

Biosurfactants and Their Biodegradability: A Review and Examination



Shrey Patel, Kaashvi Kharawala

Abstract: Surfactants are extensively employed in industrial, agricultural, and food, cosmetics and pharmaceuticals applications. Chemically produced surfactants cause environmental and toxicological hazards. Recently, considerable research has led to environmentally friendly procedures for the synthesis of several forms of biosurfactants from microorganisms. In comparison to chemical surfactants, biosurfactants have several advantages, such as biodegradability, low toxicity and ease of availability of raw materials. This paper offers an in-depth review of the types of surfactants, the need for bio-surfactants, their types and advantages, especially biodegradability. It also examines the biodegradability of selected four surfactants and finds that the biosurfactant is more easily biodegradable than the chemical surfactants.

Keywords: Surfactants, Biosurfactants, Biodegradability, COD, BOD

I. INTRODUCTION

Surfactants are extensively employed in industrial, agricultural, and food, cosmetics and pharmaceuticals applications. Chemically produced surfactants lead to environmental and toxicological hazards due to their composition (Makkar and Rockne, 2003). Recently, considerable research has led to environmentally friendly procedures for the synthesis of several forms of biosurfactants from microorganisms [1]. Biosurfactants can be classified into glycolipids, polymeric biosurfactants, phospholipids and lipopeptides (Fakruddin, 2012). According to Marchant and Banat (2012), biosurfactants may be more biodegradable than chemical ones [2]. However, Vecino et al. (2017) believe that the antimicrobial properties of biosurfactants could prevent or delay their biodegradation [3]. Millioli et al. (2009) state that this could cause problems from an environmental perspective [4]. Therefore, it is important to examine whether biosurfactants are biodegradable to understand their effect on the environment (Chen et al., 2017). However, there is not much existing research that evaluates the biodegradability of biosurfactants [5]. This study attempts to fill the gap in the existing literature by testing a small sample of four surfactants (of which three are chemical and one is a biosurfactant) and comparing the biodegradability of each.

Additionally, it also provides a detailed review about surfactants, and particularly bio-surfactants [6]. The paper is organized as follows [7]. The next section deals with an in-depth review about surfactants, their various types, need for biosurfactants, types and advantages of biosurfactants, and applications of bio-surfactants [8]. The next section discusses the materials and methods used for testing the biodegradability of selected four surfactants [9]. This is followed by the findings of the tests conducted. Finally, the discussion section provides the conclusion, practical implications of the study, limitations and further scope for research [10].

II. MEANING AND USES OF SURFACTANTS

Surfactants are active chemicals in soaps and detergents that can concentrate at the air-water interface [11]. They are frequently employed to remove oily materials from a particular medium due to their propensity to concentrate at the air-water interface which comes from their ability to enhance the aqueous solubility of Non-Aqueous Phase Liquids (NAPLS), by lowering the surface/interfacial tension at air-water and water-oil interfaces (Yin et al, 2009) [12]. Surfactants are one of the primary ingredients of household detergent of all types, home cleaning products including floor cleaner and toilet cleaner, and personal use products like shampoos, shower gels and hand soaps [13]. Surfactants perform functions such as wetting, emulsifying, foaming, disinfection and decontamination (Yuan et al, 2014) due to which they are widely used in various industries such as oil and mining, textiles, pharmaceuticals, food processing, paper manufacturing, cosmetics, rubber and metal processing (Wang, Li and Liu, 2005). Surfactants produce molecular clusters called micelles in the water or oil phase solution and adsorb to the interface between a solution and gases or solids [14]. In order to exhibit these properties, a surfactant's chemical structure should have two functional groups with differing affinities in the same molecule [15]. Surfactants are often classified according to their use, but such a classification may not be very useful because of the sheer number of uses [16]. A better classification is based on their dissociation in water (Salager, 2002). Using this characteristic, surfactants can be categorized as hydrophilic – those that are soluble in water, or hydrophobic (lipophilic) – those that are soluble in lipids [17]. Surfactants are also categorized into ionic surfactants and non-ionic surfactants [18]. Ionic surfactants can be further divided into anionic (where the hydrophilic group dissociates into anions in aqueous solutions), cationic (that dissociate into cations), and amphoteric surfactants (that dissociate into anions and cations often depending on the pH) (Nakama, 2017) [19].

