DEPARTMENT OF ECOLOGY
State of Washington

Alkylphenol Ethoxylates in Products

Lay of the Land Alternatives Assessment

Revised May 2021
Publication 20-04-026

Publication and Contact Information

This document is available on the Department of Ecology's website at: https://apps.ecology.wa.gov/publications/summarypages/2004026.html.

This assessment was completed through a contract between the Department of Ecology and SRC, Inc. Ecology staff authored the executive summary. SRC, Inc. authored the lay of the land alternatives assessment that follows.

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Hazardous Waste and Toxics Reduction Program

Washington State Department of Ecology

Olympia, Washington

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Table of Contents

List of Figures and Tables

Page

Figures

Tables

Executive Summary

Washington Department of Ecology (Ecology) contracted an alternatives assessment (AA) on the use of alkylphenol ethoxylates (APEs) in products from 2019 – 2020. This was not a full alternatives assessment as defined by the Interstate Chemicals Clearinghouse (IC2) AA guidance document,[2] but instead what we termed a "lay of the land."

In this format, the goal was not to thoroughly evaluate alternatives to a specific chemical in one particular product or use, but to get an overview of how a chemical is used and what alternatives are available in different industry segments. Beyond a cursory level, we did not assess individual alternatives for hazard, cost, availability, or performance. This assessment can be used to further refine future AA efforts and pollution prevention in order to choose sectors with the biggest potential impact and the best chance of success.

SRC, Inc. was chosen as the contractor for this project, and they completed the final draft of the report in June 2020. SRC and Ecology met monthly over the course of the contract in order to prioritize areas of interest and identify sectors in which Ecology could help provide information. SRC investigated APE use in thirteen different sectors, listed below.

Ecology requested that SRC's research prioritize information specific to Washington state and highlight potential exposure pathways to humans and the environment. Three sectors—laundry detergents, cleaning products, and textiles—already have extensive reports and AAs published by other agencies. As such, Ecology asked SRC to provide only an overview of new information in those sectors.

Ecology hopes this report will help agencies worldwide identify promising areas for investigating reduction in APE use and potential safer alternatives that could replace APEs for those uses.

The applications and markets for APEs that were researched in this report include:

- Laundry Detergents
- Cleaning Products
- Textiles
- Paints and Coatings
- Metalworking
- Emulsion Polymerization
- Deicers
- Oil and Gas Exploration
- Agriculture

[2] http://theic2.org/alternatives_assessment_guide#gsc.tab=0

- Pulp and Paper
- Personal Care Products
- Fire Fighting Gels and Foams
- Cooling Towers

Overview

The Washington Department of Ecology (Ecology) contracted SRC, Inc. to perform an assessment of the current use and sources of alkylphenol ethoxylates (APEs) and to identify potential functional and inherently safer alternatives to APEs, which are considered chemicals of concern to the Puget Sound. The purpose of this report was not to conduct a full alternatives assessment, but to provide a "lay of the land" on the impact of APEs in Washington state, particularly with regard to the Puget Sound area water quality and wildlife. It was not the purpose of this document to do a comprehensive review of environmental fate or aquatic toxicity studies for APEs. These data have been summarized and documented in previous publications and will not be repeated in this assessment.

The first step of the assessment was to identify and engage stakeholders to obtain information related to APEs and alternatives in products. Despite reaching out to a multitude of contacts, stakeholder interaction was limited. The response rate was about 10% and most of these were achieved by referral from non-governmental organizations (NGOs). Therefore, this assessment was predominantly informed from literature evaluation.

A literature search was performed to gather information pertaining to APEs, particularly related to industrial and consumer uses that could impact the aquatic environment. Data on monitoring studies and market share information, types of products, function and purpose in those products, and available alternatives in each market sector were collected and evaluated. Information on APEs and alternatives in various market sectors were obtained from published alternative assessments, product guides, manufacturer and supplier websites, literature searches, and ingredient disclosures. Surfactant selection guides by major manufacturers, such as The Dow Chemical Company and Stepan Company, were heavily relied on to provide insight into the alternatives being used in various markets.

This report is broken down by market sectors in which APEs are used. The function of APEs as surfactants in products in each of these market sectors were identified and data pertaining to use volume, disposal, and regulations were reported, if available. Under each market sector, alternatives known to be used were characterized. An overview of alternatives is also presented. The list of potential alternatives to APEs is broad and ranges across many surfactant types. Alternatives known to be used in Washington state for each use were specified, if available.

High-level hazard assessments for the identified alternatives were summarized by surfactant class and used the GreenScreen® List Translator and the Safer Chemicals Ingredients List (SCIL) tools. Seventy-four alternatives were identified in this report. Of these, 46 are listed on the SCIL. Two publicly available full GreenScreen® assessments were available that labelled two alternatives as Benchmark 2 (use but search for safer substitutes). The remainder were classified with the GreenScreen® List Translator, which labelled 23 as LT-P1 (possible high concern) and 49 as LT-UNK or NoGSLT (unknown concern). It is worth noting that 17 of the LT-P1 chemicals are on the SCIL. Overall, alcohol ethoxylates are the most common alternative surfactant type used across all markets. Two of the most commonly used were C9-11, ethoxylated (Chemical Abstracts Service [CAS] number 68439-46-3) and D-glucopyranose, oligomeric, decyl octyl glycoside (CAS 68515-73-1).

Despite the documented availability of alternatives, APEs are still used in various market sectors. The reasons for this include the low cost and high performance of APEs and that there is no economic incentive for the sectors to substitute. While growing regulatory pressures and societal concerns have led to manufacturers and retailers implementing their own voluntary phase-outs, APEs are also not banned or restricted in the US at the federal level. Until there is complete phase-out of APEs, the market sectors in which they are used can contribute directly to releases in the Puget Sound area.

1. Introduction

APEs have been listed as a priority chemical in Washington state under Chapter 70.365 RCW (Revised Code of Washington), also known as the Pollution Prevention for Healthy People and Puget Sound Act, which was passed into law on May 8, 2019 (Washington State Legislature 2019a). The law allows state agencies to address toxic pollution that affects public health and the environment. APEs have also been identified as a chemical of concern in Control of Toxic Chemicals in Puget Sound: Assessment of Selected Toxic Chemicals in the Puget Sound Basin, 2007-2011 (Ecology and King County 2011) and in Priority Classes of Chemicals of Significant Concern to Vulnerable Populations and Orcas released by Toxic-Free Future (2019). Identifying inherently safer alternatives to APEs in its various applications is a high priority for substitution.

The first step of the assessment was to identify and engage stakeholders to obtain information related to APEs and alternatives in products. Stakeholder engagement was ongoing throughout the contract period of work. Targeted parties were manufacturers, trade groups, non-governmental organizations (NGOs), state governments, suppliers, and end users. Despite reaching out to a multitude of sources, stakeholder interaction was limited. The response rate was about 10% and most of these were achieved by referral from NGOs. Even with limited interaction, representation across the various groups was attained. Input was received from a trade organization, NGOs, a retailer, state government agencies, and a manufacturer.

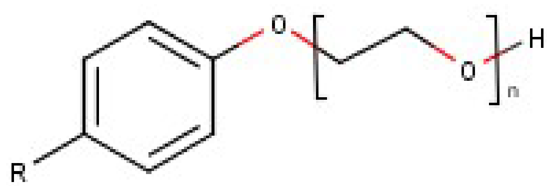
Since there was limited stakeholder interaction, this assessment was predominantly informed from literature evaluation. A literature search was performed to gather information pertaining to APEs, particularly related to uses that could impact the aquatic environment. Data on monitoring studies and market share information, types of products, function and purpose in those products, and available alternatives in each market sector were collected and evaluated. Alternatives assessments previously published for laundry detergents, cleaning products, and textiles were summarized and used to inform the use and impact of these markets in Washington state. Information on APEs and alternatives in other market sectors were obtained from searching product guides, manufacturer and supplier websites, literature searches, and ingredient disclosures.

APEs are a class of low cost, high-performance nonionic surfactants that are produced in large volumes; their use in consumer and industrial products has led to widespread release to the aquatic environment. APEs are composed polyethoxylated (EO)n ethers of linear- or branched-alkylphenols (see Figure 1). APEs cover a wide range of molecular weights, as the repeating monomeric ethoxylate unit can vary from 1 to 100. APEs can exist as hundreds of isomers within a single alkyl chain length, differing in the degree of ethoxylation, linearity vs. branching of the alkyl substituent, and the substitution pattern along the phenol ring. (Dow 2010; PRI 2015). The most commercially relevant APEs are octylphenol ethoxylates (OPEs) and nonylphenol ethoxylates (NPEs) (Dow 2013). Due to the complexity of these compounds, a variety of Chemical Abstracts Service (CAS) numbers exist for various isomers and mixtures of these compounds. A list of names and CAS numbers for relevant NPEs, OPEs, and other APE compounds can be found in Appendix I; however, this does not represent a comprehensive list of all APE identifiers available.

Figure 1. Alkylphenol ethoxylate structure.

Notes:

- n = number of ethylene oxide units
- R = C_9H_{19} for nonylphenol ethoxylate, generalized formula
- R = C_8H_{17} for octylphenol ethoxylate, generalized formula



The occurrence and fate of APEs and their breakdown products in environmental media have been extensively studied and reviewed (DTSC 2018; EPA 2010; PRI 2015; Toxic-Free Future 2019; Venkatesan and Halden 2013). APEs can partially break down in the environment by degradation and elimination of the polyethoxy ethers. This produces APEs with progressively shorter polyethoxylated chains until more persistent degradation products are formed. Typical degradation products include the mono- and di-ethoxy APEs (AP1EO, AP2EO), alkylphenol ethoxycarboxylates, and alkylphenols, such as nonylphenol (NP) and octylphenol (OP), which are persistent in the aquatic environment, accumulate in soils and sediments, are highly toxic to aquatic organisms, and suspected endocrine disruptors (BAuA 2012; EPA 2005, 2018a). Wastewater treatment plants (WWTPs) are a large contributor of APE degradation products to the environment, since APEs are only partially degraded during the sewage treatment process (EPA 2005).

The detection of APEs in the environment is mainly correlated with anthropogenic activities. APEs are used in laundry detergents and cleaning products, paints and coatings, agriculture, pulp and paper processing, textile manufacture and processing, metalworking, emulsion polymerization, oil and gas exploration, agriculture, and personal care products (Dow 2013). There have been efforts made in the US to reduce and eliminate APEs from products, including the Defense for the Environment (DfE) Alternatives Assessment for Nonylphenol Ethoxylates (EPA 2012a) and the Safer Detergent Stewardship Initiative (SDSI), a recognition program from businesses to promote the voluntary commitment to use safer alternative surfactants in detergents (EPA 2019a).

Every environmental compartment has the potential to be contaminated by APEs and their degradation products. They enter the environment mostly through wastewater, but large-scale applications of APE-containing pesticides also result in their direct release. APEs and their short-chain ethoxylates and alkylphenol degradation products have been detected in an abundance of environmental media. These include surface waters and groundwater, WWTP biosolids, sediments, soil, air, drinking water, stormwater runoff, house dust, fish and wildlife, and human milk, blood, and urine. There is pervasive, low-concentration environmental contamination with NP (DTSC 2018; Muller et al. 2019; PRI 2015; Toxic free future 2019; Venkatesan and Halden 2013).

APEs enter WWTPs due to their widespread use, especially in “down the drain” products, where they undergo degradation to form alkylphenols and short-chain ethoxylates. It is estimated that about 60% of the long-chain APEs entering WWTPs are released to the aquatic environment as the more stable and toxic degradation products like NP and OP (Venkatesan and Halden 2013).

Many studies have summarized the toxicity of APEs to aquatic organisms (DTSC 2018; EPA 2005, 2018b). There is particular concern for their estrogenic effects and high toxicity to fish, aquatic invertebrates, and algae.

Finding alternatives for APEs in the various product markets depends on their physical properties, effectiveness when used in combination with other formula ingredients, and ability to meet the specific product application roles (Oxiteno 2019). Some markets, such as laundry detergents and cleaners, may have a broader range of alternatives available, since the surfactants used in the formulations are less specialized. However, in some markets, such as metalworking, the formulations are designed to meet very specific requirements for the conditions and applications of use and APEs are harder to replace with other surfactants (Losey 2019).

A variety of substitutes are available for APEs; however, information on the extent of their use and all of the markets in which they are employed in the US is not readily available. In this report, hazard assessment for the identified alternatives are summarized by surfactant class and by prescreening using GreenScreen® List Translator (GreenScreen 2020) and the Safer Chemicals Ingredients List (EPA 2019b).

