technical applications. Because of the predominant negatively charged nature of natural colloids and surfaces, cationic surfactants form strong adsorption layers and hydrophobize the surfaces of these materials. Applications of cationic surfactants include softeners, cosmetic products, electro-dicoatings, and the stabilization of adhesive polymer latexes as well as in mining and paper manufacturing.

As industrial technology makes further progress, demands for high-performance surface active compounds are increasing. In response to these demands,

*Correspondence to: V.K. TYAGI, Department of Oil and Paint Technology, Harcourt Butler Technological Institute, Kanpur-208002, INDIA
E-mail: vinod_tyagi1960@yahoo.co.in, dipts_hbti2004@yahoo.co.in

novel cationic gemini surfactants have been successfully designed and developed. These surfactants are composed of two cationic head groups and two hydrophobic groups separated by a spacer group which is shown in **Fig. 1**. These surfactants show much better surface active properties than their conventional analogs.

The present paper attempts to explore the potential of a different class of cationic surfactants i.e. cationic gemini surfactants. Some examples of cationic gemini surfactants are depicted in **Fig. 2**.

2 Synthesis

2.1 Bis-Quaternary Ammonium Salts

The alkanediyl- α, ω bis (alkyl dimethyl ammonium bromide) or bisquaternary ammonium bromides have been by far the most investigated dimeric surfactants. These surfactants designated by the abbreviation m-s-m, 2Br-, s and m being the carbon numbers of the alkyl chain of the amphiphilic moieties. These surfactants are formally the dimers of the quaternary dimethyl ammonium bromides surfactants with two unequal alkyl chain of carbon numbers m and s/2. Synthesis of bis-quaternary ammonium salts are given below:

A. Kim *et al.* (7) synthesized a new type of surfactants, by the reaction of long chain alkyldimethyl amine with epichlorohydrin in the presence of amine hydrochloride or various dichloro compounds to afford the bis-ammonium salts, in which two quaternary alkyl ammonium chlorides are formally connected with a spacer. Although epichlorohydrin has been used for the reaction with alkyl amine, many kinds of products have been reported depending on the reaction conditions (8-13). Furthermore two patents (14, 15) claimed the product bis-ammonium salt from the reaction of alkylamine with epichlorohydrin in hydrochloric acid/isopropanol/water system, but the reaction path was left ambiguous and may be different from that in this work.

In the present case, the reaction proceeds conveniently and almost quantitatively under mild conditions.

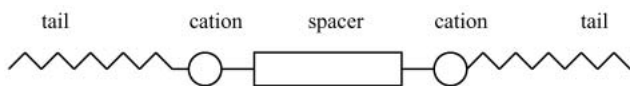
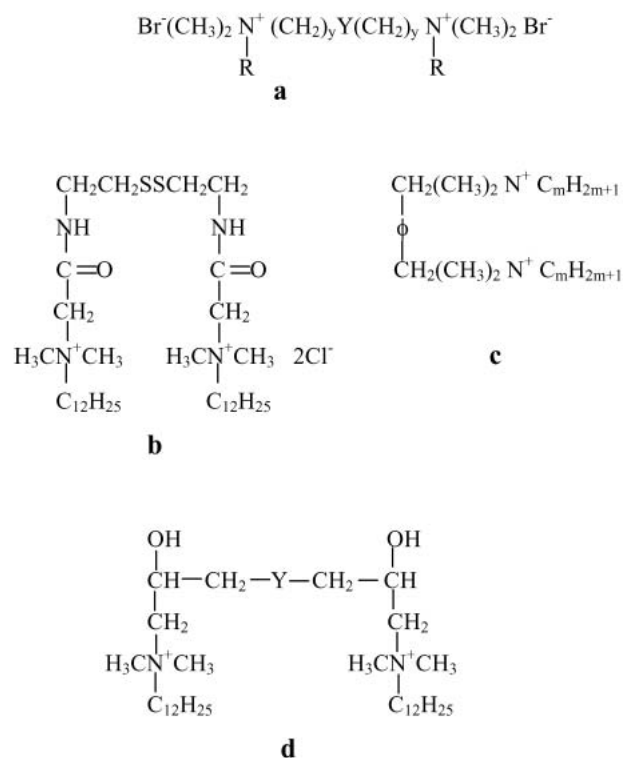


Fig. 1 Schematic Representation of Cationic Gemini Surfactant.

