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Synthesis of Detergent by Greener Method: A Review

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Abstract: Detergents are surfactant-based formulations widely used for domestic and industrial cleaning. Conventional detergent production largely depends on petroleum-derived raw materials and energy-intensive chemical processes, which contribute to environmental pollution and toxicity in aquatic systems. Many commonly used surfactants show poor biodegradability and can cause skin irritation due to the presence of harsh chemicals generated during sulphonation and ethoxylation processes. In recent years, increasing environmental concerns have shifted attention toward greener approaches for detergent synthesis based on the principles of green chemistry. This review highlights sustainable methods for detergent production using biodegradable surfactants derived from renewable feedstocks. Green synthesis routes such as enzymatic catalysis, solvent-free reactions, and energy-efficient processes are discussed with emphasis on waste minimization and reduced energy consumption. Bio-based surfactants synthesized from fatty acids, fatty alcohols, sugars, and amino acids demonstrate effective detergency with lower toxicity compared to conventional surfactants. Special attention is given to methyl ester sulfonate (MES), alkyl polyglucosides, and sucrose esters due to their renewable origin and high biodegradability. The performance of green detergents is evaluated based on surface activity, biodegradation behavior, and environmental compatibility. The review concludes that the application of green chemistry principles in detergent synthesis offers a sustainable alternative without compromising cleaning efficiency.

Key words: surfactant, Green chemistry, biodegradable, ecofriendly, MES

Introduction: The word detergent is derived from the Latin term detergere, which means “to clean or remove.” Detergents are chemical formulations designed to eliminate dirt, grease, and unwanted materials from various surfaces. Their cleaning action is primarily due to the presence of surfactants, which operate at interfaces by lowering surface or interfacial tension between two immiscible phases such as solid–liquid, liquid–liquid, or liquid–gas systems [1].

Surfactants are commonly referred to as surface-active agents because of their ability to accumulate at interfaces. Structurally, a surfactant molecule contains a hydrophilic (water-loving) head group and a hydrophobic (water-repelling) hydrocarbon tail. This dual nature enables detergents to solubilize oily dirt in water through micelle formation.

For many decades, commercial detergents have been synthesized from petroleum-based raw materials. Although these products exhibit excellent cleaning performance, their poor biodegradability and persistence in the environment raise serious ecological concerns. Discharge of such detergents into water bodies leads to foaming, toxicity to aquatic organisms, and eutrophication.

Used cooking oil (UCO), generated in large quantities by households, restaurants, and food industries, is often disposed of improperly, causing blockage of drainage systems and environmental contamination. However, UCO can serve as a valuable renewable feedstock for producing eco-friendly surfactants such as methyl ester sulfonate (MES). Conversion of waste oils into detergents aligns well with green chemistry principles by reducing waste generation and dependence on non-renewable resources. The increasing demand for sustainable cleaning products has therefore encouraged the development of greener detergent synthesis routes.[2]

Surfactant: Surfactant are the key functional components of detergents and are responsible for their cleaning efficiency. They can be synthetic or natural. Surfactants possess a dual affinity, consisting of a polar water attracting segment and a non polar hydrocarbon segment. It acts in between two phases with different polarities.

Liquid- liquid phase	Oil- water
Liquid-gas phase	Air- water
Solid-liquid phase	Surface- water

Surfactants adsorb at interfaces, leading to significant reduction in surface and interfacial tension and hydrophilic and hydrophobic regions in the same molecule. The hydrocarbon chain is always a nonpolar portion i.e. hydrophobic tail. And the polar part which is hydrophilic head. This dual nature allows surfactants to perform main roles like cleaning, emulsification, dispersion and foaming. Based on the charge of head group. They are may be ionic, nonionic, zwitterion or amphoteric. The market of surfactant is mainly depend on cost, variety and availability of hydrophobes. It increases the aqueous solubility of hydrophobic molecules decreases the surface tension. Surfactants reduces the surface tension of water from 72 mN/m to 35mN/m and the interfacial tension of water and n-hexadecane from 40mN/m to 1mN/m. surfactants are widely used in cosmetic, pharmaceuticals, food processing, agriculture and environmental remediation.