2. Production and Functional Uses

a. Production and Consumption

Total surfactant demand in the US was estimated to be 7.7 billion pounds in 2007, with anionics and nonionics accounting for 40 and 35%, respectively, and cationics and amphoterics making up the rest (Rust and Wildes 2008). APEs are produced at an estimated 450 million pounds per year in the US (EPA 2016a). NPEs make up approximately 80-85% of the total production volume of APEs, while the annual consumption is estimated to be 300 to 400 million pounds per year. OPEs make up most of the rest of the APE production. NPE surfactants are referred to by their degree of ethoxylation; commercially available NPEs range from four moles of ethoxylates (NPE4) to 80 moles of ethoxylates (NPE80). NPEs with nine moles of ethoxylates (NPE9) are the most commonly manufactured NPE (EPA 2010). In comparison, the largest market volume surfactants globally, alcohol ethoxylates and linear alkylbenzene sulfonate, are used at an estimated 840 and 860 million pounds annually in the US, respectively (OECD SIDS 2005; Sanderson et al. 2013)

The Alkylphenols & Ethoxylates Research Council (APERC) reported that the total consumption of APEs in North America declined almost 50% between 2005 and 2015 based on market reports. This decline was contributed to voluntary initiatives and proposed regulatory actions (APERC 2017).

Several large corporations have implemented voluntary phase-outs for certain APE-containing products. Some examples include Walmart, The Home Depot, and Target. Walmart restricted the use of NPEs in household and personal care products along with seven other priority chemicals and claimed it has achieved a 95% reduction, by volume, in use of these chemicals since 2013 (Franklin 2016). The Home Depot stated that APEs and NPEs have been eliminated from most of their interior and exterior latex water-based wall paint formulas and committed to a complete phase out of APEs from these paints by the end of 2019. The Home Depot also certified that no NPEs are present in their indoor wall-to-wall carpet, household cleaners, or laundry detergents (The Home Depot 2017). Target stated that it will work to remove beauty, baby care, personal care, and household cleaning products containing NPE from its shelves by 2020 (Target 2016).

Laundry detergents and cleaning products have been subject to the most regulation concerning the use of APEs. Both the European Commission and South Korea have restricted the use of NPEs to ≤0.1% in domestic, industrial, and institutional cleaning products (DTSC 2018; ECHA 2009). California has banned APEs from specific household cleaning products, including general purpose cleaners and degreasers, glass cleaners, heavy-duty hand cleaners, and oven or grill cleaners (DTSC 2018).

The European Commission has also restricted the use of NPEs in textiles. Textile articles that contain NPEs present at concentrations ≥0.01% and are expected to be washed in water during their lifecycle cannot be marketed and sold after February 3, 2021 (ECHA 2016).

Production, use, and sales volumes in various markets pertaining to specific states could not be obtained. This was partially due to limited stakeholder response and the lack of information in public literature and compendiums. This information is often protected under antitrust requirements and confidential business information (CBI) (Losey 2019).

The only manufacturer of APEs found in the Puget Sound watershed was Silver Fern Chemical, Inc. They are a chemical manufacturer and supplier located in Seattle, WA that produces a variety of surfactants, including NPE and NPE alternatives (Silver Fern 2020).

b. Functional Uses

APEs are used as surfactants that, through their functional properties, act as wetting agents, emulsifiers, foaming agents, and dispersing agents (BizNGO 2013; EPA 2018a). The versatile properties make APEs suitable for use in a variety of market applications. APEs are employed in industrial, institutional, and consumer laundry detergents and cleaning products, paints and coatings, agriculture, pulp and paper processing, textile manufacture and processing, metalworking, emulsion polymerization, oil and gas exploration, agriculture, and personal care products (Dow 2013). A breakdown of the global use patterns of NPEs by market sector is shown in Table 1.

Table 1. Use distribution of NPEs by market sector in 2015 (DTSC 2018).

Market sector	Use (% by weight)
Industrial and institutional cleaners (includes laundry detergents and cleaning products)	39
Leather and textiles	20
Paints and coatings	13
Oilfield chemicals	11
Agrochemical	6
Other	11

3. Pathways to the Environment in Washington state

Environmental Monitoring

In the fall of 2017, monitoring of field samples from Seattle area waterways subject to urban runoff was performed to identify chemical signatures that may have been contributing to urban stormwater mortality syndrome in Coho salmon. Samples were taken from Miller Creek, which drains into Puget Sound, the Lower Duwamish Waterway, Longfellow Creek, and Thornton Creek, as well as in storm water from a high traffic area in Seattle, WA. The samples had detectable concentrations of the OPEs, OP6EO, OP8EO, OP9EO, OP10EO, and OP11EO. The detected amounts were not quantified, and the authors stated that due to the ubiquity of OPEOs in products and environmental compartments, the source of the OPEOs cannot be directly linked to automotive products, such as antifreeze (Peter et al. 2018).

Results of the National Reconnaissance Study of Pharmaceuticals and Personal Care Products (PPCPs) in surface waters in the US conducted by the US Geological Survey (USGS), which sampled 139 streams in 30 states, showed 4-NP, NP1EO, OP1EO, NP2EO, and OP2EO among the most frequently detected compounds, with detection frequencies of approximately 50, 45, 42, 38, and 25%, respectively (Lubliner et al. 2010).

The estimated surface runoff loads for NP in the entire Puget Sound basin were 23-24 kg/year based on a surface runoff study conducted in 2009-2010 (Ecology and King County 2011).

In a study to better understand the role of contaminants of emerging concern, streambed sediment samples were collected from 23 sample sites in the lower Columbia River basin of Oregon and Washington, including the lower Columbia River, the Willamette River, the Tualatin River, and several small urban creeks in Oregon. The total concentration of two APE degradates, para-NP and 4-tert-OP, measured at all sites evaluated equaled approximately 2200 and 100 ng/g, respectively, with detection frequencies of approximately 30 and 10%, respectively. Concentration and detection frequency were higher in the smaller tributaries and streams and areas in proximity to WWTP effluents, suggesting a higher risk of exposure to aquatic life in these areas (Nilsen et al. 2014).

In the Puget Sound, Sinclair Inlet, which receives effluent from Bremerton Westside WWTP and South Kitsap Water Reclamation Facility, Puyallup River estuary, which receives effluent from Tacoma Central WWTP, and Nisqually estuary, a reference site with no known direct inputs from WWTP effluent, were sampled for contaminants of emerging concern. Two fish species commonly found in the Puget Sound, Pacific staghorn sculpin and juvenile Chinook salmon, collected from Sinclair Inlet, Puyallup estuary, Nisqually estuary, and Voight's Creek hatchery were also sampled. NP, NP1EO, and NP2EO, degradation products of NPEs, were some of the more ubiquitous compounds detected in the study. Concentrations of NP1EO and NP2EO in the estuary waters ranged from 2.12 to 18.6 ng/L. NP was detected in nearly every sample at high concentrations in water (14-41 ng/L) and fish tissue (8-76 ng/g). NP1EO and NP2EO were detected most fish tissue samples (1.3-60 and 1.4-51 ng/g, respectively) (Meador et al. 2016).

In 2018, water samples were collected from 18 sampling sites in the Puget Sound, expected to be representative of the range of local contamination conditions in the nearshore environment. NP3EO, NP9EO, NP11EO, NP12EO, NP13EO, OP5EO, OP9EO, OP10EO, OP11EO, OP12EO, and OP13EO were detected among the samples, but their concentrations and were not quantified and the detection frequencies were not reported (Tian et al. 2020).

In a study conducted in 2014 by Ecology that collected 44 fish tissue samples from 11 waterbodies throughout the state, 4-n-OP, NP1EO, and NP2EO were present in 48% of samples at concentrations ranging from 445 to 4080 ng/kg (wet weight). While WWTP effluents are considered the primary source of these compounds in the aquatic environment, fish sampled in waterbodies with no direct WWTP effluent had detectable concentrations, suggesting that stormwater and septic systems may also be contamination pathways (Mathieu and Wong 2016).

APEs were among the most frequently detected chemical classes in bay mussels transplanted to 18 locations representing a range of potential contaminant exposures throughout the Puget Sound. NP2EO and NP1EO were detected in mussel tissue samples at concentrations ranging from 1.11 to 4.4 ng/g ww and 1.78 to 17.3 ng/g ww, respectively. 4-NP was detected at all 18 locations at concentrations of 13.7 to 27.9 ng/g ww and 4n-OP was detected at 16 locations at concentrations of 0.708 to 1.57 ng/g ww. The exposure of mussels to APEs was reported to be associated with increased impervious surfaces in upland watersheds, suggesting surface runoff from urbanized areas are a potentially important source of contamination to receiving waters (James et al. 2020).

Due to direct application of APE-containing pesticides, or the contamination of waters, sediments, and soil with NPE and NP, food items may contain NP residues, which can lead to direct exposure to the human population Commercially available fruits and vegetables have had measured NP residue concentrations ranging from 5 to 50 μg/kg (wt) (PRI 2015).

Based on recent monitoring data, APEs are being detected in various environmental compartments in the Puget Sound watershed.

Releases to the Environment

WWTP effluents are one of the major sources of APEs and their degradates in the environment (Venkatesan and Halden 2013). APEs have been detected often and at high concentrations in the effluent of WWTPs. NP1EO, NP2EO, and OP2EO have been detected at frequencies of 62.5, 62.5, and 32.5%, respectively, near WWTPs across the US (Lubliner et al. 2010). Washington state has approximately 321 municipal WWTPs, of which 106 publicly owned WWTPs are in the greater Puget Sound area. Effluent collected in 2014 at the final stage of processing just before discharge from Bremerton West WWTP and Tacoma Central WWTP in the Puget Sound contained NPE degradation products 4-NP, NP1EO, and NP2EO at concentration ranges of 506-1690, 1120-1760, and 1690-2610 ng/L, respectively (Meador et al. 2016). It was noted that a large percentage of the chemicals detected in Puget Sound effluents in this study were among the highest concentrations reported in the US. This may result from per capita usage of these compounds, as the population growth rate in the Puget Sound area is high in comparison to the average global growth rate. It may also be a result of the treatment processes used at these WWTPs (Lubliner et al. 2010; Meador et al. 2016).

In a 2008 study developed to characterize concentrations and removal efficiencies of pharmaceuticals and personal care products by WWTP technologies, 4-NP was detected at concentrations ranging from not detected (nd) to 400 ng/L, nd-200 ng/L, and nd, in wastewater influent, secondary effluent, and tertiary effluent or reclaimed water, respectively. The greatest removal efficiency from treatment at WWTPs was obtained by tertiary treatment technologies, which included the combination of enhanced biological nutrient removal and filtration processes; however, this treatment process is utilized by relatively few WWTPs in the Puget Sound basin (Lubliner et al. 2010).

Since APEs are often found at higher concentrations in surface waters near WWTPs, monitoring the mouths of tributaries, sites downstream, and effluent of WWTPs and comparing these to influent concentrations would provide useful insight into controlling release from these sources.

Land application of biosolids and reclaimed water can lead to considerable contamination loading to the terrestrial environment. Approximately 50% of the 7 million dry tons of biosolids generated each year from WWTPs in the US are land-applied, with <1% being applied to agricultural lands (Lubliner et al. 2010). An estimated annual load of NP and NPEs to sewage sludge has been determined to be 2408-7149 metric tons, of which 1204-4289 metric tons are applied on US land. In sewage sludge composite samples collected across the US, NP was the most abundant analyte, followed by NP1EO and NP2EO, at concentrations of 534, 62.1, and 59.5 mg/kg, respectively (Venkatesan and Halden 2013). Once applied to land, NP is persistent and can possibly transport to surface or groundwater.

In Washington state, about 85% of biosolids produced are used as fertilizer and a soil amendment. A permit is required for biosolid application (Ecology 2020c). In biosolids sampled from nine municipal WWTPs (two located in Washington), the detergent metabolite p-NP was one of the most commonly detected compounds. If an agricultural application rate of 10 dry tons of biosolids per acre was applied, the mass loading rate of p-NP for a single application was estimated to be 760 g/acre (Lubliner et al. 2010).

Washington state contains WWTPs that provide reclaimed water throughout the state that can be used for irrigation, landscaping, improving wetlands and streamflow, and recharging groundwater (Ecology 2020b). Use of reclaimed water in Washington state requires a permit and the Department of Health and Department of Ecology are both required to review reclaimed water proposals. Removal of 4-NP from the constructed wetland treatment process used for reclaimed water was found to be 37 and 42% removal in the summer and winter, respectively (Lubliner et al. 2010).