Neighbouring group participation by the hydroxyl group contributing to the ease of this reaction is discussed. The reaction route is studied by ^1H NMR.

Bis-dialkylmethyl ammonium salts from epichlorohydrin and bis-alkyldimethyl ammonium salts from 1,3-dichloropropane were prepared as shown in **Scheme 1** and **Scheme 2** (7).

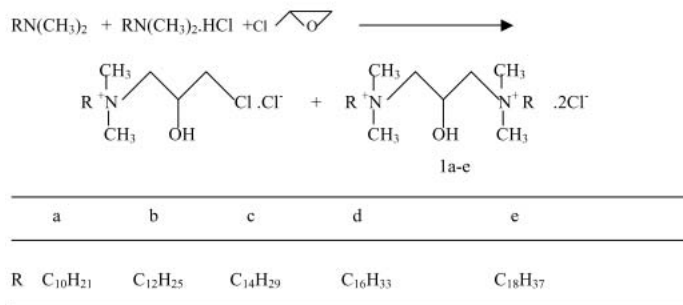
B. Ricci *et al.* (16) reported micellar-improved synthesis of bis-quaternary ammonium salts by epichlorohydrin route. They prepared bis quaternary ammonium salts from long chain alkyldimethyl amines and epichlorohydrin. An improved preparation of bis quaternary ammonium salts from N, N-dimethyl octylamine; N, N-dimethyl dodecylamine or N, N-dimethyl oleylamine, their amine hydrochlorides and epichlorohydrin can be achieved by carrying out the reaction in aqueous micellar medium. The amine hydrochlorides are used as functional surfactants to produce self-micel-



- R = $\text{C}_m\text{H}_{2m+1}$ or $\text{C}_m\text{H}_{2m+1}\text{CO}_2\text{CH}_2$
- Y = CH_2 , O, S, CHO, $(\text{CHOH})_2$, or $\text{N}(\text{CH}_3)$
- ϕ refers to a phenylene ring C_6H_4
- $(\text{CH}_2)_y$ where y = number of methylene groups

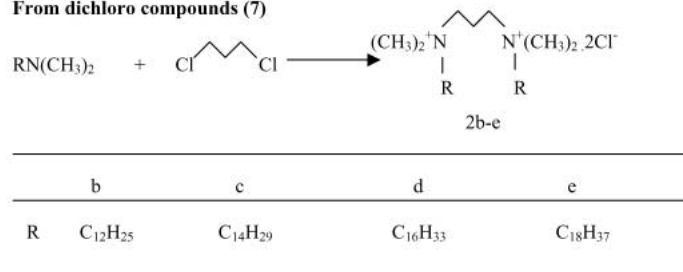
Fig. 2 Structures of Cationic Gemini Surfactants.

From epichlorohydrin route (7)



Scheme 1

From dichloro compounds (7)



Scheme 2

lization and solubilization of reactants. The formation of micelles is necessary condition for successful quaternization. Aqueous micellar medium lead to the conclusion that this micellar improved synthesis enables easier and cheaper access to bis-quaternary salts as intermediates and by using water as a solvent under mild conditions. These surfactants have unique aggregation abilities and better surface active properties than single-chain surfactants of equivalent chain length (17, 18).

Now a days the synthesis of bis quaternary ammonium salts is based on three different routes.

1. Reaction of long chain tertiary amines with dihalogenated substrates such as organic dibromides or dichlorides.
2. Reaction of N, N, N' N'-tetra methyl polyethylene diamines with alkyl halides.
3. Reaction of long chain tertiary amines with a haloalkylene oxides substrate, commonly epichlorohydrin.

C. A novel gemini surfactant with two lipophilic groups and two hydrophilic groups was prepared by using triethylamine, epichlorohydrin and bis (2-hydroxy-5-nonylphenyl) methane which was prepared from p-nonylphenol and formaldehyde. The structure was characterized by IR, ¹H NMR, and elemental analysis. The good surface activity of surfactants was shown obviously by measurement of surface tension and critical micelle concentration in aqueous solution (19).