Comparison between Synthetic and Natural Surfactants on the basis of their properties:

Sr.no	Properties	Synthetic surfactant	Natural surfactant
1	Raw material sources	Derived mainly from petroleum-based feedstocks	Derived from renewable sources like sugars, fatty acids

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2	Synthesis method	Often involves harsh chemicals, strong acids, and high energy efficiency	Produced by enzymatic process or microbial fermentation
3	Biodegradability	May show slow or incomplete degradation	Biodegradable into nontoxic products
4	Toxicity	Can be toxic to aquatic life and cause skin irritation	Generally low toxicity and skin-friendly
5	Environmental impact	Contributes to water pollution and bioaccumulation	Minimal environmental persistence
6	Green chemistry involved	Limited compliance with green chemistry principles	Strongly align with green chemistry principles
7	Examples	LAS, AES,	Surfactant, MES, APGs.

Commercial method of detergent synthesis:

Detergents are synthesized from raw materials derived from petroleum compounds using strong acids, high temperature and intensive energy requirements. The widely used surfactant is linear alkyl benzene sulphonate (LAS).

i. Uses of Raw materials like, linear alkyl benzene (LAB), benzene, linear olefins (C_{10}- C_{14}), Sulphur trioxide or olefin, sodium hydroxide (NaOH) these materials are obtained from nonrenewable petroleum sources.

ii. These process includes reactions likeAlkylation (formation of linear alkyl benzene), Sulphonation, and Neutralization which neutralized with sodium hydroxide to sodium salt.
   a) Alkylation:
      Benzene + linear olefin ⟶ linear alkylbenzene (LAB)
   b) Sulphonation
      LAB + SO_3 ⟶ Alkyl benzene Sulphonic Acid
   c) Neutralization
      Alkyl benzene Sulphonic Acid + NaOH ⟶ Linear Alkylbenzene Sulphonate

iii. LAS (Linear Alkylbenzene Sulphonate) is an active cleaning agent.

iv. The surfactant is mixed with builders, fillers, additives and formed a commercial detergent or liquids
   Builder: sodium carbonate, sodium silicate
   Fillers: sodium sulphate
   Additives: enzymes, perfumes, optical brighteners

Greener method for detergent synthesis:

This synthesis follows the principles of green chemistry where it uses renewable material resources, mild conditions for reaction, and biodegradable surfactants which claims less environmental impact.

i. Raw materials are derived from renewable sources that are vegetable oils, fatty acids, fatty alcohols, sugars, amino acids by replacing the petroleum compounds to improve biodegradability.

ii. Synthesis of green surfactant:

a) Alkyl polyglucoside (APGs) are made from glucose reacts with fatty acids. APGs are non-ionic, highly biodegradable, can cause low skin irritation.
Glucose + Fatty Alcohol ⟶ Alkyl Polyglucoside

b) MES are derived from used cooking oil by transesterification using SO_3 and neutralize with NaOH. It is an anionic surfactant which has a renewable origin and good detergency.
Fatty Acid Methyl Ester ⟶ MES

c) Bio-surfactant produced from microorganisms. The process involves fermentation using waste substrates or renewable sources. These bio-surfactants are fully biodegradable and less toxic.
Sugars/Oils ⟶ Microbial Fermentation ⟶ Biosurfactants

iii. The catalysts used in the process are enzymes and solid acid catalyst.

iv. The reaction time is reduced by using energy efficient process such as lower temperature pressure, microwave or enzymatic methods.

v. Sodium carbonate is used as natural builders. And add enzyme additives for low temperature washing

By using this process it can minimize the carbon footprint, and causes less harm to aquatic environment.