Surface runoff from municipal and state roadways may also be a source of APEs to the environment. In a study of the estimated toxic chemical loadings to the Puget Sound from these sources, the largest unit area loading rates for NP was for surface runoff from highways, likely due to its presence in antifreeze and lubricants. In terms of probability of exceedance (POE) concentrations, which indicate the probability that a reported value for a chemical might be exceeded, highways had the highest 50% POE concentrations of NP at 5.9 μg/L. Commercial/industrial land use had a 50% POE of 4.0 μg/L and residential, agricultural, and forest/field/other land use categories had substantially lower concentrations. Based on these data, the estimated absolute loading rates for NP ranged from 3.3 to 41 mt/year; contributions to these loading rates were residential areas, 36%; commercial/industrial areas, 31%; highways, 14%; agricultural, 9%; and forest/field/other, 10% (EnviroVision Corporation 2008).

APEs are not a reporting requirement under the Toxics Release Inventory (TRI) at the time of this report; however, in 2018, EPA finalized a rule that will add a category of NPEs, consisting of 13 specific NPEs, to the TRI list of reported chemicals. The 13 NPEs subject to the TRI listing rule are presented in Table 2. The year 2019 will be the first reporting year and the first forms are due July 1, 2020. It is estimated that 178 facilities across the country will submit a TRI reporting form. The upcoming TRI report will help greatly in informing industrial or institutional NPE releases to the environment (EPA 2018a).

Table 2. TRI NPEs category members.

CAS number	Chemical name
7311-27-5	Ethanol, 2-[2-[2-[2-(4-nonylphenoxy)ethoxy]ethoxy]ethoxy]-
9016-45-9	Poly(oxy-1,2-ethanediyl), α-(nonylphenyl)-ω-hydroxy-
20427-84-3	Ethanol, 2-[2-(4-nonylphenoxy)ethoxy]-
26027-38-3	Poly(oxy-1,2-ethanediyl), α-(4-nonylphenyl)-ω-hydroxy-
26571-11-9	3,6,9,12,15,18,21,24-Octaoxahexacosan-1-ol, 26-(nonylphenoxy)-
27176-93-8	Ethanol, 2-[2-(nonylphenoxy)ethoxy]-
27177-05-5	3,6,9,12,15,18,21-Heptaoxatricosan-l-ol, 23-(nonylphenoxy)-
27177-08-8	3,6,9,12,15,18,21,24,27-Nonaoxanonacosan-1-ol, 29-(nonylphenoxy)-
27986-36-3	Ethanol, 2-(nonylphenoxy)-
37205-87-1	Poly(oxy-1,2-ethanediyl), α-(isononylphenyl)-ω-hydroxy-
51938-25-1	Poly(oxy-1,2-ethanediyl), α-(2-isononylphenyl)-ω-hydroxy-
68412-54-4	Poly(oxy-1,2-ethanediyl), α-(nonylphenyl)-ω-hydroxy-, branched
127087-87-0	Poly(oxy-1,2-ethanediyl), α-(4-nonylphenyl)-ω-hydroxy-, branched

4. Applications and Markets

Laundry Detergents

State of the market

NPEs are used as surfactants in industrial and institutional laundry detergents due to their low-cost and high cleaning efficiency, despite the concern for NPEs in the aquatic environment. The purpose of NPEs is to lower the surface tension of water against the laundry surface to enable wetting and spreading of the cleaning solution. Laundry detergents are the predominant source of APEs to the aquatic environment, as they can release significant amounts of NPEs to WWTPs due to their “down the drain” application. The California Department of Toxic Substances Control (DTSC) published an extensive report on the use of NPEs in laundry detergents in May 2018 (DTSC 2018).

There has been wide-spread voluntary phase-outs of NPEs in industrial and household laundry market. It is believed that the use of NPEs in household laundry detergents has been completely phased out in the US (DTSC 2018). The SDSI, started in 2007 under EPA’s DfE Program, is a recognition program from businesses to promote the voluntary commitment to use safer alternatives surfactants in detergents (EPA 2019a).

In 2010, the Textile Rental Services Association of America (TRSA), the primary trade association for the industrial laundry industry, provided the EPA with a commitment to phase out the use of industrial laundry detergents containing NPEs by 2014. TRSA represents about 98% of industrial laundry facilities in the US (TRSA 2010). At present, the EPA has not confirmed a complete phase-out and has estimated that this commitment by TRSA only covers about 50% of NPE laundry detergent use (DTSC 2018). For example, an industrial cleaning supplies distributor located in Washington markets some detergent products that contain the NPE, nonoxynol (CAS 9016-45-9) (Walter E. Nelson Co. 2020).

The Minnesota Green Chemistry Forum (MGCF) and Minnesota Pollution Control Agency (MPCA) estimated that, since 2013, over 800 thousand pounds of NPE use per year had been eliminated through use reduction by large-scale industrial laundries, resulting in up to 40% reduction of levels entering WWTPs (MPCA 2020).

Despite all of the voluntary phase-outs, DTSC reported that on-premises launderers like hotels, hospitals, and nursing homes may still use laundry detergents containing NPE. An estimated 2 billion pounds of laundry are washed per year at these sites in California, with detergents that can contain 5-50% NPEs (DTSC 2018). Detergents containing NPEs intended for use in large-scale operations like on-premises laundries were available from over 25% of laundry detergent manufacturers in 2017 (DTSC 2018). In Minnesota, hundreds of hospitals, hotels, and long-term care facilities were surveyed in 2016 and it was found that most respondents had eliminated the use of NPE (MPCA 2020).

Prisons are often covered under state purchasing contracts which may restrict the use of APEs in detergents (Doherty and Ernst 2019; MPCA 2020).

Washington contains 1,051 hotel properties, 92 community hospitals (which represent 85% of all hospitals), and 217 certified nursing home facilities. (AHLA 2020; KFF 2017, 2018). Using the estimation methods by DTSC to determine the quantity of laundry generated annually by on-premises launderers, Washington state is estimated to generate 377 million pounds of laundry per year (Table 3).

Table 3. Estimated amount of laundry generated per year by on-premises launderers in Washington (DTSC 2018).

Notes:

- Hotels and motels: There are 1,051 hotel properties, which serve 25 million occupied room nights per year, in Washington (AHLA 2020).
- Hospitals: Washington had 405 hospital inpatient days per 1,000 population for community hospitals in 2018 (KFF 2018). The 2018 state population was 7.5 million people (US Census Bureau 2019).
- Nursing facilities: Washington had 15,993 nursing home residents in 2017 (KFF 2017).
- Laundry generated per year: Calculated with DTSC estimation method (DTSC 2018).

Facility type	Units	Millions of units per year	Laundry generated (millions of pounds) per year
Hotels and motels	Occupied room nights	25 (AHLA 2020)	331
Hospitals	Inpatient days	3.0 (KFF 2018)	4.5
Nursing facilities	Resident days	5.8 (KFF 2017)	41
Total			**377**

Washington has five healthcare laundry providers accredited for patient safety, according to the Healthcare Laundry Accreditation Council (HLAC 2020). These include Ecotex Healthcare Laundry Service (Tacoma), Kalispel Linen Services (Airway Heights), MediCleanse (Renton), Puget Sound Service (Kent), and Sterile Surgical Systems (Tumwater). These launderers provide outsource services to hospitals and some also service hospitality facilities; they do not provide services for all hospitals in the state. MediCleanse states on their website that they only use NPE- and phosphate-free detergents (Medicleanse 2020). No information on the types of laundry detergents that the other service companies use could be obtained. These organizations may be good targets for future outreach efforts by Ecology.

Alternatives

Chemical alternatives to NPEs are readily available based on the number of manufacturers that have removed NPEs from their products and the amount of NPE-free options available. EPA's DfE Safer Choice Program offered an Alternatives Assessment for NPE surfactants in laundry and cleaning products (EPA 2012a). Using DfE Criteria for Safer Surfactants (EPA 2016b) to define safer NPE and OPE alternative surfactants, the assessment provides a list of eight alternative surfactants from different surfactant classes that meet the criteria, are frequently used in DfE-approved formulations, and/or are included on the CleanGredients® website (Table 4). It should be noted that this is not a comprehensive list of alternatives, as there are over 300 surfactants approved by the Safer Choice Program. The complete list of surfactants in the Safer Choice Program can be found on the Safer Choice product website.[3] In DTSC's profile on NPEs in detergents, alcohol ethoxylates, alkylbenzene sulfonates, and alkyl ether sulfates have also been identified as the most commonly used alternative to NPEs in detergents (DTSC 2018). Data gathered in Minnesota also confirmed that alcohol ethoxylates are the most common alternative to NPE in large laundry facilities (MPCA 2020).

Table 4. Safer alternative surfactants for detergents and cleaners.

CAS number	Chemical name	Surfactant class
68439-46-3	C9-11 Alcohols, ethoxylated (6EO)	Alcohol ethoxylates
68131-39-5	C12-15 Alcohols, ethoxylated (9EO)	Alcohol ethoxylates
64366-70-7	Oxirane, methyl-, polymer with oxirane, mono(2-ethylhexyl ether); Ecosurf EH-9	Alcohol propoxylates
68515-73-1	D-Glucopyranose, oligomeric, decyl octyl glycosides	Alkyl polyglucosides
68411-30-3	Benzenesulfonic acid, C10-13-alkyl derivs., sodium salt	Alkylbenzene sulfonates
151-21-3	Sodium lauryl sulfate	Alkyl sulfates
9004-82-4	Polyoxy(1,2-ethanediyl), alpha-sulfo-omega-dodecyloxy-, sodium salt	Alkyl ether sulfates
1338-41-6	Sorbitan monostearate	Sorbitan esters

A list of APE surfactant alternatives used in industrial laundry detergents in Washington state is shown in Table 5. These were obtained from safety datasheet (SDS) information and ingredient disclosures from distributors who serve the State (Walter E. Nelson Co. 2020; WCP Solutions 2020). There is some overlap with the DTSC list of alternatives, which corroborates extensive use of alcohol ethoxylates.

[3] https://www.epa.gov/saferchoice/products

Table 5. Alternative surfactants used in industrial laundry detergents in Washington.

CAS number	Chemical name	Surfactant class
68439-46-3	C9-11 Alcohols, ethoxylated (6EO)	Alcohol ethoxylates
68131-39-5	C12-15 Alcohols, ethoxylated (9EO)	Alcohol ethoxylates
68515-73-1	D-Glucopyranose, oligomeric, decyl octyl glycosides	Alkyl polyglucosides
9004-82-4	Polyoxy(1,2-ethanediyl), alpha-sulfo-omega-dodecyloxy-, sodium salt	Alkyl ether sulfates
25155-30-0	Sodium dodecylbenzenesulfonate	Alkylbenzene sulfonates
110615-47-9	Lauryl glucoside	Alkyl polyglucosides
68002-97-1	Alcohols, C10-16, ethoxylated	Alcohol ethoxylates
68439-50-9	Alcohols, C12-14, ethoxylated (9EO)	Alcohol ethoxylates
68608-26-4	Sodium C10-18 secondary alkyl sulfonate	Petroleum sulfonates
68551-12-2	Alcohols, C12-16, ethoxylated	Alcohol ethoxylates
27176-87-0	Dodecylbenzene sulfonic acid	Alkylbenzene sulfonates

Cleaning Products

State of the market

APEs are used in cleaning products as surfactants at about 2-5% of the formulation weight. The types of cleaners on the market include all-purpose, bathroom, glass, carpet, floor and car cleaners, and disinfectants for household, business, or industrial purposes. The use of cleaning products can result in the release of NPEs to WWTPs and the municipal solid waste system as a product of their discharge down the drain and their disposal on solid wipes. They can also be released directly to the environment from the use of outdoor cleaners. An alternatives assessment for NPEs in all-purpose cleaners was conducted in accordance with California's Safer Consumer Products regulations in 2013 (BizNGO 2013).

Cleaning products have been subject to some regulations concerning the use of APEs. Both the European Commission and South Korea have restricted the use of NPEs to ≤0.1% in domestic, industrial, and institutional cleaning products (DTSC 2018; ECHA 2009). Also, California has banned APEs from specific household cleaning products, including general purpose cleaners and degreasers, glass cleaners, heavy-duty hand cleaners, and oven or grill cleaners (DTSC 2018).