D. Russel et al prepared the double chain surfactants with two quaternary ammonium head groups: 2-(7 trimethyl ammonio heptyl)-2-decyl-4-(8-trimethyl ammonio octyl)-5-octyl-1,3 dioxalane dibromide [1] and 2-(3-trimethyl ammonio propyl)-2-tetra decyl-4-(8-trimethyl ammonio octyl)-5-octyl-1,3 dioxalane dibromide [2]. Surfactants [1] and [2] form micelles and undergo acid catalyzed hydrolysis to give the single-chain surfactants (20).

2.2 Cationic Gemini With Amide Head Groups

A novel gemini surfactant bis [N, N'-(dodecanoylamino) ethyl] triethylene diamine bromide (BDEDE) was synthesized from ethyl bromide and bis (2-dodecanoyl aminoethyl) ethylene diamine (BDEE). The latter was prepared from lauric acid and N, N'-bis (2-amino ethyl) ethylene diamine. The structure of gemini

surfactants was characterized by IR, ^1H NMR, ^{13}C NMR, and elemental analysis. Its cmc 1.05 mmoldm^{-3} (mM) and $\gamma_{\text{CMC}} 31.0 \text{ mNm}^{-1}$ were determined. The cmc of cationic gemini surfactants decreased by approximately two orders of magnitude than cmc of dodecyl trimethyl ammonium bromide (21).

2.3 Pyridinium Cationic Gemini Surfactants

Quagliotto *et al.* prepared a new series of pyridinium cationic gemini surfactants by quaternization of 2, 2' (α , ω alkanediyl) bispyridines with alkylating agents, whose reactivity is briefly discussed. They used the long chain alkyl triflates (trifluoro methane sulfonates) for both overcoming the steric hindrance in pyridines and obtaining higher synthetic yields. The new 2, 2' (α , ω alkanediyl) bis (1-alkyl pyridinium) series accounted for good surface active properties. These compounds have Krafft point below 0°C . The characterization of the behavior of this series was performed by conductivity measurements (22).

2.4 Cationic Gemini Surfactants Having Butylene Spacers

In the early 1970s Bunton and coworkers published a series of papers on micellar catalysis of nucleophilic substitution and decarboxylation reactions using dicationic detergents-compounds containing two quaternary ammonium surfactants monomer connected at the head group level by an alkyl or 2-butynyl spacer (2, 23, 24). Nearly three decades later, research into such surfactants, now commonly referred as gemini surfactants have their exceptional activity and widening utility have become apparent (1, 25, 26).

Menger *et al.* (27) prepared geminis based on two issues:

1. First they determined the viability among gemini surfactant of heterocyclic head groups such as pyrrolidine and piperidine which is shown in **Fig. 4**.
2. Second was the issue of spacers flexibility or rigidity because spacer occupies a major role in the colloidal properties of geminis. However, most studies have involved fully saturated alkyl groups as flexible spacers (28, 29) or aryl group as rigid spacer (1, 30, 31). Thus, the 2-butynyl group provides a spacer of "intermediate" bending stiffness. Using these geminis, they show how the distinction between flexible and rigid spacers is not necessarily clear cut in regard

to micellization, especially at chain lengths where dicationic geminis deviate from "classical" cmc behavior.

To pursue this study they synthesized the cationic gemini surfactants having a 2-butynyl spacer (**Fig. 3**) and chain length varying from 8 to 18 carbons. Geminis with more flexible butyl spacers were also synthesized from comparison purposes.

Tatsumi *et al.* (32) prepared a new series of new cationic gemini bis (alkylammonium dichlorides having a butylenes or butynylene spacer and an oxycarbonyl group in lipophilic part, and almost quaternized by reaction of corresponding mono (ester-amine) with highly reactive allylic compounds. These surfactants showed good biodegradability too.