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Ionic surfactants are usually hydrophilic in nature, whereas nonionic surfactants can be hydrophilic or lipophilic in nature, depending on the balance between the ability of the hydrophilic group to attract water and that of the lipophilic group to attract oil (Nakama, 2017) [20].

Anionic Surfactants are the most commonly used surfactants [21]. They dissociate in water in an amphiphilic anion, and a cation. This is usually an alkaline metal (Na⁺, K⁺) or a quaternary ammonium [22]. Anionic surfactants are of various types such as alkylbenzene sulfonates, fatty acid, lauryl sulfate, di-alkyl sulfosuccinate, lignosulfonates, etc [23]. About 50 % of the world's total production of surfactants is anionic (Salager, 2002). They have a range of uses such as foaming agents, detergents, dispersants, emulsifiers, antistatic agents and stabilizers (Yuan et al, 2014) [24].

Cationic Surfactants often originate from natural fatty acids and are costlier than anionic surfactants, as a result of the high-pressure hydrogenation reaction needed to synthesise them. their synthesis [25]. They dissociate in water into an amphiphilic cation and an anion, usually of the halogen type [26]. Most cationic surfactants are nitrogen compounds. For e.g. fatty amine salts and quaternary ammoniums [27]. Cationic surfactants can be categorized into open-chain cationic surfactants, heterocyclic group cationic surfactants and bonded intermediate connection cationic surfactants according to their chain structure [28]. This type of surfactants has applications in sterilization, rust, breaking, corrosion and mineral flotation (Yuan et al, 2014). Amphoteric surfactants exhibit both anionic and cationic dissociations [29]. They are categorized into imidazoline, betaine, lecithin, and amino acid-type as per the type of anion (Wang, Xu and Wang, 2007). This type of surfactants is usually costly, less toxic, mild on the skin and are biodegradable [30]. These properties make them ideal for use in products such as cosmetics, shampoos and shower gels [31]. They are also widely used in industrial softeners and antistatic agents because they are highly biologically compatible and less toxic (Salager, 2002). Non-ionic surfactants make up around 45% of the total production of surfactants [32]. This type of surfactants does not dissociate into ions in aqueous solutions (Nakama, 2017). Their hydrophilic group is of a non-dissociable type, such as alcohol, phenol, ether, ester, or amide [33]. Most non-ionic surfactants are in liquid and slurry form and their solubility in water decreases with the increasing temperature [34]. Non-ionic surfactants have different physicochemical properties from ionic surfactants due to their structural features (Li, Liu and Xie, 2008). They have several applications in industries such as paper, food, textile, plastic, medicines, glass, dyes, fiber, pesticides, to name a few [35]. Polymeric surfactants or surface-active polymers are created when one or more macromolecular structures demonstrating hydrophilic and lipophilic properties combine as separated blocks or grafts [36]. They have several applications in the production of foodstuffs, cosmetics, paints, and petroleum production additives [37]. Macromolecule surfactants are polymeric surfactants with a relative molecular mass greater than 10000, and a surface-active substance [38]. They are useful as thickeners, gelling agents, fluidity-improving

agents, emulsifiers, dispersing agents and antistatic agents [39].

Specialty surfactants have many special properties that are unique from conventional surfactants [40]. One of the most prominent is the fluorocarbon surfactant which exhibits high degree of surface activity and is highly thermally and chemically stable which makes it ideal for use in fire protection, mineral processing, and manufacturing of textile, paper, leather, pesticides and chemicals (Wu and Li, 2002).