Some manufacturers and retailers have banned the use of APEs in their cleaning products, such as S.C. Johnson & Company (S.C. Johnson 2020a) and The Home Depot. The Home Depot asked retailers to exclude nine chemicals of concern, including NPEs, from all residential household cleaning chemical products sold online or in-store by the end of 2020. They've also implemented an EcoOptions® program that identifies environmentally friendlier products, including EPAs Safer Choice approved products (The Home Depot 2017).

Some industrial cleaning products used in Washington still contain NPEs. For example, an ingredient disclosure list by a distributor located in Washington contains the NPE nonoxynol (CAS 9016-45-9) in multiple floor cleaners and multi-purpose cleaners (Walter E. Nelson Co. 2020).

Alternatives

Chemical alternatives to APEs are readily available based on the number of products currently in commerce that contain APE alternatives. EPA's DfE Safer Choice Program offered an Alternatives Assessment for NPE surfactants in laundry and cleaning products (EPA 2012a). Using DfE Criteria for Safer Surfactants (EPA 2016b) to define safer NPE and OPE alternative surfactants, the assessment provides a list of eight alternative surfactants from different surfactant classes that meet the criteria, are frequently used in DfE-approved formulations, and/or are included on the CleanGredients® website (Table 4). It should be noted that this is not a comprehensive list of alternatives, as there are over 300 surfactants approved by DfE. Alcohol ethoxylates appear to be the most widely used alternative to APEs in detergents and cleaners.

In addition, an alternatives assessment for NPEs in all-purpose cleaners was conducted in accordance with California's Safer Consumer Products regulations in 2013. This assessment focused on the eight alternatives identified in EPA's assessment. Of the eight alternatives, this assessment considered alkyl sulfate (CAS 151-21-3) to be the safest alternative to NPEs for all-purpose cleaners. Alkyl polyglucoside (CAS 68515-73-1) and alkylbenzene sulfonate (CAS 68411-30-3) were also considered safer, but were recommended for further assessment to fill data gaps (BizNGO 2013).

A list of APE surfactant alternatives used in industrial cleaning in Washington state is shown in Table 6. These were obtained from SDS information and ingredient disclosures from distributors who serve the state (Walter E. Nelson Co. 2020; WCP Solutions 2020). The most commonly used surfactants in industrial cleaning products were the alcohol ethoxylates, specifically alcohols, C9-11, ethoxylated (CAS 68439-46-3).

Table 6. Alternative surfactants used in industrial cleaning products in Washington.

CAS number	Chemical name	Surfactant class	Type of cleaner
9005-64-5	Polyoxyethylene sorbitan monolaurate	Sorbitan esters, ethoxylated	Drain and grease trap odor eliminator
25155-30-0	Sodium dodecylbenzenesulfonate	Alkylbenzene sulfonates	Floor cleaner; dish detergent; all-purpose cleaner

CAS number	Chemical name	Surfactant class	Type of cleaner
532-02-5	Sodium alkylnaphthalene sulfonate	Naphthalene sulfonates	Carpet cleaner
1643-20-5	Lauramine oxide	Amine oxide	Carpet cleaner; degreaser; bathroom cleaner; all-purpose cleaner
68439-50-9	Alcohols, C12-14, ethoxylated (9EO)	Alcohol ethoxylates	All-purpose cleaner; floor cleaner; carpet cleaner; rust remover; degreaser; bathroom cleaner
68439-46-3	Alcohols, C9-11, ethoxylated	Alcohol ethoxylates	Degreaser; all-purpose cleaner; floor cleaner; carpet cleaner; bathroom cleaner
68515-73-1	D-Glucopyranose, oligomeric, decyl octyl glycosides	Alkyl polyglucosides	Car cleaner; all-purpose cleaner; floor cleaner
5324-84-5	Sodium caprylyl sulfonate	Alkyl sulfonate	Carpet cleaner; floor cleaner
68551-12-2	Alcohols, C12-16, ethoxylated	Alcohol ethoxylates	Degreaser; floor finish
68604-71-7	Disodium cocoamphodipropionate	Coco esters	Bathroom cleaner; degreaser
68002-97-1	Alcohols, C10-16, ethoxylated	Alcohol ethoxylates	Bathroom cleaner; floor restorer
68131-39-5	C12-15 Alcohols, ethoxylated (9EO)	Alcohol ethoxylates	Disinfectant; all-purpose cleaner
110615-47-9	Lauryl glucoside	Alkyl polyglucosides	Floor finish; glass cleaner; bathroom cleaner
70750-46-8	Tallow dihydroxyethyl betaine	Glyceride betaines ethoxylated	Bathroom cleaner
9004-82-4	Polyoxy(1,2-ethanediyl), alpha-sulfo-omega-dodecyloxy-, sodium salt	Alkyl ether sulfates	Glass cleaner; dish detergent
9003-11-6	Polyethylene/polypropylene glycol	Polyalkylene glycol	Dish detergent
68603-58-7	t-Alkylamines, C12-14, ethoxylated	Alkyl amine ethoxylates	Dish detergent
126-92-1	Sodium ethylhexyl sulfate	Alkyl sulfates	Carpet cleaner; all-purpose
30364-51-3	Sodium myristol sarcosinate	Acyl sarcosinates	Bathroom cleaner
61789-40-0	Cocamidopropyl betaine	Cocamides	Bathroom cleaner; degreaser
61788-90-7	Cocamine oxide	Cocamine oxide	Floor cleaner

CAS number	Chemical name	Surfactant class	Type of cleaner
85480-57-5	Potassium alkyl benzene sulfonate	Alkylbenzene sulfonates	Bathroom cleaner
68911-48-0	Alcohols, C7-21, ethoxylated	Alcohol ethoxylates	Bathroom cleaner

There are hundreds of consumer cleaning products on the market, so it is not feasible to assess them all. Therefore, the smartlabel® product search (CBA 2020) and EWG's Guide to Healthy Cleaning (EWG 2020a) were used to identify the most commonly used surfactants for some popular cleaning products sold by major retailers. It is assumed that these products are available in Washington state since they are sold by national retailers. Cleaning product brands surveyed were Clorox®, Green Works®, Seventh Generation®, Lysol®, S.C. Johnson products (S.C. Johnson 2020b), method®, and Simply Green®. The identified surfactants can be seen in Table 7. Alkyl polyglucosides and amine oxides, specifically D-glucopyranose, oligomeric, decyl octyl glycosides (CAS 68515-73-1) and lauramine oxide (CAS 1643-20-5), were the most commonly used surfactants in these products.

Table 7. Consumer cleaning product alternative surfactants used in Washington.

CAS number	Chemical name	Surfactant class	Type of cleaner
68515-73-1	D-Glucopyranose, oligomeric, decyl octyl glycosides	Alkyl polyglucosides	All-purpose cleaner; bathroom cleaner; disinfecting wipe; glass cleaner; floor cleaner
110615-47-9	Lauryl glucoside	Alkyl polyglucosides	All-purpose cleaner; bathroom cleaner
1643-20-5	Lauramine oxide	Amine oxide	All-purpose cleaner; bathroom cleaner; outdoor house cleaner; floor cleaner; dish detergent
68439-51-0	Alcohols, C12-14, ethoxylated propoxylated	Alcohol propoxylates	Disinfecting wipe; dish detergent
68439-46-3	Alcohols, C9-11, ethoxylated	Alcohol ethoxylates	All-purpose cleaner; glass cleaner
68584-22-5	Dodecylbenzene sulfonate	Alkylbenzene sulfonates	Bathroom cleaner
1643-20-5	Lauramine oxide	Amine oxide	All-purpose cleaner; glass cleaner
61792-31-2	Lauramidopropylamine oxide	Amine oxide	Bathroom cleaner
25155-30-0	Sodium dodecylbenzenesulfonate	Alkylbenzene sulfonates	Carpet cleaner; bathroom cleaner; disinfectant cleaner

CAS number	Chemical name	Surfactant class	Type of cleaner
132778-08-6	C9-11 Alkyl polyglucoside	Alkyl polyglucosides	All-purpose cleaner; bathroom cleaner; disinfecting wipe
151-21-3	Sodium lauryl sulfate	Alkyl sulfates	Dish detergent; bathroom cleaner; disinfectant; floor cleaner
68439-50-9	Alcohols, C12-14, ethoxylated (9EO)	Alcohol ethoxylates	Granite cleaner; floor cleaner
68002-97-1	Alcohols, C10-16, ethoxylated	Alcohol ethoxylates	All-purpose cleaner

Textiles

State of the market

APEs are used as a detergent or emulsifier in the textile manufacturing and processing applications, including fabric lubrication, sizing, treatment, and dyeing. They are used in leather processing as detergents for wet degreasing of hides (RIKZ 2001). OPEs can act as emulsifiers in finishing agents, which cover the leather and textiles in a polymer film to make them more resistant to water, dust, and light (DEPA 2013). The largest concern of release APEs to wastewater is for textile clothing, fabric accessories, and interior textile articles containing APEs that can be washed in water. These include clothing, bags, curtains, linens, towels, blankets, mats, and rugs (SCA 2013).

NPE represents about 80-85% of the total volume of APEs used as detergents and emulsifiers in textile manufacturing. The remaining amount consists mostly of OPE and a minor amount of dodecylphenol ethoxylates. Most of the APEs use in textile manufacturing are used as detergents, while only a small number are used as emulsifiers (SCA 2013).

APEs can be discharged to WWTPs through the laundering of the clothing due to their presence in newly processed textiles. It was estimated that the washing of textiles contributes approximately half of the NPE concentrations released to wastewater (SCA 2013).

NPEs were measured at concentrations ranging from <2 to 311 mg/kg (average of 96 mg/kg) in a survey of 15 pieces of clothing and bed linen conducted by the Danish EPA. OPEs were detected in seven of the samples at an average concentration of <1.6 mg/kg and a maximum of 10 mg/kg. Another study reported NPE concentrations of <1 to 10,608 mg/kg (average of 652 mg/kg) in 20 towels (DEPA 2013). In the UK, 28 out of 100 pairs of undergarments contained NPEs with concentrations ranging from 3.3 to 1759.7 mg/kg. It was also stated that further testing on six pairs of undergarments showed that NPEs were released from all samples at an average release of over 99.9% after two washes, further indicating that textiles contribute to the release of APEs to WWTPs (DEPA 2013). Since clothing can be imported from countries without regulations for APEs, these data are relevant to APE detection and release from clothing in the US. In an unpublished study on APEs in clothing fabrics, conducted by Toxic-Free Future, OPEs were detected in 5 of 20 clothing items tested. The concentrations ranging from not detected to 337 mg/kg. No NP or NPE was detected (detection limit of 25 mg/kg) (Schreder 2020).

The European Commission has restricted the use of NPEs in textiles. Textile articles containing NPEs at concentrations ≥0.01% that can be expected to be washed in water during their lifecycle cannot be marketed and sold after February 3, 2021. This includes suppliers outside the European Union (EU) (ECHA 2016). This restriction is expected to reduce the average concentration of NPE in textiles by 73% and reduce emissions of NP/NPE to the aquatic environment by 34% in the EU (SCA 2013).

Unfortunately, OPEs are not restricted and may be used as NPE replacements in this market. Also, since leather articles are not normally washed in water, they are also not subject to most restrictions (SCA 2013).

Retailers in the US are implementing their own chemical strategies to phase-out APEs from certain textiles. For example, all wall-to-wall indoor carpet sold at The Home Depot and Lowe's is verified as NPE-free (Lowe's 2019; The Home Depot 2017). In 2011, retailers Adidas, C&A, H&M, Li Ning, NIKE, and PUMA committed to achieve zero discharge of 11 hazardous chemicals, including APEs, for all products in their supply chains by 2020 (SCA 2013). Manufacturers have also taken steps to use alternatives to APEs. Huntsman International, a chemical manufacturer, created Huntsman Textile Effects, which has committed to a safer, more sustainable textile industry. Huntsman Textile Effects developed a list of their products that do not intentionally contain a list of priority group chemicals, among which are APEs (Huntsman 2013).

There are also several certification standards that textile processors and manufacturers can obtain to demonstrate that they use zero or low APEs in their products. The Global Organic Textile Standard certifies that prohibited substances, including NPEs, are excluded from the supply chain of textile materials and products (GOTS 2016). Bluesign® is an independent industrial standard for textile production chains that encourages an increase in sustainable processes. The bluesign® criteria limits APE concentrations in textile production to 100 mg/kg (Bluesign 2019). The OEKO-TEX® Standard 100 certification is an international standard for textile products of all processing steps that restricts the level of more than 300 harmful chemicals, including NPE and OPE, in its requirement. The criteria limits for NPE and OPE are 100 mg/kg under their Annex 4 requirements. The Standard 100 also offers an expanded requirement in Annex 6, which offers stricter constraints for improved environmental performance during production, and the limit for NPE and OPE under this requirement is 50 mg/kg (OEKO-TEX 2020).

