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Health Hazards of Surfactants.

D Raga Sudha[1], and G Nageswara Rao[2]*.

[1]Department of Chemistry, St. Joseph's College for Women(A), Visakhapatnam, India.
[2]School of Chemistry, Andhra University, Visakhapatnam-530003, India.

ABSTRACT

Surfactants are the main components in household detergents used all over the world. They are widely used as detergents, foaming agents, emulsifiers and stabilizers. Cationic surfactants are widely used for sterilization, corrosion breaking and mineral flotation. Amphoteric surfactants have wide application in the personal protective equipment such as shampoo, shower gel, cosmetics, etc. and also can be used in industrial softeners and antistatic agents. Large quantities of surfactant-containing wastewater are discharged into the environment, affecting aquatic life, polluting the water and deteriorating human health. Therefore, it is important to monitor and control discharge of surfactants in to water bodies. Surfactants strip the skin of its natural oils, causing dry skin, eye irritation and allergic reactions. Inflammatory skin reactions include itchy skin and scalp, eczema and dermatitis. A certain toxicity of surfactants will pass into the animal through food chain and skin penetration. When the surfactant concentration in water is too high, surfactants can enter the gills, blood, kidney, pancreas, gallbladder and liver and produce aquatic toxicity effect. The use of biosurfactants is found to be an eco-friendly approach for avoiding the hazards caused by chemical surfactants.

Keywords: Surfactants, industrial effluents, water pollution, health effects, biosurfactants

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Corresponding author

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INTRODUCTION

Understanding chemical incidents or accidents has become more relevant today in the wake of the accidents happened in Beirut Port, LG Polymers, Visakhapatnam, India and in several pharma industries. These incidents are mostly due to human negligence and lack of proper maintenance of the pipeline and storage tanks. We need to assess the hazards due to the processes and the production of various chemical products in industries across the globe. In this article we discuss the toxic effects of surfactants.

Surfactants are widely used in every house in the form of a detergent, which is a surfactant or mixture of surfactants with cleaning properties in dilute solutions. Household detergents include laundry detergents, home cleaning supplies and personal toiletries. Surfactant is added to remove dirt from skin, clothes and household articles. Apart from serving as cleansing agents, surfactants find many applications as used for emulsion polymerization and polymer stabilization in plastics and elastomers, cleaning, spinning, weaving and finishing of textiles, wetting agents and emulsifiers in agricultural chemicals and pulping and deinking in paper industry, sterilization, corrosion breaking, mineral floatation, as additives in paints, as antistatic agents in metal processing and in oil drilling operations. The use of surfactants in agrochemicals, cosmetics, pharmaceuticals, petroleum industry and food industry gives an idea on the prospects of surfactant utility and disposal.

The surface-active agents tend to produce stable foams in water bodies which form a thick and dense lather over the surface of water. Elevated quantities of surfactant-containing waste water are discharged into the environment, affecting aquatic life, polluting the water and deteriorating human health. Toxicity of surfactants is a manifestation of unwanted biological activity. Hence, it is important to monitor and control emission of surfactants in environmental water. The use of biodegradable and environmental friendly detergents should be encouraged.

Chemistry and applications of Surfactants

Surfactants are amphiphilic organic substances. Due to their surface-active properties, they are added to achieve cleaning, rinsing and fabric softening. A surfactant molecule contains a strong hydrophobic (or lipophilic) chain attached to a hydrophilic group. The hydrophilic group has common -COOH, $-SO_3H$ and a polyoxyethylene chain; lipophilic group has common -Si, -CF, $-CF_2$, and a polyoxypropylene chain. This amphiphilic structure has affinity for water and for oil, tending the surfactant molecules to congregate at the interface between the aqueous medium and non-aqueous phases of the system imparting properties such as foaming and particle suspension.

Based on polar head group, surfactants are classified as anionic (negatively charged), cationic (positively charged), non-ionic (without any charge) and ampholytic (both charges). The anionic surfactants find their use in shampoo, hand soap, bleaching, relaxer, exfoliant, scalp treatment, bubble bath, foot treatment, shaving cream, anti-aging lotions, body wash, cleansing agent, bath products, facial makeup, deodorants, perfumes, stain repellents, fabric protector, metal plating, firefighting foams, increasing softness and absorbency of paper, textiles and leather, hydraulic fluid for aviation industry, flame retardants, pesticides, detergents, solid deodorants, rubbers, latex paints, inks, polymer industry, floor wax, textiles, firefighting foam and sealants.