III. EFFECTS OF CHEMICAL SURFACTANTS

Surfactants have applications in numerous fields, and their breadth of use will continue to expand, as will their consumption. After use, wastewater containing surfactants is invariably released into bodies of water, posing a major threat to ecosystems. Some of the major effects are [41]:

A. Effects on aquatic plants

The degree of surfactant harm to aquatic plants is proportional to the degree of its concentration. When the quantity of surfactants in the water is large, it affects the growth of algae and other microorganisms in the water, lowering the primary productivity of water bodies and therefore jeopardising the aquatic food chain. The reason for this is that surfactants can cause acute poisoning by increasing membrane permeability, allowing material exosmosis and cell structure to deteriorate over time. Superoxide dismutase, catalase, peroxidase activity, and chlorophyll concentration all decline (Liu and Feng, 1997). Surfactant build-up accelerates over time [42].

B. Effects on aquatic animals

Surfactant toxicity can be passed on to aquatic animals through animal feeding and skin penetration. Surfactants can enter the gills, blood, kidney, pancreas, gallbladder, and liver causing aquatic poisoning (Yuan et al, 2014) [43]. Surfactants are easily absorbed by the body surface and gills of fish, and they are dispersed to body tissues and organs via blood circulation. When fish come in contact with surfactants, they suffer several adverse effects evident by the rise in serum transaminases and alkaline acid phosphatase activity. Contaminated fish enter human bodies through the food chain, inhibiting numerous enzymes and so lowering immunity (Zhang et al, 2008) [44].

C. Effects on the water environment

Water contamination can occur when wastewater containing surfactants is dumped into the environment. When the surfactant concentration exceeds 0.1 mg/L, the water may form a foam insulating layer which reduces exchange between the water body and the gas environment, causing dissolved oxygen levels to drop. Hypoxia causes a high number of microorganisms to perish, causing water bodies to deteriorate [45]. Surface tension decreases to a level below the critical micelle concentration (CMC) when the concentration of surfactants increases. When the concentration of surfactant exceeds CMC, it also leads to an increase in the concentration of insoluble or soluble-water contaminants. This causes indirect contamination and changes in water characteristics (Michael, 1991). Surfactants can also destroy bacteria in

the environment and prevent harmful compounds from degrading.

Because most detergents use a lot of polyphosphate, the effluent contains a lot of phosphorus, that causes eutrophication. When the concentration of surfactants in plant wastewater exceeds a particular level, it affects aeration, sedimentation, sludge nitrification, and many other processes, increasing the difficulty of wastewater treatment [46]. Surfactants enhance emulsification and dispersion and thus reduce treatment efficiency (Yuan et al, 2014).

D. Effects on the human body

Surfactants can affect the human body on the skin and within the body. Surfactants are the major elements in modern-day detergents, and long-term use can cause irritation and harm to the skin. Surfactants harm enzyme functioning in the human body, causing the body's normal physiological function to be disrupted (Yuan et al, 2014). Surfactants are hazardous and can accumulate in the human body, making their degradation difficult (Stepanets, 2001).

Non-ionic surfactants, in general, are not electrically charged and are not associated with protein [47]. They cause minor skin discomfort. Cationic surfactants are the most toxic, while the anionic surfactants are less so. Research shows that sodium dodecyl benzene sulfonate (SDBS) can be absorbed via the skin, leading to liver damage, cancer, and other chronic symptoms (Lewis, 1990).

IV. BIOSURFACTANTS

The environmental impacts of surfactants have recently received a lot of attention due to their toxicity and difficulty in being degraded in the environment (Van Hamme, Singh & Ward, 2006).

Growing environmental concerns, biotechnology advancements, and stricter regulations have led to biosurfactants emerging as a viable option to artificial surfactants (Henkel et al, 2012).

Biosurfactants are amphiphilic compounds produced by living surfaces either on microbial cell surfaces or are excreted extracellular hydrophobic and hydrophilic moieties. They can amass between fluid phases and lower inter-surface and interfacial tension (Cunha et al, 2004) through the same mechanisms as chemical surfactants (Singh, Van Hanne and Ward, 2007).

V. TYPES OF BIOSURFACTANTS

Biosurfactants are categorised primarily based on their chemical structure and microbiological origin. Biosurfactants are of four types - glycolipids, lipopeptides, phospholipids and polymeric biosurfactants (Fakruddin, 2012).

A. Glycolipids

Most biosurfactants are glycolipids. Among these too, the most common ones are rhamnolipids, trehalolipids and sophorolipids (Yuan et al, 2014).