Alternatives

Alternatives that effectively substitute APEs in the manufacturing of textiles already exist. Alcohol ethoxylates and glucose-based detergents have been identified as the most common nonionic surfactants to replace APEs as a detergent in textile manufacturing. Alternatives to APEs as emulsifiers in textile processing include alcohol ethoxylates or cocamides (SCA 2013).

Anionic surfactants are not appropriate alternatives to APEs in textiles, as they poorly interact with fibers and other compounds in the manufacturing process, unless they are specifically designed for stability in concentrated electrolytes. Cationic surfactants are almost exclusively used as a finishing agent in the dyeing process; however, they are not a suitable replacement for the function APEs provide as detergents (SCA 2013).

Alcohol ethoxylates were the most reviewed and suitable alternative to NPEs in textile manufacturing processes. They make up about 90% of the alternatives in textiles. They had many desirable properties such as resistance to water hardness, effectiveness in cleaning synthetic fibers, rapid biodegradation, and low foaming. Alcohol ethoxylates have also been shown to function better than NPEs in some cases, including improved solution stability and better stability in acid and caustic cleaners (SCA 2013).

The most commonly used alcohol ethoxylate in this application as a detergent is alcohols, C12-15, ethoxylated (CAS 68131-39-5) (SCA 2013). Glucose-based detergents, such as alkylpolyglucosides, have been mentioned as a suitable substitute for NPE as a detergent in textiles; however, they are not as effective of an alternative as alcohol ethoxylates (SCA 2013).

There are several different alternatives types that are possible replacement to APEs used as emulsifiers. Fatty alcohol ethoxylates, cocamides, alkylpolyglucosides, and combinations of alcohol ethoxylates, have all been mentioned. Data on specific chemicals were not available (SCA 2013).

Several major manufacturers supply products that act as suitable detergent alternatives to APEs in the textile process. There also exist products that are stable emulsifier alternatives and dispersants for printing and finishing. These are shown in Table 8 (BASF 2015; Dow 2014; Sasol 2019; Stepan 2019a, 2019b). Note that this is just a small representation of all of the chemicals and products available.

Table 8. APE alternative products in textile manufacturing.

Manufacturer	Product series	CAS number	Chemical name	Surfactant class	Type
The Dow Chemical Company	ECOSURF™ EH	64366-70-7	2-Ethylhexanol, ethoxylated, propoxylated	Alcohol alkoxylates	Detergent

Manufacturer	Product series	CAS number	Chemical name	Surfactant class	Type
The Dow Chemical Company	ECOSURF™ SA	68937-66-6	Alcohols, C6-C12, ethoxylated, propoxylated	Alcohol alkoxylates	Detergent
The Dow Chemical Company	ECOSURF™ SA	69277-22-1	Alcohols, C10-16, ethoxylated, propoxylated	Alcohol alkoxylates	Detergent
The Dow Chemical Company	ECOSURF™ LF	1013910-41-2	Oxirane, 2-ethyl-, polymer with oxirane, mono-C12-14-sec-alkyl ethers	Alcohol ethoxylates	Detergent
The Dow Chemical Company	TERGITOL™ TMN	60828-78-6	Polyoxyethylene 2,6,8-trimethyl-4-nonyl ether	Alcohol ethoxylates	Emulsifier; dispersant
The Dow Chemical Company	TERGITOL™ 15-S	84133-50-6	Alcohols, C12-14-secondary, ethoxylated	Alcohol ethoxylates	Detergent
The Dow Chemical Company	DOWFAX™	119345-04-9	Benzene, 1,1'-oxybis-, tetrapropylene derivatives, sulfonate	Alkyldiphenyloxide disulfonate	Emulsifier
The Dow Chemical Company	DOWFAX™	36445-71-3	Benzenesulfonic acid, decyl(sulfophenoxy)-, disodium salt	Alkyldiphenyloxide disulfonate	Emulsifier
BASF	Lutensol® TO	69011-36-5	Isotridecanol ethoxylate	Alcohol ethoxylates	Detergent
Sasol	SAFOL 23E	68002-97-1	Alcohols, C10-16, ethoxylated	Alcohol ethoxylates	Detergent
Stepan Company	BIO-SOFT® D	25155-30-0	Sodium dodecylbenzenesulfonate	Alkylbenzene sulfonates	Detergent
Stepan Company	BIO-SOFT® N91-6	68439-46-3	Alcohols, C9-11, ethoxylated	Alcohol ethoxylates	Detergent
Huntsman Corporation	SURFONIC® T	61791-26-2	Tallow amine ethoxylated	Amine ethoxylates	Dispersant

Alcohol ethoxylates have been reported as being approximately 5-40% more expensive than APEs in textile manufacturing. However, these data are from 2012 and prices tend to decline with time after demand increases (SCA 2013).

Paints and Coatings

State of the market

In 2015, Paints and coatings account for 13% of NPE usage globally. NPEs function as binder emulsifiers and pigment dispersants, and help in improving wetting by restricting foam formation during applications and processing (DTSC 2018). Some of the most common dispersing agents for paints and coatings use APEs to promote pigment affinity (Clariant 2020b). Paints and coatings may be considered a large contributor of APEs to WWTPs, as they are often washed down the drain during cleaning and disposal (DTSC 2018).

There are no regulations in the US on the use of APEs in paints. However, a shift in the market has begun. This is driven by various factors including retailers committing to more environmentally friendly business strategies, input from environmental NGOs about the hazards associated with APEs, and the potential of future regulation of APEs in paints and coatings. With the upcoming addition of NPEs to the TRI, the American Coating Association reported that some of their industry members are planning on reformulating their products to lower NPE concentrations or replace NPEs with safer chemical alternatives. They have stated that reformulating may be preferable to being subject to the new reporting requirements (EPA 2018b).

According to stakeholder input, major retailers are focused on offering more sustainable, environmentally friendly products and are committing to phasing out APEs in indoor paints. There are no specific consumer campaigns calling for the elimination of APEs, as most consumers are not aware what APEs are or what products they are in. In paints, consumers are more interested in volatile organic compounds (VOCs) and GreenGuard certification, which do not cover APEs. NGOs, such as the Natural Resources Defense Council, Mind the Store, and Healthy Building Network (HBN), provide the most advocacy and support for retailers to phase out APEs.

NPEs chemical function in paint formulations is highly specialized, so reformulation takes a substantial amount of time and increases cost for companies (Losey 2019). Performance is the most important characteristic of paint for consumers, retailers, and manufacturers, so reformulation also requires extensive evaluation to ensure that the performance is acceptable. Companies must be willing to make the initial cost investment to reformulate, restructure the supply chain, and change process infrastructure knowing that there is uncertainty regarding their return on this investment. The expectation is that further movement away from APEs will cause the supply chain to stabilize and manufacturing costs to decrease. APEs are used in both solvent- and waterborne formulations. It has been reported that trends are shifting from solvent- to waterborne systems (Clariant 2020a), and waterborne coatings may use replacements to APE surfactants such as epoxide chemistries to achieve advanced performance. According to the American Coatings Association, suppliers and formulators have moved or are moving to APE-free products (Challener 2020).

The Home Depot has stated that APEs have been eliminated from most of their interior and exterior latex water-based wall paint formulas and they committed to a complete phase out APEs from these paints by the end of 2019 (The Home Depot 2017).

In order to mitigate the release of paints containing APEs to the environment, programs for collection of leftover consumer paint are essential. In some areas, local governments do not accept latex paint in their waste collection due to the high cost of managing the waste. With limited disposal options, consumers may opt to discharge their excess paint down the drain and ultimately to their local WWTP or their private septic system. In 2005, Washington state collected approximately 693,000 gallons of leftover consumer paint collected at Household Hazardous Waste facilities, the second largest waste stream behind oil. It was estimated that this cost local Washington governments $5.5 million, or 89 cents for every person in the state to recycle paint (NPSC 2020).

On May 9, 2019, Governor Jay Inslee signed a law creating a new paint recycling program in Washington. The program will provide a safe, convenient, and environmentally responsible way to reuse or recycled leftover latex or oil paints to Washington residents and businesses. It is estimated that this program could result in the collection and recycling of 1.3 million gallons of paint annually. PaintCare, a non-profit organization created by the American Coating Association, will run the program and has already successfully implemented the program in other states. The program is required to be implemented by November 30, 2020 (NPSC 2019).

Alternatives

Since paint formulations are highly specialized, reformulation to remove NPEs takes a substantial amount of time. So, while the market is seeing a shift towards NPE-free paints, progress in reformulating has been slow. Despite this, NPE-free paints exist on the market, with more being added each year. Benjamin Moore and Sherwin-Williams both offer APE-free paint in their product lines. Benjamin Moore's Aura®, Natura®, Regal Select®, and ben® lines and Sherwin Williams' Emerald®, Harmony®, and Superior® lines are marketed as NPE-free (HBN 2018). These products are available at similar prices to NPE-containing paints, indicating that major manufacturers are becoming successful in updating their production process.

Attempts to contact Benjamin Moore, Sherwin-Williams, Behr, Glidden, and PPG for more information on APEs in paint were unsuccessful.

Green Seal offers a GS-11 certification for paints, coatings, stains, and sealers. The GS-11 Standard prohibits the use of APEs in these products (Green Seal 2015). Green Seal offers a search function to find products that are GS-11 certified. Using this tool, Benjamin Moore's Natura® interior paints, Bona US's Optum™ floor sealer, Hillyard's Icon® wood floor finish and Star® wood floor sealer, G.J. Nokolas & Co.'s ECO-SB RFU clear metal lacquer, and KoreKote's SmartKote epoxy coating were identified. The surfactants used in the Hillyard products were found using their SDS's (Hillyard 2020) and are shown in Table 9.

Table 9. APE alternatives used in paints and coatings.

CAS number	Chemical name	Surfactant class	Product type
134180-76-0	Oxirane, methyl-, polymer with oxirane, mono(3-(1,3,3,3-tetramethyl-1-((trimethylsilyl)oxy)disiloxanyl)propyl) ether	Alkoxylated siloxanes	Floor sealer
204336-40-3	1-Hexanol, 3,5,5-trimethyl-, ethoxylated, propoxylated	Alcohol alkoxylates	Dry erase paint, Floor finish
68439-46-3	Alcohols, C9-11, ethoxylated	Alcohol ethoxylates	Acrylic paint; interior/exterior alkyd paint; interior latex paint
68439-57-6	Alkenes, C14-16 alpha-, sulfonated, sodium salts	Alkyl sulfonates	Interior latex paint
9014-85-1	2,4,7,9-Tetramethyldec-5-yne-4,7-diol, ethoxylated	Alcohol ethoxylates	Interior latex paint
9003-11-6	Polyethylene/polypropylene glycol	Polyalkylene glycol	Acrylic paint
68987-81-5	Alcohols, C6-10, ethoxylated propoxylated	Alcohol alkoxylates	Acrylic paint
61791-12-6	Castor oil, ethoxylated	Ethoxylated seed oil	Interior wall sealer

Healthy Building Networks' (HBN) Pharos comprehensive chemical database (HBN 2019) contains common product profiles that list the most commonly present substances in a given product type. Among these, the product "low VOC eggshell acrylic paint," listed alcohols, C9-11, ethoxylated (CAS 68439-46-3) as its common surfactant.

Health Product Declaration® Collaborative maintains an industry collaborative database known as Health Product Declarations (HPD) open standard, which allows for reporting of product contents and associated health information for products used in the building industry. The HPD Public Repository contains published HPDs created by manufacturers that are available to consumers. Paints and coatings are among the products in the standard (HPDC 2020). Some products identified as APE-free through the HPDs not already mentioned above include Benjamin Moore's Ultra Spec® SCUFF-X® and Notable® Dry Erase Paint, Kelly-Moore Paints interior product lines, Miller Paint acrylic indoor paint, and Dunn-Edwards Corporation Vinylastic Select® wall sealer. These products use alternatives shown in Table 9.

Arkema coating resins under the EnVia® trade name are suitable for use in paints, coatings, pressure sensitive adhesives, and sealants and are all certified APE-free. Information of the surfactants used in these products was unavailable (Arkema 2020).

In response to the shift to develop dispersants that are free from chemicals of concern, such as APEs, Clariant developed Dispersogen® PLF 100, a dispersant that improves performance and efficiency by suppressing leaching effects in paints. This dispersant contains branched oxo alcohol ethoxylates (Clariant 2020b).