vi. **Natural surfactants and their origin:**

Sr.no	**Natural surfactant**	**Origin**	**Properties**
1	Methyl ester sulfonate (MES)	Used cooking oil (UCO)	Good detergency
2	Alkyl polyglucosides (APGs)	Plant biomass, vegetable oil	Highly biodegradable
3	Sucrose Esters	Sugarcane, beetroot	Highly biodegradable, less skin and aquatic toxicity
4	Amino acid based sulphonates	Natural amino acids (glycine, taurine etc.)	Low aquatic toxicity, good foam
5	Surfactin	Sugars, agrowaste	Non-toxic, highly biodegradable

6	Rhamnolipid	Plant oils	Low aquatic toxicity. Highly biodegradable
7	Sophorolipid	Glucose, oils	Low aquatic toxicity, highly biodegradable

Principles of Green Chemistry in Detergent Synthesis:

Green chemistry emphasizes the development of chemical processes that minimize the generation and use of hazardous substances throughout productions. In detergent manufacturing, green chemistry provides a framework for replacing harmful chemicals with safer and sustainable alternatives. The application of these principles aims to achieve both environmental protection and industrial efficiency.

The use of renewable feedstocks such as plant oils, sugars, and microbial metabolites reduces dependence on petroleum-based raw materials. Designing surfactants that readily degrade into non-toxic products helps prevent long-term environmental accumulation. Safer synthesis routes, including enzymatic catalysis and microbial fermentation, allow reactions to occur under mild conditions and avoid the use of strong acids or toxic reagents. Energy efficiency is another important consideration, as greener processes often operate at lower temperatures and pressures. Bio-based surfactants generally exhibit reduced toxicity toward humans and aquatic organisms. Although challenges such as higher production costs and scale-up limitations remain, continued

advances in green chemistry and process engineering are expected to improve the feasibility of sustainable detergent production.

i. Use of renewable feedstocks: surfactants are derived from plant biomass or microbial metabolism rather than petroleum based compounds
ii. Design for degradation: natural surfactants are break down easily under natural conditions which minimizes the risk.
iii. Safer synthesis method: fermentation and enzymatic processes can operate under mild conditions and avoid harsh reagents
iv. Reduced toxicity: bio-surfactants exhibits less toxicity profiles, which is favorable for human health and environment
v. Energy efficient processes: under mild conditions surfactant can be made.

There are some disadvantages also such as production cost, yield variability etc. remain barrier to full replacement of synthetic surfactant in markets.

Performance and evaluation of natural surfactants:

1. **Surface and interfacial performance:** surfactants reduce the surface tension between two phases. Surfactin and rhamnolipids are capable of significantly lowering the surface tension of water at relatively low concentration. The critical micelle concentration is commonly used

to compare efficiency. Natural surfactant have low CMC value as compare to synthetic surfactant.

2. **Detergency and Emulsification:** detergency is evaluated through soil removal tests, oil dispersion studies and emulsification index. Natural surfactants have strong emulsifying ability for oils and hydrophobic stains because of their amphiphilic structure i.e. head and tail. Their cleaning performance is comparable to synthetic surfactants.
3. **Physicochemical stability**: The stability of surfactant under various conditions like pH, temperature, and salinity is important for practical applications**.**

Biodegradability and Environmental Impact:the natural surfactant or bio-based surfactant plays a crucial role in environment as the synthetic surfactant causes harm to environment and human health. With their chemical composition it is determined that they are harmful compare to bio-surfactants. biodegradability tests indicate fast breakdown into non- toxic products, minimizes environmental persistence. The natural compounds are less toxic and cause no harm to environment. [4-5].

Limitation:

1. Although biosurfactant are recognized for biodegradable and less toxic impact of environment, several other technical and economic barriers are there to limit the industrial adoption. The primary challenge is the cost of production. Biosurfactants or natural surfactants derived from fermentation process that required specific carbon sources, growth conditions, and extended processing time. These traits increases the cost of production.
2. **Low production yield**: Many microorganisms naturally secrete small quantities of product therefore it makes difficult to achieve commercial concentrations. Lesser the raw material lower the yield production.
3. **Scale-up difficulties**: Large scale fermentation abrupted by the issues like excessive foaming, limited oxygen transfer, and contamination risks, which affect process efficiency and consistency.[5]

Nevertheless, continuous progress in green chemistry, biotechnology, and process optimization is expected to enhance the industrial viability of these systems.

