

Chemistry of Detergents and Their Impact on Environment

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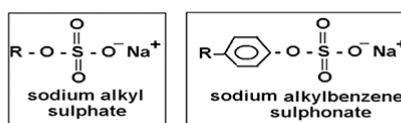
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ABSTRACT: A detergent is a surfactant or mixture of surfactants that has cleaning properties in dilute solution with water. A detergent is similar to soap, but with a general structure $R-SO_4^- Na^+$, where R is a long-chain alkyl group. Like soaps, detergents are amphiphilic, meaning they have both hydrophobic and hydrophilic regions. Most detergents are alkylbenzenesulfonates. Detergents tend to be more soluble in hard water than soap because the sulfonate of detergent doesn't bind calcium and other ions in hard water as easily as the carboxylate in soap does. Detergents are a class of surfactants with cleaning properties when diluted in water. Most detergents are alkylbenzenesulfonates. Detergents are classified according to the electrical charge they carry as anionic, cationic, or non-ionic. While detergents are used for cleaning, they also find use as fuel additives and biological reagents.

KEYWORDS: detergents, environment, harmful, impact, chemistry, surfactant, soaps, water

I. INTRODUCTION

The general formula of detergents are



where R represent a Long-chain hydrocarbon

Types of Detergents

Detergents are classified according to their electrical charge:

- **Anionic detergents:** Anionic detergents have a net negative electrical charge. The liver produces bile acids, which are anionic detergents the body uses to digest and absorb fats. Commercial anionic detergents are usually alkylbenzenesulfonates. The alkylbenzene is lipophilic and hydrophobic, so it can interact with fats and oils. The sulfonate is hydrophilic, so it can wash away soiling in water. Both linear and branched alkyl groups may be used, but detergents made with linear alkyl groups are more likely to be biodegradable.

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- Cationic detergents: Cationic detergents have a net positive electrical charge. The chemical structures of cationic detergents are similar to those of anionic detergents, but the sulfonate group is replaced by quaternary ammonium.
- Non-ionic detergents: Non-ionic detergents contain an uncharged hydrophilic group. Usually, these compounds are based on a glycoside (sugar alcohol) or polyoxyethylene. Examples of non-ionic detergents include Triton, Tween, Brij, octyl thioglucoside, and maltoside.
- Zwitterionic detergents: Zwitterionic detergents have equal numbers of +1 and -1 charges, so their net charge is 0. An example is CHAPS, which is 3-[(3-cholamidopropyl)dimethylammonio]-1-propanesulfonate.[1,2]

The largest application of detergents is for cleaning. Dishwashing detergent and laundry detergent are the most common formulations. However, detergents are also used as fuel additives and biological reagents. Detergents prevent fouling of fuel injectors and carburetors. In biology, detergents are used to isolate integral membrane proteins of cells.

Since they are used on a large scale, detergents are partly responsible:

- For eutrophication of rivers: The phosphorus and nitrogen compounds in detergents get concentrated in rivers. These two nutrients enable increased growth of aquatic plants (algae) that invade the entire aquatic area. When plants die, their decomposition consumes oxygen from the aquatic environment. Added to this is the consumption of oxygen due to the decomposition of the surfactants present in the detergents. Fish and invertebrates do not find adequate oxygen and die by asphyxiation. All this contribution of organic matter continues to decompose nevertheless but this time without oxygen. This is anaerobic fermentation that releases hydrogen sulphide and that smell of "rotten eggs";
- For the contamination of groundwater by contributing nutrients (surfactants) and mineral salts such as phosphates, nitrates, ammonium, boron, etc.;
- For the decline of coastal plants subjected to polluted spray;
- For the cloudy water phenomenon. Very surprising in the late 50s when large foam ponds due to excessive foam appeared on rivers. It was the alarm bell![3,4]
- For the disturbance of aquatic organisms:

When not treated fully in water treatment plants, the surfactants in detergents affect the natural defences of these organisms (their skin, scales, shell, walls of the plants or the bacteria) against chemical substances and pathogens. Finally, some surfactants such as ethylene glycol disrupt the hormonal system of aquatic animals. Fortunately, the law has developed considerably since the 70s. EU rules have been progressively strengthened.

Current legislation calls for:

- an obligation to treat waste water;
- a ban on foaming surfactants;
- facilities for placing biodegradable products on the market;
- enhanced biodegradability requirements.