Metalworking

State of the market

NPEs have been used as emulsifiers in metalworking fluids. Emulsifiers in water-miscible metalworking fluids play a critical role in processes such as high-speed machining. This market requires emulsifiers with high performance and low foaming properties (Huntsman 2017). NPEs are highly effective for formulating soluble oil, semisynthetic, and metal cleaning compounds (Huntsman 2005). Metalworking fluids normally contain APEs in concentrations between 2 and 4% (BAuA 2012). Stricter regulations on the available additives, such as NPE, have led to the need for alternatives.

OPEs are also used in metalworking for acid-based cleaners, emulsifiers for soluble oils, and couplers and defoamers in semisynthetic formulations (Huntsman 2005).

Cutting fluids, micro-emulsions and solution cleaners, wetting agents, and lubricants are all metalworking products in which an emulsifier is needed (Huntsman 2017). Metalworking fluids containing these emulsifiers also contain chemically complex compounds that perform other functions and these fluid formulations are recycled throughout the metalworking process. However, these fluids eventually become excessively contaminated with oil, dirt, and metals and need to be disposed of. Metalworking fluid wastewater that is discharged to WWTPs is typically required to be pretreated onsite to specified parameters set by local authorities prior to release. The pretreatments include evaporation, membrane separation, treatment to break oil-water emulsions for volume minimization processes, and/or biological treatment and chemical treatment for destruction processes (TERC 2020). It is not reported how these processes affect the levels of APEs in fluid wastewater before its release to WWTPs. In Washington state, before discharge of metalworking fluids to local WWTPs, an appropriate permit under WAC 173-303-071(3)(a) must be obtained (Ecology 2015).

The aerospace industry contains a manufacturing sector that involves metalworking, which produces fluid waste. Washington state has over 1,350 aerospace-related companies, with over half of these being in the Puget Sound area, although it is unknown how many of these are manufacturing facilities. In 2014, Washington state manufactured 95% of all commercial airplanes produced in North America (Washington State Office of the Governor 2020). The amount of fluid waste generated from these facilities was not located. Some metalworking companies in Washington state that have an active water discharge permit are in Table 10 (Ecology 2020d).

Table 10. Metalworking companies in Washington with an active water discharge permit (Ecology, 2020d).

Company	Location (WA)
Accra-Fab, Inc.	Liberty Lake
QUAL-FAB	Seattle
The Boeing Company	Auburn
McClean Iron Works, Inc.	Everett
Miller Fabrication	Auburn
Allied Steel Fabricators Inc.	Redmond
Grating Fabricators Inc.	Vancouver
Morfab Company, Inc.	Woodinville
Nor Tech Fabrication, LLC	Kelso
Madlyn Metal Fab LLC	Vancouver
FarWest Fabricators	Moxee
Imperial Fabricating Company	Chehalis
MacDonald-Miller Facility Solutions	Seattle
Fabrication Products Inc	Vancouver
Standard Steel Fabricating Co	Seattle
Vulcan Products Company	Woodinville
NW Modern Fab, LLC	Bellingham
Thompson Metal Fab, Inc.	Vancouver
Fabricated Products Inc.	Vancouver
Waite Specialty Machine, Inc.	Longview
Western Fabrication	Kelso

The EU restricted the use of NPE at concentrations ≤0.1% in metalworking fluids (if not used in closed systems) in 2005 (SCA 2013).

The volume of APEs compared to APE alternatives currently being used in metalworking is unknown.

Alternatives

Due to restriction and limitations on emulsifiers like NPE, formulators have needed to look for safer alternatives with broad range benefits (Huntsman 2017). NPE alternatives for metalworking applications and fluids exist on the market. They include amine ethoxylates, ethylene oxide/propylene oxide (EO/PO) copolymers, alcohol alkoxylates, alcohol ethoxylates, and castor oil ethoxylates (Huntsman 2018). These alternatives can be seen in Table 11.

Table 11. APE alternatives in metalworking applications and fluids.

CAS number	Chemical Name	Surfactant Class	Function
61791-26-2	Tallow amine ethoxylated	Amine ethoxylates	Emulsifier; wetting agent
9003-11-6	Polyethylene/polypropylene glycol	Polyalkylene glycol	Emulsifier; dispersant
68131-39-5	Alcohols, C12-15, ethoxylated	Alcohol ethoxylates	Cleaner
68154-97-2	Alcohols, C10-12, ethoxylated, propoxylated	Alcohol alkoxylates	Cleaner
68439-51-0	Alcohols, C12-14, ethoxylated, propoxylated	Alcohol alkoxylates	Emulsifier; wetting agent; rinse aid; solubilizer
68987-81-5	Alcohols, C6-10, ethoxylated propoxylated	Alcohol alkoxylates	Emulsifier; wetting agent; rinse aid; solubilizer
68920-66-1	Alcohols, C16-18 and C18-unsatd., ethoxylated	Alcohol ethoxylates	Emulsifier; cleaner; penetrant; wetting agent
69011-36-5	Isotridecanol ethoxylate	Alcohol ethoxylates	Emulsifier; cleaner; penetrant; wetting agent
61791-12-6	Ethoxylated castor oil	Ethoxylated seed oils	Emulsifier; cleaner; penetrant; wetting agent
68439-50-9	Alcohols, C12-14, ethoxylated	Alcohol ethoxylates	Emulsifier; cleaner; penetrant; wetting agent
67254-71-1	Alcohols, C10-12, ethoxylated	Alcohol ethoxylates	Emulsifier; cleaner; penetrant; wetting agent
66455-14-9	Alcohols, C12-13, ethoxylated	Alcohol ethoxylates	Emulsifier; cleaner; penetrant; wetting agent

Alcohol alkoxylates have low foam production, can act as defoamers in water-based systems, can solubilize carboxylate-based corrosion inhibitors in water, can boost lubricity, and can be used in cleaners and rinse aids. They are best suited for synthetic and semisynthetic formulas but can also be used in soluble oil formulations and low foam cutting fluids. Due to this range of characteristics, alcohol alkoxylates are attractive candidates for metalworking operations (Huntsman 2005).

EO/PO block copolymers can be used in soluble oils, synthetic and semisynthetic formulations, and forming lubricants because of their defoaming, wetting, lubricity, solubilization, emulsification, thickening, and dispersing functionality. These properties depend on the ratio of EO to PO, the molecular weight, and the blocking pattern (Huntsman 2005).

Linear alcohol ethoxylates are widely used in metalworking operations as emulsifiers, cleaners, penetrants, and wetting agents. Short alcohol chain, alcohol ethoxylates with low ethoxylation are good solubilizers. Alcohol ethoxylates with 10-12 or 12-14 carbons and about 6EO are efficient cleaning agents, while those with 12-14 carbons and 7-12EO work well as cutting fluids in soluble oils and semisynthetic cutting fluids. Often, two alcohol ethoxylates are used in combination to achieve a wide range of emulsification performance (Huntsman 2005).

An important group in the formulation of metalworking lubricants are castor oil ethoxylates. They are good emulsifiers for many oils used in metalworking since they have an affinity for the oil phase (Huntsman 2005).

Emulsion Polymerization

State of the market

APEs are used as emulsifiers in emulsion polymerization. Polymers produced by emulsion polymerization include synthetic rubber, plastics, and polymer dispersions. Polymer dispersions can then be used in adhesives, paints, textiles, and paper. The advantages of APEs in emulsion polymerization include their excellent emulsifying properties, compatibility with different polymerization chemistries, low solidification points, low VOC, narrow range EO adduct distribution, and low cost (Sharp et al. 2008). However, due to the environmental concern of APEs, replacements have become available.

Emulsion polymerization formulations typically use both a nonionic surfactant and an anionic surfactant, which together provide better stabilization for the micelles. The main nonionic and anionic surfactants used for the past 45 years were APEs with a high number of EO units (>20) as the nonionic emulsifier and APE based ether sulfates with 3-7 moles EO as the anionic surfactant. They provided the best cost and performance properties in the industry (Sasol 2015a).

The total surfactant usage for emulsion polymerization was 235 million pounds in 2006. Of this, nonionic surfactants accounted for 121 million pounds, while anionics made up most of the remainder. The volume of sales of NPEs were 39 million pounds and OPEs were 50 million pounds in 2006 (Sasol 2015a). It has been estimated that 50% of OPEs produced are used as emulsifiers in emulsion polymerization and that the concentration of OPE in the final product is about 1.5% (BAuA 2012). Triton™ X Series OPE surfactants from Dow can be used in emulsion polymerization (Dow 2015). NPE emulsifiers are still in use, however, in areas where these are regulated, different APEs, such as tributylphenol ethoxylates, are being used as NPE replacements (Clariant 2015).

Alternatives

Despite all the cost and performance advantages of APEs and their sulfate analogs in emulsion polymerization, their use in North America is declining. Unlike other regions such as Canada and the EU which are regulating the use APEs in emulsion polymers, the pressure to switch to alternatives in the US is coming from retailers selling the latex dispersion products that contain the emulsion surfactant (Sasol 2015a).

Surfactants identified for use in making polymer emulsions other than APEs are ethoxylated glycerides, ethoxylated sobitan esters, ethoxylated alcohols, castor oil ethoxylates, cocoamide ethoxylates, and sorbitan monooleates (Fink 2013).

Clariant International, one of the leading manufacturers of surfactants in the world, claims that NPEs traditionally used in emulsion polymerization can be replaced by fatty alcohol ethoxylates. While Clariant makes a variety of APE-free surfactants, they state that their Emulsogen® LCN and Genapol® X Series are the closest replacements for NPE surfactants (Clariant 2015; DEPA 2013). See Table 12 for the chemical ingredients these formulas contain.

Table 12. Chemical ingredients contained in Clariant International replacements for NPE surfactants.

CAS number	Chemical name	Surfactant class
9043-30-5	Isotridecanol, ethoxylated	Alcohol ethoxylates
34398-01-1	Alcohols, C11, ethoxylated	Alcohol ethoxylates

BASF makes a series of APE replacement options for polymerization control and post-polymerization emulsion polymerization stabilization. These include Disponil®, Lutensol®, Lutensit®, Emulan®, and Pluronic® (BASF 2020a). See Table 13 for the chemical ingredients these formulas contain (BASF 2013, 2015; Cognis 2009).

Table 13. Chemical ingredients contained in BASF APE replacement options for polymerization control.

CAS number	Chemical name	Surfactant class
9043-30-5	Isotridecanol, ethoxylated	Alcohol ethoxylates
151-21-3	Sodium lauryl sulfate	Alkyl sulfates
1639-66-3	Sodium dioctyl sulfosuccinate	Alkyl sulfosuccinates
68649-29-6	Alcohols, C10-16, ethoxylate propoxylate phosphoric acid	Alcohol alkoxylates
9003-11-6	Polyethylene/polypropylene glycol	Polyalkylene glycol

Sasol North America published a document outlining APE replacements for emulsion polymerization (Sharp 2008). The APE alternatives identified as historically used in emulsion polymerization are alcohol ethoxylates (linear, oxo-alcohol, and secondary types). These alternatives are acceptable and still in use; however, each of these have their disadvantages, such as increased pour points and gel phases, slow derivatization, and higher cost. As a result, newer APE alternative production methods have emerged and they include isotridecyl alcohol ethoxylate from n-butene and Fischer-Tropsch based oxo alcohol ethoxylates, which are both produced using a narrow range ethoxylation base-catalyst. These newer alcohol ethoxylates have properties equal to or more effective than APEs (Sharp et al. 2008). The APE alternatives produced by these processes are in Table 14 (Sasol 2015b).

Table 14. Sasol North America APE alternatives.

CAS number	Chemical name	Surfactant class
9043-30-5	Isotridecanol, ethoxylated	Alcohol ethoxylates
34398-01-1	Alcohols, C11, ethoxylated	Alcohol ethoxylates
66455-14-9	Alcohols, C12-13, ethoxylated	Alcohol ethoxylates
68131-39-5	Alcohols, C12-15, ethoxylated	Alcohol ethoxylates
68951-67-7	Alcohols, C14-15, ethoxylated	Alcohol ethoxylates

After expanding their nonionic emulsifier alternatives, Sasol's Performance Chemicals also created alternatives to anionic APE based ether sulfates, which were the anionic industrial standard in emulsion polymerization. These non-APE based alternative anionic emulsifiers are the NOVELUTION® Series, narrow range ethoxylated linear or branched alcohol sulfates, and ALFONIC® Series, broad range ethoxylated linear or branched alcohol sulfates. These alternatives can work as a "drop in" replacement to APE ether sulfates (Sasol 2015a).

