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Surfactant and its applications: A review

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ABSTRACT
Surfactants are organic compounds with amphipathic character and have great structural diversity. The commercialization of synthetic surfactant has taken place in 20th century. Surfactants are one of the most widespread chemical of any industry and use everywhere from cloths, foods, detergents, pharmaceutical, and agriculture to modern science. The wide range of applications of surfactants makes its more concern about more and advance research in the next future. This review provides an overview of surfactants classification, structural characteristics and application in the various fields in detail.

Keywords: Surfactant, Structural characteristic, Classification, Application

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I. INTRODUCTION

The term surfactant (short form of the surface active agent) was first coined by Antara product in 1950. These are organic compounds consists of at least two parts, one is the lyophobic part which is insoluble in a specific solvent and other is lyophilic part which is soluble. This dual character of surfactant makes it amphipathic in nature [1]. When the solvent is water, the term hydrophilic and hydrophobic normally used. The hydrophobic chain is usually a branched or linear with number of 8-18 carbon atom of length. The polar head group may be nonionic or ionic depending on the charge of molecule [2].

In solution the hydrophobic group extends out of the bulk water phase, while the water soluble head group found in the aqueous phase. When surfactant molecule moving to the surface, it force apart the water molecule as a result of which the water molecule have lost the hydrogen bonds with each other, and thus reduce the surface tension. Usually, surfactants reduce the surface tension of water from 72 to 35 dyne/cm which helps in the formation of emulsion, allowing easier spreading between different liquids. When surfactant are present in low concentration it adsorb onto the interfaces.

Another property of surfactant is that in solution it tends to form aggregates from monomer called micelle and the process of aggregation called micellization [3]. The concentration at which micelle formation first appear is kwon as critical micelle concentration (CMC). The micelle formation occurs at very low concentration of surfactant which decreases the free energy of system. Micelles are also used to enhance the solubility of material which usually insoluble or poorly soluble in dispersed medium the process known as solubilization. It is a spontaneous dissolving of a nonsoluble substance into an isotropic soluble solution by surfactant [4].

The minimum temperature at which micelle formation takes place from surfactant is called kraft point or kraft temperature [5]. Below this temperature, CMC formation does not occur. So, it is a point of phase transition and above it solubility of the surfactant increases very fastly because of process of micellization takes place. Kraft point is obtained due to loosening of the attractive forces between hydrocarbon chains through the micelle.

When solution of surfactant with oxyethylene group are heated it become turbid at a particular temperature range and formation of a cloudy solution occur. This range of temperature is called cloud point. It depends on the polyoxyethylene chain length of the surfactant. When the concentration of surfactant increase other aggregates are also formed which called as lyotropic liquid crystals, anisotropic in nature [6].

There are many research article have been written on surfactants, its properties and application, but to our best knowledge, no one has written about the structure of surfactant with its classification and application in different field, simultaneously. In present work, our aim is to provide a systematic classification, important structural features and different application of surfactant in detail. This type of review article may be useful to researchers engaged in the field of surfactant and its application.

II. CLASSIFICATION

A systematic classification of surfactant is given in **Fig. 1** on the basis of charge carrying by the polar (hydrophilic) part of the surfactant molecule and the literature study. Generally surfactants are four types, which are as follows:

(i) Cationic: The hydrophilic group carry a positive charge, for example quaternary ammonium chloride, $RN(CH_3)_3^+Cl^-$.
(ii) Anionic: The hydrophilic group carry a negative charge, for example alkylbenzene sulfonate, $RC_6H_4SO_3^-Na^+$.
(iii) Nonionic: The hydrophilic group carry no apparent ionic charge for example polyoxyethylenated alkylphenol $R(OC_2H_4)_xOH$.
(iv) Zwitterionic: The hydrophilic group carry both positive and negative charge for example sulfobetaine, $RN^+(CH_3)_2CH_2CH_2SO_3^-$.