Detergents contain all sorts of chemical ingredients, many of which are considered even mildly toxic to people or pets. They can contain chlorine, phthalates, formaldehyde, and in some cases, something called 1,4-Dioxane. Found mostly in paints and varnishes, as well as detergents like Tide, the EPA considers this chemical solvent to be carcinogenic if ingested. High levels of the stuff have been known to vertigo, drowsiness, headache, anorexia, and irritation of the eyes, nose, throat, and lungs in humans. It's also been known to cause cancer in some rats. [5,6]

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II. DISCUSSION

Laundry detergent is far more than just a basic cleansing soap. It contains a huge number of harmful chemicals that have a serious impact on our environment. Some of the most concerning ones are:

1. Phosphates - linked to cardiovascular (heart) disease as well as osteoporosis. These toxins are particularly damaging to the marine environment when dispersed in wastewater from your wash.
2. Bleach - often used to brighten whites, its toxic fumes cause respiratory distress and on contact with skin and eyes it is able to cause caustic burns.
3. Formaldehyde - A chemical usually associated with the preservation of dead bodies. This toxic ingredient as classified by the EPA, is a class B1 probable carcinogen. This means it has been linked with an increased risk of cancer.
4. Ammonium Sulfate and Ammonium Quaternary Sanitizers - harsh cleansing agents that are corrosive and toxic. They can cause eye, skin and lung damage even with minimal exposure.
5. Dioxane (1,4 Dioxane/ Diethylene Dioxide/ Diethylene Ether/ Dioxan) is quite possibly one of the worst additives. Dioxane is also a carcinogen and has been known to pose a combustion risk. Exposure to this toxin can damage your kidneys, lungs, central nervous system, eyes, skin and respiratory function. [7,8]

Up to 1 billion plastic detergent jugs are purchased in the US alone each year, with only 10% of these ever being successfully recycled. It stands to reason that this waste has to go somewhere, right? Sadly it most often ends up in landfills where the residues of the detergents leech into the soil and the plastic remains for hundreds of years. This is probably the most harmful and concerning effect of detergent on the environment. The presence of phosphates in laundry detergent run-off causes algal blooms which starve aquatic life of oxygen. The same chemical compounds that can burn our skin, cause cancer or hormonal issues also affect marine life. This means unnecessary cruelty and also impairs the function of the necessary ecosystems that we rely on. Synthetic surfactants contained in laundry detergent reduce the tension of the water's surface, making it susceptible to pollutants such as car exhaust and pesticides. This further impacts the aquatic environments and makes it even harder for the marine animals in these environments to flourish. All this combined with the plastic waste just goes to demonstrate how laundry detergent may clean your wash, but it is seriously doing the dirty to our environment! Liquid detergent is considered one of the worst offenders, not necessarily due to its ingredients, but as it is always sold in a heavy-duty plastic bottle. These bottles are rarely recycled despite being advertised as recyclable. In reality, billions of detergent jugs end up in our oceans, waterways and landfill every year all around the globe. [9,10]

Most liquid detergents are also heavily watered down. This contributes to a waste of water as well as a larger carbon footprint due to the added weight. Detergents are organic compounds, which have both polar and non-polar characteristics. They tend to exist at phase boundaries, where they are associated with both polar and non-polar media. Detergents are of three types: anionic, cationic, and non-ionic. Anionic and cationic have permanent negative or positive charges, attached to non-polar (hydrophobic) C-C chains. Non-ionic detergents have no such permanent charge; instead, they have a number of atoms which are weakly electropositive and electronegative. This is due to the electron-attracting power of oxygen atoms. There are two kinds of detergents with different characteristics: phosphate detergents and surfactant detergents. Detergents that contain phosphates are highly caustic, and surfactant detergents are very toxic. The differences are that surfactant detergents are used to enhance the wetting, foaming, dispersing and emulsifying properties of detergents. Phosphate detergents are used in detergents to soften hard water and help suspend dirt in water.