Deicers

State of the market

APEs are widely used as surfactants in roadway and aircraft deicers to prevent bonding between snow, ice, and moisture and various surfaces. In a screening of nine formulations of aircraft deicer and antiicer fluids (ADAF), NPEs and OPEs were identified in three and two formulations, respectively, while alcohol ethoxylates were detected in six formulations (Corsi et al. 2003). Surfactant additives typically constitute <2% of ADAFs by volume (EPA 2012b).

Deicers can contribute NPEs and OPEs to surface waters from urban runoff. Concentrations of NPEs in deicers have been reported at 641 mg/L (DTSC 2018; EPA 2010; Peter et al. 2018).

Airport runoff can contribute significant amounts of APEs in the aquatic environment. All airports discharge some or all of their deicing compounds to surface waters. Some collect a portion of their deicing wastewater for treatment and release, and others discharge untreated stormwater to soil and groundwater (EPA 2012b). The Federal Aviation Administration (FAA) enforces the Aerospace Material Specification standards (AMS 1431 and AMS1435D) for solid and liquid airport runway deicers issued under SAE International; however, the details of these specifications are only available behind a paywall (Clariant 2020c; SAE 2018).

A field study at General Mitchell International Airport, Milwaukee, WI collected water samples from two airport outfalls, the receiving stream, and an upstream reference site during a time of high ADAF applications. NPEs were measured at maximum concentrations of 1190 μg/L in runoff samples, 77 μg/L in the receiving stream, and <5.0 μg/L in the upstream reference, while maximum NP concentrations were 7.67, 3.89, and <0.04 μg/L, respectively (Corsi et al. 2003).

Snowbank and snowmelt runoff samples collected within a medium-sized airport over 4 years contained APEs and its degradation products. The ratio of degradation products to APE concentrations increased in the downstream direction from the snowbank, to melt runoff, to the surface water outfalls (Corsi et al. 2006).

In 2010, the EPA stated that they will support and encourage manufacturers to eliminate the use of APEs in deicers (EPA 2010).

Washington state has 134 airports; 60 of these are in the Puget Sound area (WSDOT 2020). It was estimated that Seattle-Tacoma International Airport has chemical oxygen demand (COD) discharges of 1.5 million pounds and 56 thousand pounds from ADAF applications and pavement deicers, respectively, to the Puget Sound (EPA 2012b). COD discharges are characterized in this report as the measure of organic compounds in the deicers and their ability to degrade in surface waters. Maps of the Puget Sound airports are shown in Figures 2 and 3. These data were taken from the Washington State of Department of Transportation (WSDOT 2020).

Figure 2. Airports in the Olympic Region of Washington.

Figure 3. Airports in the Northwest Region of Washington.

Alternatives

Alternatives are available for ADAFs. It is uncertain the extent to which manufacturers have modified their formulations to replace APEs. Alcohol ethoxylates seem to be the most common alternative to APEs in deicers, based on their detection in ADAFs (Corsi et al. 2003; EPA 2012b).

Table 15. Alternatives mentioned in an EPA assessment of airport deicing (EPA 2012b).

CAS number	Chemical name	Surfactant class
60828-78-6	Polyoxyethylene, 2,6,8- trimethyl-4-nonyl ether	Alcohol ethoxylates
61827-42-7	Isodecylalcohol, ethoxylated	Alcohol ethoxylates
9002-92-0	Alcohols, C12, ethoxylated	Alcohol ethoxylates
9003-11-6	Polyethylene/polypropylene glycol	Polyalkylene glycol
25155-30-0	Sodium dodecylbenzenesulfonate	Alkylbenzene sulfonates

Oil and Gas Exploration

State of the market

NPEs are used as surfactants in hydraulic fracturing in oil and gas exploration. In EPA's Analysis of Hydraulic Fracturing Fluid Data from the FracFocus Chemical Disclosure Registry 1.0 (EPA 2015), oil and gas operators disclosed information about the ingredients used in hydraulic fracturing fluids at individual wells resulting in 37,017 disclosures from 428 well operators with a fracture date between January 1, 2011 and February 28, 2013. From these data, 122,915 ingredient records that were claimed to be CBI by well operators were evaluated. While these ingredients were claimed to be proprietary, the general chemical class was frequently provided. Seventeen chemicals were identified with a CBI standardized chemical family name related to NPEs in 653 CBI ingredient records (0.52% of total CBI records submitted). NPE (CAS 9016-45-9) was listed as one of the 21 most frequently reported (73 disclosures) additive ingredients in Dunn County, North Dakota, detected at a median maximum concentration in hydraulic fracturing fluid of 0.0039% by mass. Poly(oxy-1,2-ethanediyl)-nonylphenyl-hydroxy (mixture) (CAS 127087-87-0) was listed as one of the 20 most frequently reported (617 disclosures) additive ingredients in Garfield County, Colorado, detected at a median maximum concentration in hydraulic fracturing fluid of 0.0022% by mass (EPA 2015). It was reported that the median amount of water per disclosure in Garfield County, CO was 1.7 million gallons (6.4 million kg) and the median maximum concentration of water by mass in fracturing fluid is 88%. Using this information, it can be calculated that the median maximum amount of poly(oxy-1,2-ethanediyl)-nonylphenyl-hydroxy (mixture) per fracturing fluid disclosure is 161 kg.

NPEs have also been identified as a surfactant, wellbore cleaner, emulsifier, and wetting agent additive in acidizing techniques for oil exploration. As opposed to hydraulic fracturing, where chemicals make up only 0.5% of the fracturing fluid, acidizing additives (not including acids and silica) can be present at up to 2.6% in acid maintenance, 3.5% in matrix acidizing, and 9.4% in acid fracturing. NPE is one of the 10 most frequently used chemicals in acidizing treatments. Out of 580 reported acidizing events in California from April 2013 to August 2015, polyethylene glycol nonylphenyl ether (CAS 9016-45-9) was used 256 times at mean and maximum amounts of 30.29 and 147.32 kg/treatment, respectively, polyethylene glycol mono (branched P-nonylphenyl) ether (CAS 127087-87-0) was used 6 times at mean and maximum amounts of 7.45 and 12.23 kg/treatment, respectively, and polyethylene glycol nonylphenyl ether (CAS 26027-38-3) was used 5 times at mean and maximum amounts of 6.90 and 12.23 kg/treatment, respectively (Abdullah et al. 2017). Structures for these different NPE compounds used in hydraulic fracturing are shown below.

Figure 4. Polyethylene glycol nonylphenyl ether (CAS 9016-45-9).

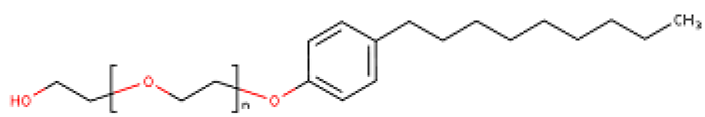


Figure 5. Polyethylene glycol mono (branched P-nonylphenyl) ether (CAS 127087-87-0).

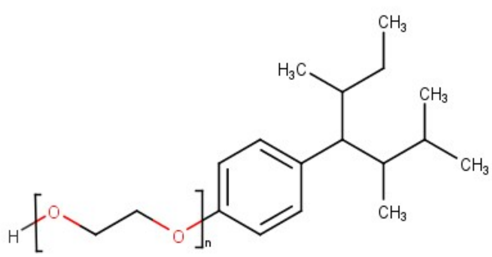
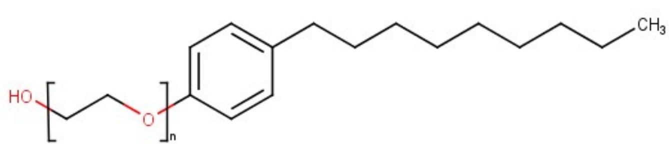


Figure 6. Polyethylene glycol nonylphenyl ether (CAS 26027-38-3).



Normally, fracking liquids are disposed of by pumping waste liquid into empty aquifers, but NPEs can be released into the aquatic environment during oil stimulation, production, and wastewater management and disposal methods. Surface release mechanisms include accidental spills and leaks, placement of a disposal well into an aquifer, filtration from unlined wastewater pits, and reuse and disposal of inadequately treated wastewater. Subsurface releases may occur through wormhole and fault pathways leading to aquifers, leaks from deteriorated abandoned wells, and structural failure of a production or disposal well (Abdullah et al. 2017).

According to the FracFocus Chemical Disclosure Registry, there are no hydraulic fracturing wells in the state of Washington dating back to 2011 when the disclosure registry was created (GWPC & IOGCC 2020). On May 8, 2019, Washington Governor Jay Inslee signed a bill banning hydraulic fracturing for oil and gas exploration within the state (Washington State Legislature 2019b).

Alternatives

The FracFocus Chemical Disclosure registry listed the chemicals most often used in hydraulic fracturing surfactant formulations (see Table 16) (GWPC & IOGCC 2020). Of these, only lauryl sulfate would be a direct alternative to NPE. The other chemicals may be needed for the surfactant formulation to meet all of the performance needs.

Table 16. Most often reported surfactant formulation chemicals in hydraulic fracturing.

CAS number	Chemical name	Purpose
151-21-3	Lauryl sulfate	Used to increase the viscosity of the fracture fluid
67-63-0	Isopropanol	Product stabilizer and/or winterizing agent
107-21-1	Ethylene glycol	Product stabilizer and/or winterizing agent
64-17-5	Ethanol	Product stabilizer and/or winterizing agent
91-20-3	Naphthalene	Carrier fluid for the active surfactant ingredients
67-56-1	Methanol	Product stabilizer and/or winterizing agent
67-63-0	Isopropyl alcohol	Product stabilizer and/or winterizing agent
111-76-2	2-Butoxyethanol	Product stabilizer

Agriculture

State of the market

APEs are components in various pesticide, biocide, and herbicide products as an inert adjuvant in order to improve the efficacy of the active ingredient (DTSC 2018.) Multiple NPEs, OPE (CAS 9036-19-5), and dodecylphenol ethoxylate (CAS 9014-92-0) have been identified as spray adjuvants used in the US (WSDA 2019). Agrochemicals account for 6% of NPE usage globally, which can lead to contamination of surface water, sediments, and soils (DTSC 2018). NPEs are estimated to be present at amounts of 0.25-2.5% in pesticide formulations (Bakke 2003).

Of all the markets in which APEs are used, agrochemicals are the only use that the EPA regulates. The EPA has approved tolerance exemptions for APEs used as inert ingredients applied to crops during and after the growing season and to animals and as active and inert ingredients used in antimicrobial food-contact surface sanitizing solutions. APEs are also approved for use in organic agriculture, although the number of approved active ingredients they can be mixed with is highly reduced compared to conventional practices (PRI 2015).

Washington does not have a searchable list of registered adjuvants, but there are approximately 800 adjuvants registered in the state. It is estimated that 17% of these may contain APEs (Foss 2019). The Washington State Department of Agriculture (WSDA) Criteria for Registration of Spray Adjuvants for Aquatic Use requires that adjuvant formulations must contain 9.5% or less concentration of APEs (WSDA 2011).

Using the Pesticide Information Center OnLine (PICOL) pesticide label database, a list of 409 trade name products were classified as surfactant adjuvants registered for use in Washington in the current year, 2020. The list includes both APE and APE-free compounds. The database does not allow searching by surfactant name, so to determine the surfactant used in these products, a manual search of each Safety Data Sheet (SDS) would need to be conducted. Often these SDS do not provides CAS numbers, but a general description of the surfactant class (WSU 2020).

Despite APE adjuvants being registered for use in Washington, not all registered adjuvants by the WSDA may be used under permit. Most aquatic pesticide use in Washington requires a permit from Ecology. Some use on federal land or tribal land would be covered under EPA permits. However, part of the certification on these permits require Ecology approval, so they are also subject to Ecology permit restrictions. No adjuvants containing APEs registered for aquatic application may be used under Ecology permits due to aquatic toxicity. This includes the Aquatic Plant and Algae Management General Permit (APAM) and the Aquatic Noxious Weed Control General Permit. Therefore, the only scenarios in which APEs may enter the aquatic environment from pesticide use are through run-off from land use or from treatments made to man-made water bodies. Man-made waste bodies are usually made for specific purposes and not habitats, however treatment to these areas must not have any discharge to natural surface water during and for 2 weeks post application according to APAM permits (Ecology 2019; Jennings 2019).