Cationic surfactants find use in fabric softeners, antimicrobial agents, disinfectants, rash cream, facial lotion, cleanser, makeup and sunscreen, mouth washes, toothpastes, hair conditioners, throat sprays, cosmetics and nasal sprays. Non-ionic surfactants are used in shampoo, skin creams and lotions, hair conditioners, eye liners, foaming agent, softening of paper, dyeing in textile industry, gels, lubricant and wetting agents, cosmetics, food products, pharmaceuticals, detergents, conditioners, cosmetics and beauty products. Zwitterionic surfactants are used in shampoo, anti-static conditioning agent, for amplification of DNA in PCR, Foam boosting agent, cleansers, cosmetics and protein purification. Commonly used detergents are a mixture of surfactants, abrasives, preservatives, colouring agents, perfumes, foaming agents and optical brighteners etc.

Environmental impact of surfactants

Worldwide discharges of surfactants enter water bodies leading to accumulation of potentially toxic substances and cause serious environmental problems. The effect of surfactant toxicity starts from its synthesis,

disposal and subsequent exposure to the environment. Surfactant synthesis critically affects the environment aggravating the problems related to global warming, climate change, ozone layer depletion and greenhouse gas emission which cannot be totally avoided. Both petrochemical or oleo chemical based surfactant production results in atmospheric emission, water borne wastes and solid waste, causing eutrophication of rivers and lakes (Fig. 1).

Fig 1: Surfactants polluting rivers.

Effect of surfactants on Humans

The permissible level of surfactants in humans is about 5 mg/person from drinking water, detergents and food. The effect of surfactants on human health is presented in Table 1.

Table 1: Effect of surfactants on human health

Surfactant	Acute effects	Chronic effects
Sodium dodecyl sulphate	Erythema, redness, Irritation to mouth, skin and lungs[8]	DNA damage, Membrane damage to lymphocytes[8]
Sodium dodecyl benzene sulphonate	Skin and eye irritation, possible eye damage, nose and throat irritation[26]	Spastic paralysis, damage to Gastrointestinal track leads to Hypermotility, diarrhoea[26]
Perfluorooctane sulphonic acid	Skin and respiratory irritation[21]	cancer, stunted growth, influenza, preeclampsia, (Stein et al., 2009) thyroid hormone , cholesterol, (Steenland et al., 2009); attention deficit hyperactivity disorder (ADHD), reduced fetal growth and birth size of animals and humans [17]
Perfluorobutane sulphonate	Alters Red blood cell counts, hemoglobin, lowers albumin[40]	thyroid hormonal disturbances, reproductive toxicity, effects on liver, kidney, hormonal and disturbances [33]
Cetyltrimethylammonium bromide (CTAB)	Nausea, Vomiting, skin irritation[13]	chemical burns throughout the esophagus and gastrointestinal tract followed by nausea and vomiting, can lead to death[13]

Benzalkonium chloride	Inflammation to human skin and severe eye irritant[31]	Damage to respiratory, immune, gastrointestinal and neuro systems, higher concentration leads to death [29]
Sodium Stearate	Eye irritation, discomfort, excess blood flow, corneal clouding and swelling, cracking, scaling and blistering [30]	Diarrhoea, bloated stomach, occasional vomiting, damage to cornea, emphysema, pneumoconiosis, haemolysis, emboli, hyperpyrexia and renal damage[30]
Alpha olefin sulphonate	Skin and eye irritation [20]	Reduces fetal growth [4]
Cetyldimethylethylammonium bromide	Skin, eye irritation, dizziness [14]	Coma, pneumonia [34]
Potassium oleate	Vomiting, fast renal excretion, skin inflammation, redness, dermatitis [12]	weak pulse, irregularities in heart rhythm, heart block and eventual fall in blood pressure, diarrhoea, bloated stomach, corneal clouding and swelling, difficulty in breathing, lung damage [12]
Laurylamine hydrochloride	Skin, eye irritation [37]	Respiratory irritation [35]
Dodecyltrimethylammonium chloride	skin burns and skin irritation [28]	Respiratory irritation, eye damage [28]
2-Phenoxyethanol	Serious eye irritation, headache, tremors, CNS depression, cough, sore throat [27]	Eczema[27]
Benzethonium chloride	Vomiting, irritation to the skin, eyes, mucous membranes and upper respiratory tract [39]	Collapse, convulsions and coma, injury to the mucous membrane, nausea, esophageal damage and necrosis, hypotension, dyspnea, cyanosis, paralysis of respiratory muscles and death [39]
Benzyldodecyldimethylammonium bromide	Severe skin burns and eye damage [7]	Respiratory irritation [7]
Perfluorooctanoic acid	Alters metabolism [25]	kidney cancer, testicular cancer, thyroid disease, high cholesterol, pre-eclampsia and ulcerative colitis [15]
Nonylphenol ethoxylates	Enhances obesity [41]	Breast cancer [3]

Effect of surfactants on Microbial world

The degree of damage by surfactants to microbial world relates to their concentration. When the quantity of surfactant is high in water, it inhibits the growth of bacteria, fungi and algae resulting in their decreased primary productivity in water bodies, thereby affecting the food chain of aquatic organisms. The effect of surfactants on various bacteria like phosphate solubilizing Acinetobacter junii, autotrophic ammonia oxidising