Rhamnolipids are made of one or two rhamnose and up to three hydroxy fatty acids, each having chain length from 8 up to 22 carbons [48]. They are widely studied and are generally formed by *P. aeruginosa* (Edwards and Hayashi, 1965).

Trehalolipids are produced by various organisms and they are comprised of disaccharide trehalose joined to mycolic acids [49]. These biosurfactants differ in their size, the structure of mycolic acid, the number of carbon atoms, and the degree of unsaturation (Asselineau and Asselineau, 1978).

Sophorolipids are synthesized by yeasts and are composed of a dimeric carbohydrate sophorose linked to a long-chain hydroxyl fatty acid through glycosidic linkage (Gautam and Tyagi, 2006).

B. Lipopeptides and lipoproteins

This type of biosurfactants is comprised of a lipid joined to a polypeptide chain (Rosenberg and Ron, 1999). Surfactin is a cyclic lipopeptide biosurfactant (Arima et al., 1968). The physiochemical properties of such biosurfactants can be modified by changing the length of the fatty acids or replacing the amino acid components of the peptide ring [50].

C. Fatty acids, phospholipids and neutral lipids

Yeast and some other bacteria generate fatty acids and phospholipid surfactants during growth on n-alkanes [51]. This type of biosurfactant is essential for medical applications (Vijayakumar and Saravanan, 2015).

D. Polymeric biosurfactants

These are the most widely researched polymeric biosurfactants and include emulsan, liposan, alasan, lipomanan and other polysaccharide-protein complexes. They are developed by the saccharide units and fatty acid residues [52]. They are polymeric in nature and have many applications as an emulsifier in food and cosmetic industries (Vijayakumar and Saravanan, 2015).

VI. ADVANTAGES OF BIOSURFACTANTS

When compared to chemically surfactants, biosurfactants have a number of advantages, including:

Biodegradability: Microorganisms can quickly destroy biological surfactants (Mohan, Nakhla and Yanful, 2006).

Low toxicity: Biosurfactants are less hazardous than surfactants made from chemicals. Biosurfactants were found to have greater EC 50 (effective concentration to reduce 50% of the test population) figures as compared to synthetic surfactants (Desai and Banat, 1997). **Raw material availability:** Biosurfactants can be made from relatively inexpensive raw materials that are readily available in huge amounts. They can use carbohydrates, hydrocarbons or lipids, individually or in combination, as carbon sources (Kosaric, 2001). **Physical factors:** Environmental parameters such as temperature, pH, and ionic strength tolerances have little effect on many biosurfactants. Krishnaswamy et al (2008) found that temperatures of up to 50°C, a pH range of 4-5-9.0, and NaCl concentrations of 50g/l and Ca concentrations of 25g/l had no effect on the lichenysin generated by *Bacillus licheniformis* strain.

Surface and interface activity: According to Mulligan (2005), an effective surfactant may reduce water's surface tension from 75 to 35 mN/m and the water/hexadecane interfacial

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tension from 40 to 1 mN/M. Surfactin may lower the surface tension of water to 25 mN/M and the interfacial tension of water/hexadecane to 1 mN/M.

