1 Introduction to surfactant biodegradation

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1.1 Introduction

The term surfactant, or surface active agent, is applied to organic molecules whose function is to promote mixing or dispersion between phases of a mixture by lowering the interfacial tension between these phases. For most applications one of these phases is water and the other phase is hydrophobic. Thus, surfactants can be used in a whole range of technical and industrial products where it is required to disperse hydrophobic materials in water or vice versa. The major use of surfactants, in terms of the quantities used, is as a component in cleaning preparations or detergents. Such cleaning operations usually result in the discharge of an aqueous effluent, and it is the biodegradability of the surfactants in that effluent, which is the subject of this book.

The earliest known manufactured surfactants are soaps which are the sodium salts of natural, saturated and unsaturated fatty acids formed from the alkaline hydrolysis of animal and plant triglycerides (fats and oils). Recipes for soap manufacture have been found on papyri and clay tablets from ancient civilisations in Egypt and the Tigris/Euphrates (Bock and Stache 1982) and the science of soap-making has progressed through the soap boilers' guilds of the Middle Ages to the sophisticated products of present day commerce.

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\begin{align*}
\text{Triglyceride} & \quad \text{Glycerol} \quad \text{Soap} \\
\text{CH}_2\text{OCOR} & + 3\text{NaOH} \quad \text{CH}_2\text{OH} \\
\text{CH}_2\text{OCOR} \quad & \text{CHOH} \quad \text{CH}_2\text{OH} \\
\text{CH}_2\text{OCOR} \quad & \text{CHOH} \quad \text{CH}_2\text{OH}
\end{align*}
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Soaps and other synthetic surface active agents used for cleaning purposes are molecules in which there is a hydrophobic group and a hydrophilic group. The nature of the hydrophilic group and the balance between the hydrophilic and hydrophobic parts of the molecule determine which particular surfactants are appropriate.

An often used broad classification of surfactants is based on the charge characteristics of the hydrophilic part of the molecule. Anionic surfactants have a negatively charged hydrophile and include soaps, sulphonates, sulphates; non-ionic...
surfactants have an uncharged hydrophilic often a polyglycol; cationic surfactants are often based on a quaternary ammonium hydrophilic while the fourth main class is the amphoteric where the hydrophilic contains both positive and negative charges, e.g. an amino carboxylic acid. A more comprehensive description of the different surfactant types is contained in subsequent chapters of this book and has been described by Porter (1991).

As previously mentioned, the major use of surfactants is as a component of cleaning preparations and in this application and several others, essentially all the surfactant is discharged to drain. The major end-uses have been reviewed by Richtler and Knaut (1988) and, as well as home use for personal hygiene, washing and cleaning, these uses include industrial cleaning, textile and leather auxiliaries, emulsifiers, paint additives, oilfield chemicals, etc. These same authors give detailed statistics and trends in consumption and point out the major difference in annual use of cleaning compounds in Western Europe and the USA (10 kg/person per year) compared with the world average (4 kg/person per year).

The estimated 1987 total surfactant consumption (Richtler and Knaut, 1988) for USA (45%), Western Europe (38%) and Japan (17%) is 6.6 M tonne/year with an approximately 1:1 split between household and other uses. Six surfactants together make up approximately 60% of this total consumption, soap (1.5 M tonne/year), linear alkylbenzene sulphonates (1 M tonne/year), alcohol ethoxylates (0.5 M tonne/year), alkyl phenol ethoxylates (0.47 M tonne/year), alcohol ether sulphates (0.35 M tonne/year) and alcohol sulphates (0.25 M tonne/year). Clearly without biodegradation the environmental burden would be enormous.

1.2 Biodegradability and the replacement of soap in detergent products

As mentioned in the introduction, soaps have been manufactured and used by mankind for thousands of years and are still very widely employed for personal hygiene and other washing purposes. The statistics above show that soap is the major surfactant in Western Europe, USA and Japan and is even more dominant in the developing countries. Why then did the biodegradability of detergents only become an issue in the middle of the 20th century when the use of soap as the main surfactant in domestic detergents began to be replaced by alternative products?

From the viewpoint of the 1990s, where awareness of environmental issues is sharply focused, two general answers to this question may be made. Firstly, the biodegradability of all substances released to the environment (including soap) is an important factor in defining the levels of a substance in the environment and hence assessing its potential for causing environmental damage (environmental risk assessment). Secondly, based on the so-called precautionary principle, where very major quantities of a substance are released to the environment, regardless of whether the anticipated levels in the environment appear likely to