2.5 Cationic Gemini Surfactants Based On Amino Acid

In past decade new cationic surfactants bis quaternary ammonium salts with halides or "bis quats", have been synthesized and studied extensively (6, 33, 34). Due to their extraordinary surface activity, they have excellent properties of dispersion stabilization and soil cleanup. However, because these molecules have poor chemical and biological degradability, due to their chemical stability, posing a risk of toxicity to aquatic organism, they could become ecologically unacceptable. New classes of gemini cationic surfactants have been synthesized from amino acid sources (arginine) (35). They are N^α , N^ω -bis (N^α -lauroylarginine)- α , ω -alkylidenediamide or bis(Arg), as shown in **Structure 1**. These surfactants consist of two symmetrical long

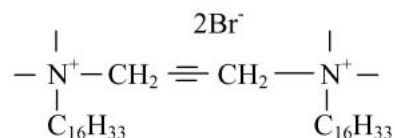


Fig. 3 Cationic Gemini Surfactants Having a 2-butynyl Spacer.

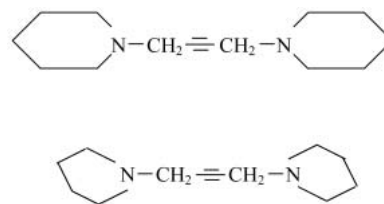


Fig. 4 Cationic Geminis with Acetylenic Spacers.

chain N^α-Lauroyl-L-arginine residues linked by amide covalent bonds to an α,ω-alkylidenediamine spacer chain of various length (n).

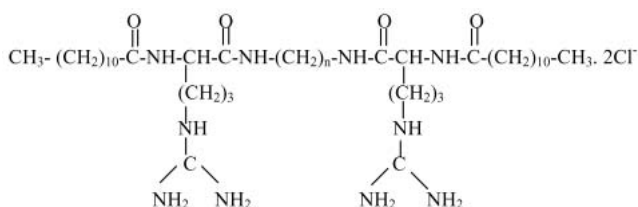
These geminis are much less toxic or hazardous. Their decomposition products after long-term exposure to the environment are less toxic or perhaps nontoxic (36).

Perez *et al.* (37) synthesized gemini surfactants derived from arginine. These surfactants are double chain amphiphiles with two hydrophilic (chiral head groups from L-arginine and linear alkyl chain) head groups. They discussed the preparation and characterization of long chain (N-Laroyl-L-nitro arginine)-α,ω-diaminoalkyl amide. These surfactants have antimicrobial activity and acute toxicity vs. *Daphnia magna* crustaceous and bioluminescent marine bacteria.

3 Surface Active Properties of Cationic Geminis

3.1 Kim *et al.* investigated the surface active properties of some bis-quaternary ammonium compounds with two alkyl chain and two ammonio groups. These surfactants showed excellent surface active properties as anionic types. The properties are summarized in **Table 1**.

- These compounds show good water solubility and their Krafft points lies below 0°C, except those with a stearyl group.
- Bis-quaternary ammonium salts from epichlorohydrin, the cmc values of these compounds are smaller by about one to two order of magnitude than those of conventional quaternary ammonium salts. As recognized in anionic gemini surfactants, due to the presence of two alkyl chains, it is likely that bis-quaternary ammonium salts exhibit large intermolecular hydrophobic interaction that make it easier for them to form aggregates in water than the mono quater-



Structure 1 Molecular Structure of Gemini Surfactants Bis(Arg).

nary ammonium salts (38).

- Compounds with decyl and dodecyl chains show maximum ability to lower surface tension. Their γ_{CMC} values increased slightly with increased alkyl chain length in their homologous series.
- The pC₂₀ of bis-quaternary ammonium salts is higher by about one order of magnitude than mono quaternary ammonium salts with same alkyl chain length. The pC₂₀ value is a useful parameter to measure the efficiency of adsorption of surfactant on an air-water interface (39) and results shown in **Table 1** which indicates that the bis-quaternary ammonium salts adsorbs more efficiently at the interface than the mono-quaternary ammonium salt.
- The foam ability and foam stability of bis-quaternary ammonium salts from epichlorohydrin are interesting. The foam ability of the compounds with decyl groups is low at 0.1 wt.% which is below the CMC. The foam ability of conventional dodecyltrimethylammonium chloride is almost zero (**Table 1**) whereas that of bis-quaternary ammonium salts with dodecyl chains is extremely high, and even higher than that of sodium dodecyl sulfate. The foam stability is also high. The maximum foam ability and foam stability were observed at the lipophilic size of dodecyl and tetra decyl chain and decreased of above these alkyl chain length.
- The surface properties, including foaming properties of bis-quaternary ammonium salts from 1, 3 dichloro propane, are almost same as those from epichlorohydrin route. It may be concluded that the hydroxyl group has a large effect on melting point of crystalline state but little effect on γ_{CMC} , CMC, pC₂₀, and foaming properties.