VII. APPLICATIONS OF BIOSURFACTANTS

Biosurfactants have sparked significant interest as they can replace some chemical surfactants and contribute towards industrial sustainability. Biosurfactants have properties that fall under the "environmentally friendly," category. Because they are made from renewable sources and are easily biodegradable, they cause less harm to the environment than chemical surfactants. Additionally, their ability to withstand high temperatures and high salt concentrations makes them appealing for a variety of industrial applications (Banat et al. 2010). Biosurfactants introduce some physicochemical properties that are not found in chemical surfactants. The main application at the moment is due to their increased oil recovery and hydrocarbon bioremediation which is possible as a result of low critical micelle concentration (CMC) (Banat et al, 2010). Biosurfactants have also been recommended for a variety of applications in the food industry (Denise Maria et al, 2009), cosmetics, for wastewater treatment and in detergent formulations (Banat et al, 2010; Damasceno, Cammarota & Freire, 2012). Biosurfactants can also replace synthetic surfactants in processes such as lubrication, softening, adhering dyes, making emulsions, dispersions, foaming, preventing foaming, as well as in biomedical industry and bioremediation of contaminated sites. Till date, biosurfactants have been mostly used in bulk product sectors such as detergents and cleaning products. However, there are a variety of different applications where biosurfactants' unique features could be advantageous and could replace chemical surfactants. Rodrigues et al. (2007) describe how biosurfactants can be used to disrupt bacterial biofilms, as well as for other medical applications. Biosurfactants could be used in preventing biofilm formation on surfaces such as catheters, or in disrupting existing biofilms on surfaces by using them in cleaning products (Dusane et al. 2010). The chemical surfactants currently used in domestic cleaning products are not very effective at disrupting biofilms, so replacing them with biosurfactants opens up a whole new world of possibilities. The effort to make laundry detergents for low wash temperatures causes production of biofilm in waste pipes, which was earlier avoided by high water temperatures. The inclusion of biosurfactants in laundry detergent formulas may also aid in the resolution of this issue. The environmental remediation field is another area where chemical surfactants could be replaced by biosurfactants. The easier biodegradability of biosurfactants would be especially appealing in situations when they are needed in bulk, such as in oil spill clean-up. In addition to the simple oil dispersion and emulsification process, biosurfactant synthesis by bacteria allows bacteria to gain access to oil substrates for growth (Perfumo et al. 2010). Enhanced biodegradation in situ would be extremely beneficial in terms of speeding up the bioremediation process and, as a result, lowering the overall damage to the environment (Franzetti et al. 2011).

VIII. BIODEGRADABILITY OF BIOSURFACTANTS

Biosurfactants are biological surfactants, "composed of a hydrophobic and hydrophilic chain, like their chemical

counterparts. However, biosurfactants are composed of natural long chains, formed by biopolymers of lipids, proteins, peptides, or sugars. Therefore, it can be speculated that they are more biocompatible and more biodegradable than their chemical homologs" (Marchant and Banat, 2012, p. 2). Most biosurfactants are antimicrobial in nature (Vecino et al., 2017). Though this makes biosurfactants ideal for many applications, especially pharmaceutical ones, it could lead to delay in or prevention of biodegradation. This could create problems from an environmental and economic perspective (Millioli et al., 2009). Therefore, it is important to research the biodegradation of biosurfactants, to understand their impact on the environment (Vecino et al., 2017). There is limited research on the biodegradation of biosurfactants. However, the published data indicates that biosurfactants can be easily biodegraded as compared to their chemical equivalents. Hirata et al. (2009) examined the biodegradability of sophorolipids formed by the non-pathogenic yeast *Candida bombicola* using the OECD Guidelines for Testing of Chemicals (301C Modified MITI Test) and found that they begin to biodegrade immediately after cultivation.

Another study demonstrated that rhamnolipid biosurfactants are biodegradable under aerobic and anaerobic conditions (Mohan et al., 2006). The biosurfactant mannosylerythritol lipid (MEL) was found to be biodegraded in five days by Kim et al. (2002). Cappello et al. (2011) found an exopolysaccharide biosurfactant (EPS2003) easily biodegradable in marine environment through certain bacterial strains. Biodegradability tests carried out on five biological surfactants formed by two *Bacillus* sp., *Flavobacterium* sp., *Dietzia maris* and *Arthrobacter oxydans*) demonstrated a direct relation between the efficiency of their degradation and the bacteria used (Lima et al., 2011). Rhamnolipid was found to be biodegraded by 92 percent in loamy and sandy soil (Pei et al., 2009). Thus, there are not many recent studies evaluating the biodegradability of biosurfactants.

IX. EXPERIMENT

This study takes a small sample of four surfactants, of which three are chemical and one is a biosurfactant, and compares the biodegradability of each.

A. Materials and Methods

The four surfactants that were tested for biodegradability were Styryl Phenol Ethelene Oxide Condensate (Sample-1), Triethanolamine Lauryl Sulphate (Sample-2), Lauryl Alcohol Ethelene Oxide Condensate (Sample-3) and APSA-80 (Sample-4). Of these, Sample 4 is a biosurfactant. Styryl Phenol Ethylene Oxide: Styryl phenol Ethylene Oxide has strong properties of oil/ water solubility, emulsification, wetting/cleaning and dispersing.