Detergents can have poisonous effects in all types of aquatic life if they are present in sufficient quantities, and this includes the biodegradable detergents. All detergents destroy the external mucus layers that protect the fish from bacteria and parasites; plus they can cause severe damage to the gills. Most fish will die when detergent concentrations approach 15 parts per million. Detergent concentrations as low as 5 ppm will kill fish eggs. Surfactant detergents are

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implicated in decreasing the breeding ability of aquatic organisms. Detergents also add another problem for aquatic life by lowering the surface tension of the water. Organic chemicals such as pesticides and phenols are then much more easily absorbed by the fish. A detergent concentration of only 2 ppm can cause fish to absorb double the amount of chemicals they would normally absorb, although that concentration itself is not high enough to affect fish directly. Phosphates in detergents can lead to freshwater algal blooms that release toxins and deplete oxygen in waterways. When the algae decompose, they use up the oxygen available for aquatic life. The main contributors to the toxicity of detergents were the sodium silicate solution and the surfactants—with the remainder of the components contributing very little to detergent toxicity. The potential for acute aquatic toxic effects due to the release of secondary or tertiary sewage effluents containing the breakdown products of laundry detergents may frequently be low. However, untreated or primary treated effluents containing detergents may pose a problem. Chronic and/or other sublethal effects that were not examined in this study may also pose a problem. [11,12]

III. RESULTS

Contamination and pollution of water are serious problems today. Many of the chemical substances that are disposed in water bodies are toxic and hazardous. Disease-causing microorganisms such as bacteria and viruses are solely responsible for waterborne diseases in both humans and animals. Water pollution caused by detergents is now a big concern in the global context. The per capita detergent consumption in India is around 2.7 kilogram per year. It is around 3.7 kg in Philippines and Malaysia and 10 kg in the United States of America. Nonylphenol, a hazardous chemical present in detergents, is known to enter water bodies and the food chains. It bio-accumulates and can pose serious environmental and health risks. It has been detected in human breast milk, blood and urine, and is associated with reproductive and developmental effects in rodents. It is recommended to find substitutes of nonylphenol.

The Bureau of Indian Statistics (BIS) has set the standard of phenolic compounds in drinking water {0.001 milligram per litre (mg/L)} and surface water (5.0 mg/L). The detergents contain suspected carcinogens, and ingredients that do not fully biodegrade. [13,14] Many laundry detergents contain approximately 35 to 75 per cent phosphate salts. Phosphates can cause a variety of water pollution problems. For example, phosphate tends to inhibit the biodegradation of organic substances. Non-biodegradable substances cannot be eliminated by public or private wastewater treatment. Some phosphate-based detergents can also cause eutrophication. Phosphate-enrichment can cause the water body to become choked with algae and other plants. Eutrophication deprives the water of available oxygen, causing the death of other organisms. In Belgium, phosphates are restricted for use in household detergents since 2003. Detergents also contain oxygen-reducing substances (ie, a chemical compound that readily transfer oxygen atoms) that may cause severe damage to the fishes and other marine animals. Detergents are capable of destroying the external mucus layers that protect the fish from bacteria and parasites, causing severe damage to the gills. Mostly fish die when detergent concentrations are near 15 parts per million (ppm); however, detergent concentrations as low as 5 ppm will kill fish eggs. A few more harmful components of detergents which are anthropogenic components such as herbicides, pesticides and heavy metal concentrations (like zinc, cadmium and lead) can cause the water to grow murky. This blocks out light and disrupting the growth of plants. Turbidity also clogs the respiratory system of some species of fishes. Pathogens from these toxic water bodies cause diseases, some fatal, in human or animal hosts. Drinking water contaminated with detergents can be hazardous to human health. The use of ecofriendly and biodegradable detergents should be encouraged to lower our laundry footprints. The University of Washington published a paper in the Journal Environmental Impact Assessment Review that discussed the volatile organic compounds that were found in multiple laundry detergents. These chemicals were not only found in laundry detergent but also in cleaning products, personal care products, and air fresheners. Unlisted toxins were found throughout all the products. The study also found that there were far worse effects on products with a fragrance than fragrance-free products. Another study published in Air Quality, Atmosphere and Health² conducted a study on three types of laundry cycles. Once without detergent, once with liquid detergent, and once with scented detergent and dryer sheets. They then studied the residual left in the clothing after the washes. They found over 25 volatile organic compounds including carcinogens acetaldehyde and benzene. These harmful carcinogens in laundry detergent can cause different types of cancer and are especially harmful to children and those who are pregnant. [15,16]

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Here are 6 ways in which Laundry Detergent can adversely affect your body:

1. Skin Health

Your skin may be affected by carcinogens in laundry detergent. Our skin is like a sponge that absorbs everything that it comes in contact with. So when we use laundry detergents with harmful chemicals in them, our skin lets those chemicals sink in. This can cause skin dryness, redness or cause a skin disease like folliculitis or eczema. If left untreated, these skin irritations can lead to skin cancer.