3.2 Conventional alkyltrimethylammonium cationic surfactants show very little foam at 0.1% concentration. In contrast C₁₂ and C₁₄ cationic geminis of structure [RN⁺(CH₃)₂]₂Y, 2Cl⁻ show very high foam where the spacer is short (3 carbon atom)

3.3 Solubilization: Solubilization is an important phenomenon required in tertiary oil recovery and detergency. Engberts *et al.* (42) have shown that cationic geminis are better solubilizers than conventional surfactants. This is because of the tubular shape of the aggregates.

The propensity of the gemini micelles for oil solubi-

Table 1 Surface Active Properties of Bis-quaternary Ammonium Salts at 20°C^a.

Compound (shown in scheme 1 and 2)	R	Krafft point (°C)	CMC (M)	γ_{CMC}	pC ₂₀	Foam (mL) ^b	
						0 min.	30 min.
1a	C ₁₀ H ₂₁	<0	3.2 × 10 ⁻³	36.5	2.9	40 (280)	0 (0) ^c
1b	C ₁₂ H ₂₅	<0	7.8 × 10 ⁻⁴	37.0	3.2	280	270
1c	C ₁₄ H ₂₉	<0	1.4 × 10 ⁻⁴	39.0	4.4	270	270
1d	C ₁₆ H ₃₃	<0	1.9 × 10 ⁻⁵	42.2	5.3	100	10
1e	C ₁₈ H ₃₇	— ^d	— ^d	— ^d	— ^d	0	0
2b	C ₁₂ H ₂₅	<0	9.8 × 10 ⁻⁴	39.2	3.3	270	270
2c	C ₁₄ H ₂₉	<0	1.1 × 10 ⁻⁴	41.8	4.5	270	260
2d	C ₁₆ H ₃₃	<0	1.5 × 10 ⁻⁵	42.0	5.4	60	10
2e	C ₁₈ H ₃₇	— ^d	— ^d	— ^d	— ^d	0	0
C ₁₂ H ₂₅ N ⁺ (CH ₃) ₃ Cl ⁻		<0 ^e	1.2 × 10 ^{-2e}	39.0 ^e	2.6 ^e	20 ^e	0 ^e
C ₁₄ H ₂₉ N ⁺ (CH ₃) ₃ Cl ⁻		— ^f	4.5 × 10 ^{-3g}	— ^f	— ^f	— ^f	— ^f
C ₁₆ H ₃₃ N ⁺ (CH ₃) ₃ Cl ⁻		— ^f	1.3 × 10 ^{-3h}	— ^f	— ^f	— ^f	— ^f

^a γ_{CMC} , Surface tension at critical micelle concentration; pC₂₀, adsorption efficiency.

^b Evaluated by semi-micro TK method with a 0.1 wt% solution.

^c At 1 wt% aqueous solution, above CMC of compound **1a**.

^d Not evaluated. reported.

^e Reported values in reference 38 (at 20°C).

^f Not reported.

^g Reported values in reference 40 (at 25°C).

^h Reported values in reference 41 (at 30°C).

lization is significantly better than conventional surfactants. The 12-2-12 gemini gives [toluene]/[surfactant] ratio of 3.8 compared to 0.78 for cetyl trimethyl ammonium bromide (CTAB). The geminis showed a distinct preference for solubilizing toluene over n-hexane (most probably due to ion-dipole interaction).

3.4 Emulsifying Properties: Geminis are superior to conventional surfactants in solubilizing styrene in water. In the production of spherical latex particles the polymerization of styrene, gemini diquats [C₁₂H₂₅N⁺(CH₃)₂(CH₃)_xN⁺(CH₃)₂C₁₂H₂₅] give rise to more extensive microemulsion region than conventional quats.