Conclusion: The synthesis of detergents by greener methods represents an important advancement to the sustainable chemical practices and environmental protection. These methods also allow better control over molecular structure, which improved biodegradability and lower toxicity. Despite the advantages, cost and availability of raw material the barrier remains the same for industrial adoption. Although challenges such as higher production costs, process optimization, and large –scale implementation remain, ongoing developments in green chemistry This review explains overall integration of green chemistry principles into detergent synthesis provides a route for developing Greener and compatible cleaning agents without disturbing chemical properties such as surface tension, relative velocity, cleansing action, etc. They supports in long-term environmental protection and sustainable industrial practices.

Reference:

1. Haritwal, S. (n.d.). Understanding detergents: Composition, functionality, and regulatory perspectives. Unpublished manuscript.
2. Stubbs, S., Yousaf, S., & Khan, I. (2022). A review on the synthesis of bio-based surfactants using green chemistry principles. DARU Journal of Pharmaceutical Sciences, 30(2), 407–426. https://doi.org/10.1007/s40199-022-00450-y
3. Liu, Z., Tian, X., Chen, Y., et al. (2019). Efficient sophorolipids production via a novel in situ separation technology by Starmerella bombicola. Process Biochemistry, 81, 1–11.
4. Sharma, R., & Lamsal, B. P. (2025). Understanding bio-based surfactants, their production strategies, techno-economic viability, and future prospects. Processes, 13(9), 2811.
5. Al Ghatta, A., Aravenas, R. C., Wu, Y., Perry, J. M., Lemus, J., & Hallett, J. P. (2022). New biobased sulfonated anionic surfactants based on the esterification of furoic acid and fatty alcohols: A green solution for replacing oil-derivative surfactants. ACS Sustainable Chemistry & Engineering, 10(27), 8846–8855. https://doi.org/10.1021/acssuschemeng.2c01766
6. Coltelli, M. B., Serpico, A., Domenech, R., Tronch, M., Galli, C., Sonzini, P., Escrivà-Cerdán, C., Mastroianni, S., Lazzeri, A., Licursi, D., & Raspolli Galletti, A. M. (2025). Fatty amines in detergents and cosmetics: Current state and biocircular perspectives. Cosmetics, 12(5). https://doi.org/10.3390/cosmetics12050227
7. Da Silva, I. G. S., De Almeida, F. C. G., Da Silva, N. M. P. R., De Oliveira, J. T. R., Converti, A., & Sarubbo, L. A. (2021). Application of green surfactants in the remediation of soils contaminated by hydrocarbons. Processes, 9(9), 1666. https://doi.org/10.3390/pr9091666
8. Dewi, D. M., & Danaryanti, A. (2022). Financial analysis of green detergent as a water-friendly solution in Indonesia. Journal of Research in Science, Social Sciences and Economics, 2(4), 382–390. https://doi.org/10.36418/jrssem.v2i03.290
9. Farias, C. B. B., Almeida, F. C. G., Silva, I. A., Souza, T. C., Meira, H. M., Soares da Silva, R. C. F., Luna, J. M., Santos, V. A., Converti, A., Banat, I. M., & Sarubbo, L. A. (2021). Production of green surfactants: Market prospects. Electronic Journal of Biotechnology, 51, 28–39. https://doi.org/10.1016/j.ejbt.2021.02.002
10. Gül, D. (2020). A green approach for the treatment of dye- and surfactant-contaminated industrial wastewater. Brazilian Journal of Biology, 80(3), 615–620. https://doi.org/10.1590/1519-6984.218064
11. Höfer, R., & Bigorra, J. (2007). Green chemistry—a sustainable solution for industrial specialties applications. Green Chemistry, 9(3), 203–221. https://doi.org/10.1039/B606377B
12. Vanjare, K. J., & Waghmode, S. (n.d.). Lipase enzyme-based green chemistry detergents for the cleaning industry. Zenodo. https://doi.org/10.5281/zenodo.5775429