As a result, it is widely used in the detergent, textile, agrochemical, emulsion polymerisation and paint industries (India Glycols, n.d.). Triethanolamine Lauryl Sulfate: Triethanolamine Lauryl Sulfate is a triethanolamine salt of Lauryl Sulfuric acid which is widely used in detergents, as a stabiliser and a solubilizer.

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It is a slightly toxic compound and cause irritation to the skin and eyes (Busch, 1982).

Lauryl Alcohol Ethylene oxide: Lauryl Alcohol Ethylene oxide is a nonionic compound, meaning that it has no electrical charge on the hydrophilic end and is usually found in the form of a highly viscous liquid. It is widely used in production of cosmetics, laundry detergents, surface cleaners and personal care products, to name a few (Tristar, 2020). **APSA 80:** It is an all-purpose spray adjuvant which is primarily used for agricultural uses as an irrigation aid, pesticides and insecticides applications. It reduces the surface tension of water and helps in improving its absorption capacity. This helps in better spread of the pesticides leading to improved disease control in crops (Amway, 2019). The biodegradability of surfactants can be examined by calculating the biodegradability index (ratio of the COD/BOD of the surfactant sample). This index informs us about the nature of the polluting matters present in the sample and the extent to which they are biodegradable. The biodegradability index also helps in ascertaining the effectiveness of the possible biological treatment which can be given to it.

The thresholds for biodegradability are as follows:

COD/BOD < 3 : Easily Biodegradable Sample

3 < COD/BOD < 5 : Fairly Biodegradable Sample

COD/BOD > 5 : Not easily biodegradable or even no degradability shown

B. Materials:

The materials used for determining the COD and BOD of the four surfactants were mercury sulphate, 0.25N potassium dichromate, concentrated sulphuric acid, silver sulphate

(AgSO₄), 0.1 N ferrous ammonium sulphate (FAS), CaCl₂, MgSO₄, Phosphate buffer solution and FeCl₃ as reagents, sodium thiosulphate, distilled water, and cultured bacteria to form dilution water.

C. Method:

For the COD test, mercury sulphate was added to 20ml of the sample to remove any chloride if present. 10ml of 0.25N potassium dichromate and 30ml of concentrated sulphuric acid were added to the solution, which was then mixed with silver sulphate (AgSO₄) that acts as a catalyst.

This solution was put in the digester at 150 °C for 2 hours. Once it cooled down to the room temperature, it was put in the condensate. 0.1 N ferrous ammonium sulphate (FAS) was used for titration. The amount of distilled water to be added was determined using the formula N1V1=N2V2.

COD was calculated using the formula:

$$\frac{(Blank - FAS\ used) \times NFAS \times 8 \times 1000}{Sample\ Volume}$$

For testing for BOD, distilled water was aerated for 24 hrs which was then used for dilution. The reagents used were CaCl₂, MgSO₄, Phosphate buffer solution and FeCl₃ to which cultured bacteria were added to form seed water or dilution water. The sample volume and the dilution water were divided into three bottles, out of which one bottle was used for the initial stage and the remaining two were used for the later stage. The samples were kept in the BOD incubator for 3 days at 27°C, and sodium thiosulphate was used for the titration.

X. FINDINGS

Table 1: Calculation of COD for all four surfactant samples

Sr No	Sample Description	Parameter	Sample Volume taken (ml) (V)	Volume used for Blank (ml) (V2)	Volume used for Sample(ml) (V1)	Normality of (N)	Result
1	Styryl Phenol Ethelene Oxide Condensate (Sample-1)	COD	0.5	28.0	15.7	0.08929	1757227
2	Triethanolamine Lauryl Sulphate (Sample-2)	COD	2	28.0	1.4	0.08929	950046
3	Lauryl Alcohol Ethelene Oxide Condensate (Sample-3)	COD	0.5	28.0	7.4	0.08929	2942998
4	APSA-80 (Sample-4)	COD	1	28.0	1.1	0.08929	1921521