Polymerization of styrene into spherical and fairly mono disperse “latex” particles (10-100 nm indiameter depending upon conditions) can be carried out in oil-in-water microemulsions. Before delving into how gemi-

nis can play role in the process, it is worthwhile to define “microemulsions”. Oil-in-water microemulsions are thermodynamically stable, optically transparent mixtures of hydrocarbon and water in which tiny hydrocarbon droplets are dispersed in water with the aid of a surfactant and a co surfactant such as n-butanol or n-hexanol. Few surfactants will form “ternary globular microemulsions” in styrene without assistance of any co surfactant. Among these are n-alkyltrimethylammonium halides. By polymerizing styrene as “oil droplets” stabilized only by a cationic surfactants (gemini or conventional). One can avoid the complications of fourth component, further simplicity can be gained by γ -ray irradiation, rather than a chemical initiator, to effect polymerization.

Cationic gemini surfactants of the alkanediyl- α,ω bis (dimethyl alkylammonium bromide) type are introduced into microemulsion polymerization which allows

the fine tuning of the phase behavior and leads to nanolatex particles with controlled properties (44).

Geminis were found to be superior to conventional single-tailed surfactants in solubilizing styrene in water. Among the 12-n-12 geminis ($n = 2, 4, 6, 8, 10, 12$), all formed single-phase oil-in-water microemulsions with styrene. Latex particle size showed a modest dependence upon spacer length maximum at $n = 10$ (45).

3.5 Skin and Eye Irritation: Dicationic geminis of structure $[C_{12}H_{25}N^+(CH_3)_2CH_2CONH]_2Y$, where Y is $(CH_2)_4$ - or $(CH_2)_2SS(CH_2)_2$ - were found to be nonirritating (Draize test) at concentration $< 0.5\%$ (46). These also confirmed antimicrobial resistance to wool fabric.

3.6 Antimicrobial Properties: Antimicrobial properties of geminis are important over the other conventional agents. But the effectivity of these compounds depends upon the length and type of spacer and the hydrophobic counterpart.

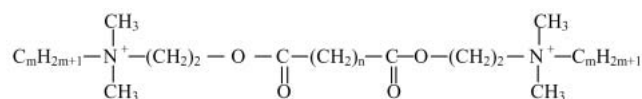
> Quaternary ammonium salts are generally known as disinfectants. The common examples are trimethyl ammonium bromide (HTAB), benzyl dodecyl dimethyl ammonium bromide (BDDAB), 2-ethoxycarbonyl pentadecyl trimethyl ammonium bromide (EPTAB), etc. as shown in **Structure 2**, may display similar biosensitivity. Effect of the length of spacer and hydrophobic tail are shown in **Table 2**. **Table 2** lists the MIC values for the Gemini series. Minimum Inhibitory Concentration (MIC) defined as the lowest concentration of antibacterial agent inhibiting visible growth after 24 h incubation at 37°C . Minimum inhibitory concentrations (MICs) were determined for this set of geminis against *E. coli*. It was found to be $6\ \mu\text{M}$, when $m = 12$ and $n = 2$. The MICs for BDDAB and EPTAB were found to be 625 and $78\ \mu\text{M}$ respectively.

> Diz *et al.* (45) prepared diquaternary ammonium geminis from N-dodecyl betaine which have been found to be more effective against 19 Gram-positive and Gram-negative microorganism other than HTAB. Diquaternary ammonium geminis of structure $[C_{12}H_{25}N^+(CH_3)_2CH_2CONH]_2Y \cdot 2Cl^-$, where Y = $-(CH_2)_4-$ or $-(CH_2)_2SS(CH_2)_2-$ were shown to have greater antimicrobial activity against both gram-positive and gram-negative organism than hexadecyl trimethyl ammonium bromide. There was no

significance in the antimicrobial activity of the two compounds with different linkages.