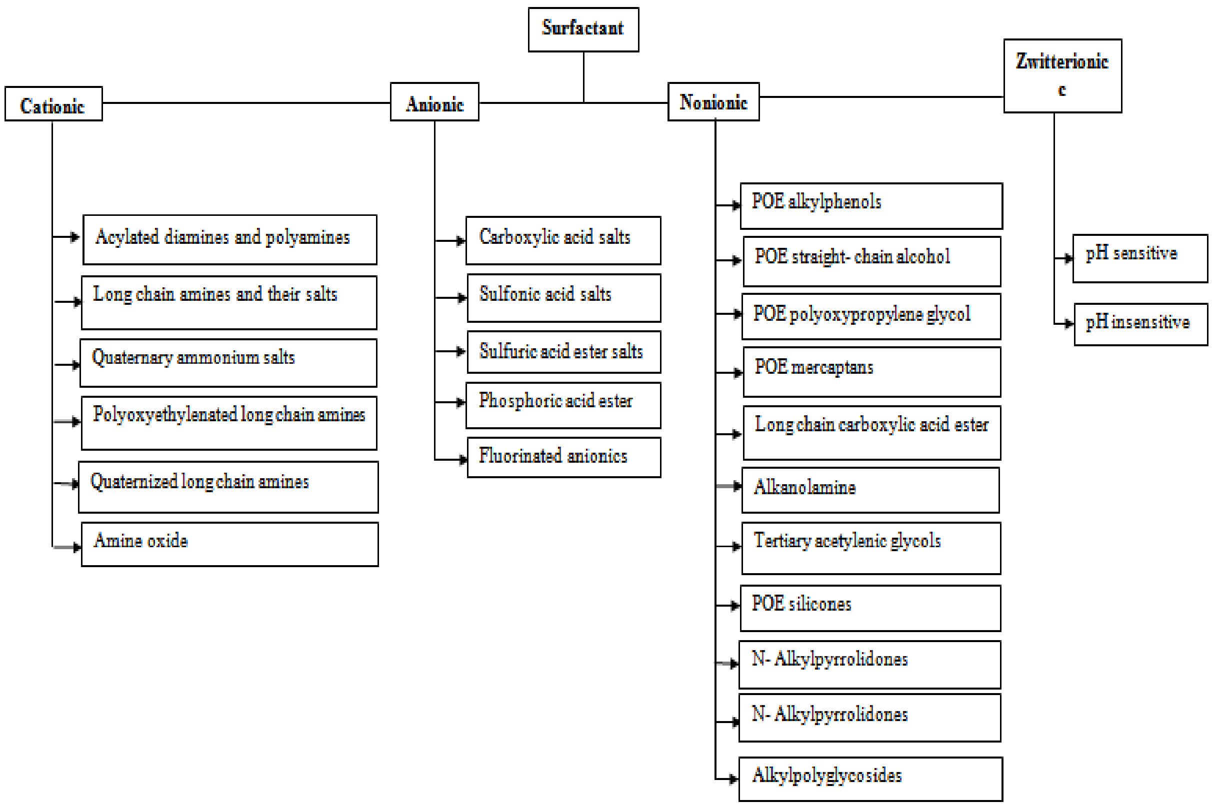

Figure 1: Systematic classification of surfactants**.**

III. STRUCTURAL CHARACTERISTICS OF SURFACTANT

Surfactants have a distinctive amphipathic molecular structure, made up of lyophilic and lyophobic group. This dual character of surfactant causes reduction of surface tension and orientation of the molecule at the surface with its hydrophilic group in the aqueous phase and hydrophobic group away from it.

Change of nature of surface by use of surfactant: The naturally occurring surfaces are negative charge and when it has to be converts in positive charge, a cationic surfactant should be used. Because a cationic surfactant absorb on a negatively charged surface and then reduction in the charge on the surface occur. Similarly, for making a cationic surfaces into anionic charge, the anionic surfactant should be used which reduces the charge on the surface and make it negatively charge. However, nonionic surfactant has both hydrophobic and hydrophilic groups; so, direction of it depends on the nature of surface and usually does not alter the charge of surface sufficiently. Amphoteric surfactant have both positive and negative charges, so it have capability to adsorb on both positively and negatively charged surfaces without changing charge of surface.

Effect of solvent on surfactant molecule: Different solvent affects the chemical structure of surfactant molecule differently. When water (aqueous) is used as a solvent, ionic group can act as lyophilic group; however, in nonpolar solvent like heptanes, ionic group may works as lyophobic group.

Effect of change in nature of hydrophobic group on surfactant: The chemical as well as physical properties of surfactants changes with the change in nature of hydrophobic group which are as follows:

Branching or unsaturation: The addition and increase of unsaturation or branching in hydrophobic group can (i) increase thermal instability, (ii) reduce biodegradability, (iii) bring oxidation, (iv) enhance solubility of surfactant in aqueous solution and organic solvent and (v) reduce the melting point of surfactant.