2. Sexual Health

A common ingredient in laundry detergent is Phthalates. This chemical is known to cause deformities in the reproductive system. Studies have shown that this chemical affects mainly men by reducing their sperm count and creating deformities in the testicles. Studies have also shown that carcinogens in laundry detergent can harm an unborn child. A fetus absorbs whatever the mother is exposed to, so it is very important for a pregnant woman to stay away from harmful detergents and just use natural ingredients.

3. Headaches

Laundry detergents that have a fragrance are far worse than fragrance-free detergents. They usually have more toxins than other products. So when we breathe in these chemicals, whether it is the smell on our clothes or the smell directly from the product, this can cause headaches. Too much of this smell can also trigger migraines.[20]

4. Hormones

Many detergents have the chemical Nonylphenol Ethoxylate, also known as NPE. NPE is actually a toxin that imitates the estrogen hormone. The hormones in our body are very important to maintaining overall health. They maintain reproductive health, emotions, and weight control. So when hormones are disturbed by toxins this can have a detrimental effect on our overall health.[21]

5. Respiratory Health

The Environmental Working Group has made it clear that fragrances are one of the top five allergy triggers. Fragrances can cause asthma attacks and swelling. The chemical phthalates are the main cause for these triggers and it has also been linked to diabetes, obesity, and poor reproductive health.

6. Disease

It might be hard to hear but yes, the carcinogens in laundry detergent have been linked to cancer as well as other life threatening diseases. Did you know that in America the rate of people being affected by some form of cancer has increased to 1 in 3? It used to be 1 in 100! However, with so many chemical and toxins everywhere we turn, the rate has drastically increased. To reduce your chances of developing a lifelong disease, reduce the amount of chemicals and toxins to which you are exposed.[19] The liver is one of our largest organs and it plays a very important role in the body. Its main role is to detoxify toxins and chemicals as well as drugs that come into the body.

The liver plays a key role in the NeuroEndoMetabolic (NEM) Stress Response. NEM Stress Response is the way that our body handles stress. An unhealthy liver can lead to many problems causing the body to become stressed. This internal stress can also translate into external stress. The liver can detoxify many chemicals but not everything. The liver

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struggles to detoxify the chemicals, toxins, and carcinogens in laundry detergent. When we use a harmful laundry detergent and it seeps into the body through the skin, the liver must process these chemicals. This puts a lot of pressure and stress on the liver, which in turn reduces the NEM stress response. Plus, if the liver is not functioning at 100 percent then the body struggles to cope with external stresses -- like work stress or financial stress. This also reduces the NEM stress response. It is true that the adrenal glands mainly cope with stress, but the whole body must be healthy to combat stress. Laundry detergents only hinder your health. Carcinogens in laundry detergent can cause many problems within the body. One major problem is that all the chemicals may lead to Adrenal Fatigue Syndrome (AFS). [17,18]

IV. CONCLUSIONS

AFS is a combination of symptoms that occurs when the adrenal glands are not functioning at their normal levels. This usually occurs after a prolonged period of extreme stress. It can also come about after chronic exposure to toxic materials in laundry detergent. As you can imagine, due to high amounts of pressure within this 21st-century society, many people experience some form of AFS. When we are stressed the adrenal glands cannot produce enough of the right hormones to counteract the stress leading to chronic fatigue. One of the main symptoms of AFS is obviously fatigue. This fatigue occurs even after you sleep a number of hours; you still feeling extremely tired. Other symptoms include food cravings, trouble concentrating, and inability to finish tasks. [22,23] The chemicals, toxins, and carcinogens in laundry detergent can have many negative effects on the body. As you would have read above, ingredients like NPE and phthalates can impact our hormones, especially our reproductive hormones in both men and women. Two of the most important hormones that these laundry detergents can affect are cortisol and adrenaline levels. When adrenaline is released it increases your heart rate and your blood pressure, thereby increasing your energy supplies. Cortisol, on the other hand, is our stress hormone. It boosts glucose in the bloodstream leading to tissue repair. Dysfunctional cortisol levels can also have some side effects including an impaired immune system and digestive system. The harmful chemicals in laundry detergents can lead to an increased level of adrenaline and cortisol, which can cause Adrenal Fatigue Syndrome. If you already experienced some form of fatigue then you need to stay away from the chemicals, toxins, and carcinogens in laundry detergent. Instead, try one of our all-natural homemade laundry detergent (carcinogen free) recipes. These recipes are easy and quick to make and you most likely already have the ingredients at home. [24]

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