- > Bis-quaternary ammonium compounds with two alkyl chains and two ammonio groups show good antimicrobial activity (17).
- > Bis (alkyl ammonium) dichlorides having butylenes spacer show antimicrobial activity.
- > Perez *et al.* (35) have reported the synthesis and evaluation of a novel class of biocompatible gemini surfactants obtained with arginine based on chemical, biological and fundamental studies. These compounds have exhibited a broad range of antimicrobial property against 16 selected microorganism. The Gram-negative bacteria are resistant than the Gram-positive bacteria, which makes them in a way suitable in the biodegradability process. In contrast to the corresponding single-chain molecules, two alkyl chains in one molecule linked by a spacer chain enhance the adsorption and aggregation properties by strengthening the inter or intramolecular hydrophobic interactions.

3.7 Hair Conditioning: The diquaternary ammonium chlorides $[C_{18}H_{37}N^+(CH_3)_2CH_2]_2CHOH \cdot 2Cl^-$ is



Structure 2 Antimicrobial Cationic Gemini Surfactant.

Table 2 MIC Values for Geminis Against *E. coli*.

Geminia		
m (chain length)	n (spacer length)	MIC/ μM
6	2	21000
12	2	6
16	2	5700
6	4	8100
12	4	25
16	4	2800
6	8	930
12	8	190
16	8	5200

^a General formation shown in **structure 2**.

claimed to exhibit hair conditioning properties superior to those of stearylalkonium chlorides. The Rubine dye test demonstrated its highest substantivity to hair (25).

4 Novel Hydrolyzable and Biodegradable Cationic Geminis

Double chain surfactants have a bright prospects in developing a new class of surfactants. Some double chain cationic surfactants have potential promise as new candidates for an environmentally friendly surfactants.

Dialkylammonium salts have been widely used in industrial and household products. Increasing usage, however, is causing environmental problems owing to poor biodegradability. Thus much attention has been paid to the development of novel surfactants (46). On the other hand, gemini surfactants have been studied because of their excellent surface active properties in comparison to corresponding single chain surfactants (47-53). As a candidate for environmentally acceptable cationic surfactants, Tatsumi *et al.* prepared a new type of hydrolyzable cationic gemini surfactants, bis (ester ammonium) salts containing oxycarbonyl groups in the lipophile which may be much easily hydrolyzed as shown in **Structure 3**.

Novel cationic gemini surfactants, 1,3-bis [acyl oxyalkyl dimethyl ammonio]-2 have hydrolyzable oxycarbonyl moieties in the lipophilic portions. These surfactants showed excellent surface active properties. Their surface properties were largely influenced by changing the position of oxycarbonyl group in lipophile moiety. These cationic gemini surfactants showed good biodegradability (54).

New cationic geminis surfactants bis (alkyl ammonium dichlorides) having butylenes or butynylene spacer and an oxycarbonyl group in lipophilic part showed

good biodegradability.

5 Applications

Cationic gemini surfactants have wide applications because of their excellent surface activity. These are as follows:

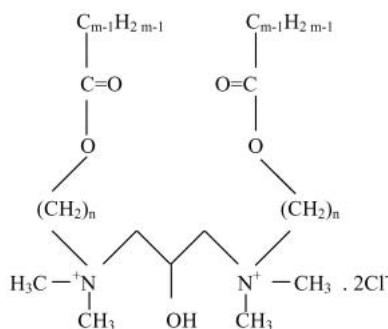
- New cationic gemini surfactants derived from amino acid sources (arginine) have potential applications in foaming, agrichemical spreading aids and cleaning processes.
- Bis-quaternary ammonium salts have found broad utility ranging from industrial to personal care applications (55-57).
- Bis-quaternary ammonium compounds with two alkyl chains and two ammonio groups show good extractive abilities as phase transfer catalyst (58).
- Water-soluble ester containing two quaternary ammonium groups are useful as bleach activator (59).
- Some cationic gemini surfactants are used as hair conditioners and fabric softeners.
- Cationic geminis with a hydroxylated spacer 1, 3-bis (dodecyl-N, N dimethyl ammonium)-2-propanol dichloride were used to separate all members of a family ergot alkaloids by micellar electro kinetic capillary chromatography (60).

6 Conclusion

This paper considered several aspects of cationic gemini surfactants. The interest of these surfactants lies in their low cmc and high efficacy in lowering the surface tension of water. Besides this, cationic geminis show interesting antimicrobial properties that may find useful applications.

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Structure 3 Biodegradable Cationic Gemini Surfactant.

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