Table 2: Blank Value Calculation of BOD for all four surfactant samples

Sr No	Sample Description	Parameter	Initial DO of Blank B1	Final DO Of blank B2
1	Styryl Phenol Ethelene Oxide Condensate (Sample-1)	BOD	7.3	6.9
			Blank value(B)=0.4	
2	Triethanolamine Lauryl Sulphate (Sample-2)	BOD	7.3	6.9
			Blank value(B)= 0.4	
3	Lauryl Alcohol Ethelene Oxide Condensate (Sample-3)	BOD	7.3	6.9
			Blank value(B)=0.4	
4	APSA-80 (Sample-4)	BOD	7.3	6.9
			Blank value(B)=0.4	

Note: Blank value (B) for all samples = B1-B2 = 7.3 – 6.9 = 0.4



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Table 3: Calculation of BOD for all four surfactant samples

Sr No	Sample Description	Initial DO of Sample C1	Final DO Of sample C2	Factor	mL Sample used (V)	Result
1	Styryl Phenol Ethylene Oxide Condensate (Sample-1)	6.7	3.7	0.9995	0.5	519740
		C = C1-C2=3				
2	Triethanolamine Lauryl Sulphate (Sample-2)	6.2	3.0	0.9990	1.0	279720
		C = C1-C2=3.2				
3	Lauryl Alcohol Ethylene Oxide Condensate (Sample-3)	5.8	2.9	0.9997	0.3	833083
		C = C1-C2=2.9				
4	APSA-80 (Sample-4)	6.8	2.8	0.9995	0.5	719640
		C = C1-C2=4.0				

Table 4: Calculation of Biodegradability Index

Sr no.	Parameter	Unit	Test Method	Result			
				Styryl Phenol Ethelene Oxide Condensate (Sample 1)	Triethanolamine Lauryl Sulphate (Sample 2)	Lauryl Alcohol Ethelene Oxide Condensate (Sample 3)	APSA-80 (Sample 4)
1.	Chemical Oxygen Demand	mg/L	IS 3025 (Part 58): 2006 RA 2017	1757227	950046	2942998	1921521
2.	Biological Oxygen Demand	mg/L	IS 3025 (Part 44):1993 RA 2019	519740	279720	833083	719640
3.	COD/BOD			3.3809	3.3964	3.5326	2.6701

The findings show that Sample 4 has the lowest COD/BOD ratio (2.6701) due to which it falls in the range of “easily biodegradable sample”. Sample 1, 2 and 3 have COD/BOD ratios of 3.3809, 3.3964 and 3.5326 respectively which falls in the range of “fairly biodegradable sample”. Thus, Sample 4, Amway APSA-80, the only biosurfactant is more easily biodegradable than the other three chemical surfactants Styryl Phenol Ethelene Oxide Condensate, Triethanolamine Lauryl Sulphate and Lauryl Alcohol Ethelene Oxide Condensate.

XI. CONCLUSION

This paper provides a detailed review of the need for biosurfactants and their benefits over chemical surfactants. Chemical surfactants have various detrimental effects on aquatic plants, water environment and on the human body. In comparison, biosurfactants have a number of advantages such as: biodegradability, low toxicity, raw material availability, physical factors, and surface and interface activity. Growing environmental concerns, biotechnology advancements, and the rise of strict regulations have resulted in biosurfactants emerging as a viable option to artificial surfactants. Biosurfactants can replace synthetic surfactants in several processes, such as lubrication, softening, adhering dyes, making emulsions, dispersions, foaming, preventing foaming, as well as in food and biomedical industries and bioremediation of contaminated sites. This study takes a small sample of four surfactants, of which three are chemical and one is a biosurfactant, and compares the biodegradability of each. Of the four surfactants that were tested - Styryl Phenol Ethelene Oxide Condensate, Triethanolamine Lauryl Sulphate, Lauryl Alcohol Ethelene Oxide Condensate and APSA-80, the findings show that Amway APSA-80, the only biosurfactant, is more easily biodegradable than the other three chemical surfactants.

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