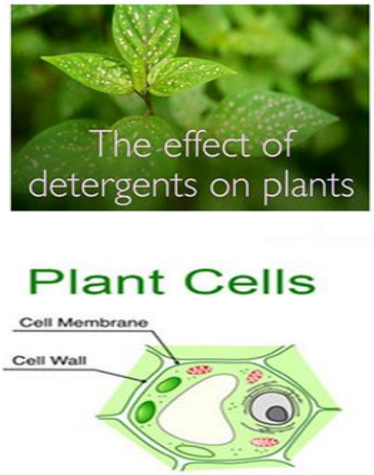
Nitrosomonas and Nitrosospira strains, DNA damage and starvation were found in bacteria, capable of utilizing SDS as sole carbon [16].

Toxicity of surfactant arises due to reactions at cell surface like depolarization of cell membrane, decreasing absorption of essential nutrients and oxygen consumption. Anionic surfactants critically affected the morphology and rigidity of sporangiophores in micro fungi and the growth and photosynthetic ability of algae. Long term exposure to detergents caused significant toxicity to Euglena gracilis affecting its cell density, motility, swimming velocity and chlorophyll content at concentrations above 1 mg/L [1]. Acute poisoning of surfactants increased membrane permeability which lead to the gradual disintegration of cell structure.

Effect of surfactant on Soil and Plants

Mild concentration of surfactant was observed to alter the soil properties whereby sorption process plays predominant role. The roots of plants were supressed or killed by the surfactants. Reduced photosynthetic activity and decreased chlorophyll (Fig. 2) were also reported by the use of detergent contaminated water [6].

Fig 2: Surfactant affected plant leaves.



Effect of surfactants on aquatic animals

The permissible levels of surfactants were reported to be 0.1 mg/L. Adverse biological effects on aquatic organisms occurred at relatively higher concentrations of surfactants [22]. When the concentration of surfactants increases in water bodies, they enter the gills, blood, kidney, liver, spleen and intestine of fishes. High concentration of surfactants caused death of fishes by reducing the swimming capacity of fishes (Fig. 3). Exposure to surfactants causes acute inflammatory reactions, oxidative stress and damage to mucus layer of fishes[36]
.

Fig. 3: Surfactant effect on Fishes.

Biosurfactants

Biosurfactants are eco-friendly alternative to synthetic surfactants. They are produced on microbial cells and contain both hydrophilic and hydrophobic moieties. These include glycolipids, phospholipids, lipopeptides, fatty acids and polymeric biosurfactants. They have several advantages over chemical surfactant such as surface and interface activity, bio-degradability, low toxicity, tolerance to temperature, pH and ionic strength and biocompatibility [19]. Biosurfactants are more effective and efficient and their CMC is about 10-40 times lower than that of chemical surfactants. Some practical approaches have been adopted to make biosurfactant production process economically attractive by making use of cheaper raw materials, optimized and efficient bioprocesses for obtaining maximum productivity. Biosurfactants are safe and find applications in agriculture, laundry detergents, biopesticides, antimicrobials, anticancer agents, antiviral activity, immunological adjuvants, antiadhesive agents, food processing industry, cosmetic industry and microbial enhanced oil recovery [32]. Some of the biosurfactants given in Table 2 can be used in place of chemical surfactants.

Table 2: Applications of Bio-surfactants

Bio- surfactant	Application
Rhamnolipid	Agriculture, Enhancement of the degradation and dispersion of different classes of hydrocarbons; emulsification of hydrocarbons and vegetable oils; removal of metals from soil [24]
Trehalolipids	Enhancement of the bioavailability of hydrocarbons [2]
Sophorolipids	Antiviral activity similar to nonoxynol – 9, Recovery of hydrocarbons from dregs and muds; removal of heavy metals from sediments; enhancement of oil recovery [23]
Lipopeptide	Biopesticide [9]
Phospholipids	Medicine [18]
Serratia marcescens UCP 1549	Agricultural and marine bioremediation [38]
Bacillus subtilis SPB1	Laundry detergent [5]

CONCLUSIONS

The use of surfactants is very common in every household use as they are widely considered to be quite safe. The surfactant industry is constantly evolving and expanding to a highly competitive sector to meet the various demands of mankind. Surfactants consumption is increasing day by day with equal contribution to domestic purposes and industry. Silent accumulation of surfactants to ecosystem exhibits considerable toxicity to aquatic organisms, plants and humans. The toxicity of surfactants increases with alkyl chain length of hydrophobic group. Surfactants are quite often considered as harmless on the basis of biodegradability and speculated low concentrations in the environment but statistical analysis reveals that these pollutants are found in concentrations higher than their permissible levels. Visible manifestations of surfactant toxicity were observed in microbes, plants, animals and humans. People should take timely measures to minimise the amount of surfactant in order to protect the environment and a continuous research is needed to understand the health hazards of surfactants.

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