Length of hydrophobic group: Increase in length of hydrophobic group can (i) reduce water solubility, (ii) bring close packing of surfactant, (iii) enhance micellization tendency and (iv) enhance surfactant sensitivity.

Aromatic group: Existence of aromatic group can (i) enhance the adsorption of surfactant (ii) reduce its biodegradability and (iii) bring lose surfactant packing [7].

When surfactant molecules have two alkyl chains and phospholipids then they form vesicles. The vesicles made up of ionic surfactant are used as membrane models [8]. Hence, the structure of surfactant provide it important properties which make it one of the most important and versatile chemical of recent areas of industries. The diversity of structure of surfactant and changes its properties with conditions provide it large application in different field of our daily life to modern science.

IV. APPLICATIONS

Surfactant constitutes one of the important parts of personal care product, laundry detergent, oil recovery industries, food, agriculture and nanotechnology etc. There are different kinds of surfactants, but mostly cationic, anionic and nonionic used in the various applications.

4.1 Detergent

A detergent is an efficient cleaning product because it made up of one or more surfactants with other chemicals. Where the role of surfactant is function as to remove dirt from cloths, skin and household article especially of kitchen and bathrooms. It breaks down the interface between oil and water and thus holds dirt, oil in suspension. By this way it allows their removal. Surfactants are able to perform this action because they contain both a hydrophilic and hydrophobic group. From ancient time, soap has been prepared with the saponification of glycerides oils and fats with NaOH or KOH and by product obtain in the form of glycerol. Soaps are the best detergent, but have sensitive to acid pH and hard water.

A surfactant to act as good detergent, it must possess good wetting agent, a good solubilizing agent and have capacity to remove oil from washing fluid. The additives which used in detergents are builders, brighteners, anti redeposition agents and co surfactant. These are added in detergents because it cannot work alone practically.

Alkyl benzene sulfonate is used with some more surfactants in laundry detergents and powder such as Surf, Daz, Airel etc [9]. Alkyl sulfates are used in detergent products especially liquid contain alkyl sulfates and it also used in toothpaste [10]. Alkyl ether sulfates are used in shampoos; shower gels, dishwashing liquids etc. because they are milder to skin than alkyl sulfates. Mono alkyl quaternary surfactants are used as fabric softners. Esterquats give detergents to their fabric softening qualities [11].

Nonionic surfactants do not react with impurities of hard water (Ca and Mg). These are more useful to replace organic dirt and oil in comparison to anionic. Nonionic surfactants are used in fabrics washing detergents, in emulsion polymerization, agrochemical formulation and in various industrial processes. Amphoteric surfactants are very mild so used in shampoos, cosmetics and have pH balance properties

4.2 Oil recovery

Various surfactants have been used for oil recovery process. Some important classes of surfactants which are used at laboratory scale are given as below.

Anionic surfactants are the most commonly used surfactant for oil recovery. Carboxylate, sulfates and sulfonates are three classes of anionic surfactants used in oil recovery process. Sulfonate surfactants like petrolium sulfonates, internal olefin sulfonates, synthetic sulfonates and alkoxy sulfonates have been most widely used surfactant. Sulfate surfactants which have been used for oil recovery process are alcohol propoxy sulfates [12], alkyl ether sulfates, tristyrylphenol alkoxysulfate surfactant [13] and dodecyl alkyl sulfates [14]. Carboxylate surfactant has stability at high temperature in both alkaline and acidic pH. Ethylene carboxylates have good salt tolerance, thermal stability and high solubility in water.

The solubility of nonionic surfactants has been affected by number of factors like hydrogen bonding and van der Waals interactions. They do not ionize in water. However, they have good tolerance for high salinity. Some examples of nonionic surfactant are polyoxyethylene stearyl ether, nonylphenol, propylene glycol monostearate, alcohol ethoxystearate etc.

Zwitterionic surfactants have ability to tolerate high temperature. They have very low CMC value. So, they are useful under tough reservoir condition [15]. Some important amphoteric surfactant are hydroxyl sulfonate, alkyldimethylpropane sultain and lauryl amido propyl betaine.

Since, oil recovery process have been done in sandstone reservoir where cationic surfactants are not useful due to their high adsorption so they are least evaluated for oil recovery applications. They have been used in combined form with anionic surfactants. Some common cationic surfactants used in oil recovery are cetylpyridinium chloride and dodecyl trimethylammonium chlorides.

4.3 Food

In production of food items, surfactants are used in solubilization of oil, liquor emulsification, extraction of cholesterol. Non ionic surfactants have most common type of surfactant used in food industries as food emulsifier. Low mass surfactant have high mobility at the interface and useful in decreasing interfacial tension. So, they frequently coat the freshly created oil water interface in emulsification process. Lecithin, monoglycerides and glycolipids are typical examples. Surfactant with high mass covers protein and polysaccharide group. The opposite charge on the protein binds to head group of surfactant.

Small molecule of surfactant and polysaccharides are two important groups of surfactant which used in stabilization of emulsions and great potential application in the food [16]. The most common example is in ice cream as the air cell formation [17]. Sorbitan esters, diglycerides decrease the interfacial tension between fat globules and surrounding liquid phase. Quality of a beer is also optimizes by foam of the dispensed beer. A good beer can be identified by the stability of foam. This stabilization occurs from amphipathic polypeptides from malt and bitter compound. The foam of beer has a smaller drainage rate because of not joining the pressure of two interfaces in close proximity. Beer that contains smaller bubbles with uniform size has comparatively stable foam.

Surfactant also play an important role in production of edible coating which is probablly ethanol based shellac and corn zein coating. These are required to form a dispersion of the coating particles, which allows proper wetting and adhesion over the candy surface. Stability of fat obtained by crystals modifiers, emulsifiers like monoglycerides, lactic acid, esters of monoglycerides, sorbitan monostearate etc [18].

4.4 Agriculture

The surface tension of the spray solution of herbicides, pesticides and fungicides also decrease by use of surfactant, to allow more intimate contact between the plant surfaces and spray droplet. It brings pesticides into close contact with surface of leaf [19] and thus, pesticides are used as a crop protector. Ethoxylated alcohol, alkylphenols, alkylamines and sorbitan are typical surfactants used in pesticides. Organosilicones surfactants have been used in commercial spray.

4.5 Nanotechnology

The important property of surfactant is to reduce interfacial tension and hence prevent coalescence of newly formed drops. Application of surfactant creates a smaller efficiency which diminishes recoalescence. The mixture of surfactant which reduces the surface tension can be used in preparation of nanoparticles. Silver nanoparticles can be obtained in microemulsion with various combinations of Brij 30 and anionic surfactant aerosol-OT. Synthesis of bimetal nanofibers can be done in presence of cetyltrimethylammoniumbromide (CTAB), which function as to control the phase structure and morphology of the product. Sodium dodecyl benzene sulfonate used as morphology directing agent. Nanoparticles can also be obtained from micellar solutions of anionic surfactants. The most widely used surfactants are dodecyl sulfate. Copper nanoparticle can be synthesising from copper dodecyl sulfate. CdSe nanoparticle have synthesized in presence of gemini surfactant (made up of two conventional surfactant molecule chemically bonded together by a spacer) 1, 10-bis (alphahexadecyl pyridine) as a soft template. NiO nanoparticle can be synthesized in presence of polymeric and cationic (CTAB) surfactant which affects distribution of particle size. Sb_2O_3 nanowires, nanotubes have been synthesized in mild condition with use of CTAB. Gold nanoparticles have been synthesized with the use of gemini surfactant which function as a phase transfer reagent [20].

The present paper provides characteristics properties of surfactant, its classification, structural features and application in different fields. Thus, this type of study may be helpful to provide important information about surfactant and its applications in the different fields.

V. CONCLUSIONS

Some interesting features about surfactant have been discussed. The adsorption of surfactant molecule at the interface is a spontaneous process, as a result of which the interfacial tension decrease and it make surfactant useful in different process. Classification of surfactant provides information about types of surfactant based on hydrophilic group. The wide range of potential applications of surfactants in various field are discussed here which suggest that surfactant plays a very important role in most of industries like detergent, food, agriculture and modern science like nanotechnology. The easy availability of raw material and low production cost make it one of the most required products of our industries. Thus, the widespread applications of surfactant make it an important material for the study.

The surfactant science is now properly mature discipline; however, there is still some space for new molecule synthesis for special purpose and recent applications such as synthesis of nanoparticle and consumer products which are environment friendly.

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