Land use applications of adjuvants in Washington are regulated by product labels and the WSDA. There are no restrictions on the percentage of APEs allowed in these applications. The Washington State Department of Natural Resources (DNR) does not require permits for ground application of pesticides/adjuvants. As of 2018, the DNR still allowed APEs adjuvant land applications for site preparation as it was listed as one of three required adjuvants for use in forest management on open contracts (DNR 2018). The APE adjuvant listed among the required adjuvants is marketed under the trade name Dyne-Amic® (Agrian 2020). This means that for forest management use, only one of these three adjuvants may be used for herbicide mixes as at a concentration of 8 oz. per acre. The adjuvant is selected by the brush being targeted and the standard used in forestry. Site preparation involves using chemicals to prepare land for new tree growth after logging. The herbicide is sprayed to the forest edge and the site is buffered by the surrounding woods (Hurd 2019). Current contracts opened in 2019 for site preparation by the DNR do not list Dyne-Amic® as a required adjuvant (DNR 2019), but it is unknown if this APE product has been completely taken out of use by DNR. Other land use applications of APEs are unknown.

Alternatives

Viable alternatives to APEs as adjuvants in pesticide sprays include alcohol ethoxylates, alcohol alkoxylates, alkylpolyglucosides, glucamides, glucamine oxides, alkylbenzene sulfonates, alkyl sulfates, and sorbitan esters. Plant-derived saponins and lecithin-based surfactants may also be used. There are no data to indicate how commonly these substances are used as adjuvants. The EPA has tolerance exemptions for residues of sorbitan esters used as ingredients on crops due to its historical use (PRI 2015).

Since the PICOL database requires manual searching of individual products to identify adjuvants, a faster way to identify possible adjuvant alternatives to APEs is through the WSDA's compiled partial list of spray adjuvant ingredient registered in the country (WSDA 2019). Alternatives with similar type and function to APEs (non-ionic surfactant, spreader, wetting agent) were identified and can be seen in Appendix II. There is no information specifying the use of these alternative as a direct substitute of APEs or if they are used in Washington state, but considering that they provide the same function these substances could be viable candidates. Future work could aim to compare the WSDA list with adjuvants reported in the MSDS's of products found in the PICOL database to determine which are most commonly used.

Since forest site preparation applications under the DNR have listed some APE-free required adjuvants, it is possible that these may be used as alternatives to APE. These were Syl-Tac-EA® (methylated seed oil; 3-(3-hydroxypropyl)-heptamethyltrisiloxane, ethoxylated acetate; polyoxyethylene dioleate) and Crosshair® (modified soybean oil) (DNR 2019).

Pulp and Paper

State of the market

APEs are commonly used as surfactants in the pulp and paper industry primarily for paper de-inking, but also for pitch control and machine cleaning (Potucek and Skotnicova 2012; RIKZ 2001).

The extent to which APEs are still used in this application is unknown. The EU restricted the use of NPE at concentrations ≥0.1% in pulp and paper production in 2005 (SCA 2013). Data on the use percentage of APEs and alternatives in the US were unavailable.

The use of APEs by the pulp and paper industry leads to releases to WWTPs. It was estimated that of the 1.7 million pounds of APEs used in the pulp and paper industry in the EU, 120 thousand pounds were released to water (RIKZ 2001).

Ecology currently regulates air, water, waste, and cleanup activities for Washington state's largest industrial facilities, including emissions limitations, operating requirements, monitoring, and reporting requirements at chemical pulp mills that use the kraft or sulfite process (Yamazaki 2020). Ten pulp and paper mills in Washington state are subject to these regulations

(Ecology 2020a). Table 17 lists these companies along with where they release their treated wastewater.

Table 17. Pulp and paper mills in Washington and their treated wastewater discharge areas.

Company	City (WA)	Details	Discharge location
Cosmo Specialty Fibers	Cosmopolis	Makes about 1.1 million pounds of dissolving pulp per day	Grays Harbor, Chehalis River
Georgia Pacific	Camas	Makes paper from purchased pulp	Columbia River
McKinley Paper Company	Port Angeles	None	Strait of Juan de Fuca
Nippon Dynawave Packaging Company	Longview	Makes about 560 million pounds of bleached liquid packaging paperboard and wetlap and slush pulp per year; treats their own wastewater along with that of eight other businesses	Columbia River
North Pacific Paper Corporation (NOPAC)	Longview	Makes bleached kraft pulp, deinked pulp from recycled newsprint, and papers out of thermomechanical pulp; sends their wastewater to Nippon Dynawave for treatment	None
Packaging Corporation of America	Wallula	Makes about 2.8 million tons of paper per day	Columbia River
Port Townsend Paper Corporation	Port Townsend	Makes about 1.8 million pounds of paper, containerboard, and unbleached pulp per day	Port Townsend Bay
Sonoco Products Company	Sumner	Makes about 276 thousand pounds of paperboard each day	White River
WestRock's Longview Fibre Pulp and Paper	Longview	Makes about 7.2 million pounds of paper and 5.6 million pounds of unbleached pulp per day	Columbia River
WestRock	Tacoma	Makes about 2.8 million paper and pulp per day	Commencement Bay

Among the discharge reporting requirements under these regulations, the mills must report the total phenolic compounds discharged once every 2 years during the permit timeframe (Ecology 2020a). The amount of total phenolic compounds and the volume of water discharged at each mill are shown in Table 18 (Ecology 2020d). The amount that APEs contribute, if any, to the total phenolic compounds concentrations detected is unknown.

Table 18. Discharge levels from pulp and paper mills in Washington.

Company	Amount of water discharged (million gallons/day)	Amount of phenolic compounds discharged (μg/L)	Sampling date
Cosmo Specialty Fibers	10.95	0.047	1/27/2020
Georgia Pacific	21.8	72	10/12/2016
McKinley Paper Company	7.41	0.009	11/1/2016
Nippon Dynawave Packaging Company	63.4	<4	3/19/2019
North Pacific Paper Corporation (NOPAC)	14.74	0.206	11/6/2019
Packaging Corporation of America	23.0	99	9/17/2019
Port Townsend Paper Corporation	12.7	<4	7/23/2019
Sonoco Products Company	N/A	N/A	N/A
WestRock's Longview Fibre Pulp and Paper	41.3	0.008	9/13/2019
WestRock	18.0	0.026	11/21/2019

There are other types of paper mills in Washington state that are not subject to Ecology's industrial facility water discharge regulations. These are recycling paper mills that use waste wood chips and recycled paper as raw materials. These mills are subject to permits by their corresponding region (Yamazaki 2020). Among these mills are Inland Empire Paper Company in Millwood, WA, International Paper Company in Union Gap, WA, and Colombia Pulp in Dayton, WA.

Alternatives

Alternatives to APEs are available for pulp and paper processing, although it is unknown as to what extent they are used. Alcohol ethoxylates are the most commonly used alternatives in pulp and paper for paper de-inking, pitch control, and cleaning (Potucek and Skotnicova 2012). Other de-inking surfactants used are alcohol alkoxylates.

Dow's Surfactant Reference Guide (Dow 2014) and BASF Pulp and Paper product lines (BASF 2020b) were used to identify alternatives that are applicable for use in the pulp and paper industry. These can be seen in Table 19.

Table 19. APE alternatives in the pulp and paper industry.

CAS number	Chemical name	Surfactant class
68920-66-1	Alcohols, C16-18 and C18-unsatd., ethoxylated	Alcohol ethoxylates
69011-36-5	Isotridecanol, branched, ethoxylate	Alcohol ethoxylates
9043-30-5	Isotridecanol, ethoxylated	Alcohol ethoxylates
1639-66-3	Sodium dioctyl sulfosuccinate	Alkyl sulfosuccinates
68649-29-6	Alcohols, C10-16, ethoxylate propoxylate phosphoric acid	Alcohol alkoxylates
68987-81-5	Alcohols, C6-10, ethoxylated propoxylated	Alcohol alkoxylates
9003-11-6	Polyethylene/polypropylene glycol	Polyalkylene glycol
84133-50-6	Alcohols, C12-14-secondary, ethoxylated	Alcohol ethoxylates
60828-78-6	Polyoxyethylene 2,6,8- trimethyl-4-nonyl ether	Alcohol ethoxylates
119345-04-9	Benzene, 1,1'-oxybis-, tetrapropylene derivatives, sulfonate	Alkyldiphenyloxide disulfonate
36445-71-3	Benzenesulfonic acid, decyl(sulfophenoxy)-, disodium salt	Alkyldiphenyloxide disulfonate

Personal Care Products

State of the market

APEs, mostly NPEs, have been used as surfactants and emulsifiers in rinse-off and leave-on products such as shampoos, lotions, and cosmetics (Toxic-Free Future 2019). NPEs that are used for personal care products (PCPs) are commonly referred to as nonoxynols. NPEs, such as nonoxynol-9, have also been used as active components in spermicides (CIR 2015). Since cosmetic products are often washed off down the drain, they can contribute to the amount released to WWTPs.

According to FDA’s Voluntary Cosmetic Registration Program (VCRP) 2015 survey for manufacturers, nonoxynol-4 was the most frequently used type of nonoxynol (90 rinse-off formulations), followed by nonoxynol-6 (65 rinse-off formulations). In another survey by the Personal Care Products Council in 2014, nonoxynol-12 had the highest reported maximum concentration of use, used at up to 8.33% in rinse-off products, such as hair dyes and colors (CIR 2015).

The EU restricted the use of NPE at concentrations ≥0.1% in cosmetics in 2005 (SCA 2013). PCPs in the US are largely unregulated. A bill has been introduced to the US Senate, the Personal Care Products Safety Act, for the FDA regulation of ingredients in PCPs along with the requirement to submit ingredient disclosures. The first set of chemicals for review do not include APEs, but they may be considered in the future (Feinstein 2019).

Due to regulatory pressures and societal concerns, The Dow Chemical Company has stated that they will not support the use of their APE-based surfactants in personal care product applications (Dow 2013).

Retailers are also working towards removing PCPs that contain APEs from their stores. Target has stated that it will work to remove beauty, baby care, and personal care products containing NPE from its shelves by 2020 (Target 2016). Dollar General and Dollar tree have implemented policies to ban NPEs from their private-label PCPs by December 2022 and December 2020, respectively (Dollar Tree 2017; Schade and Belliveau 2020).

Historical use data suggest a reduction in the use of NPEs in this market sector. For example, the number of products containing nonoxynol-4 was reduced from 575 to 90 between 1983 and 2015 (CIR 2015).

PCPs can result in direct dermal and inhalation exposure to APEs through its use in leave-on products and spray-on fragrance products (CIR 2015).

Alternatives

While data suggest a reduction in APEs in PCPs has occurred, it is unknown to what extent they are still used in comparison to alternatives. Alternatives for their use in PCPs are abundant.

Long chain alcohol ethoxylates are effectively used in the personal care market as viscosity modifiers and emollients for lotions and creams, shampoos (to aid in emulsification), perfumes (as solubilizing agents), and cosmetics (to help disperse pigments in make-up). Lauryl alcohol ethoxylates, which are derived from palm oil lauryl alcohol, are widely used “natural” surfactants in PCPs, especially for shampoo and shower gels (Oxiteno 2019, 2020). For example, laureth-7 is used in 337 products and laureth-4 is used in 181 products (EWG 2020b). This categorization as “natural” is misleading, as lauryl alcohol may be naturally derived, but the production of the ethoxylate is not.

Sodium laureth sulfates and sodium lauryl sulfate are common in PCPs and can be found in 578 and 444 products, respectively (EWG 2020b; Oxiteno 2020a). Lauramine oxides and cocamidopropyl betaines have recently become more popular in the PCPs, specifically in hair-care products, body washes, and hand soaps (Oxiteno 2020a). Sorbitan esters are another commonly used emulsifier in PCPs (EWG 2020b).

Commonly used alternatives used in consumer PCPs are shown in Table 20 (EWG 2020b; Oxiteno 2020b).

Table 20. APE alternatives in consumer personal care products.

CAS number	Chemical name	Surfactant class
9004-82-4	Sodium laureth sulfate	Alkyl ether sulfates
151-21-3	Sodium lauryl sulfate	Alkyl sulfates

CAS number	Chemical name	Surfactant class
68140-00-1	Coco monoethanolamide	Cocamides
61789-40-0	Cocamidopropyl betaine	Cocamides
68439-50-9	Alcohols, C12-14, ethoxylated (9EO)	Alcohol ethoxylates
1643-20-5	Lauramine oxide	Amine oxide
68604-71-7	Disodium cocoamphodipropionate	Coco esters
1338-43-8	Sorbitan monooloeate	Sorbitan esters
71902-01-7	Sorbitan isostearate	Sorbitan esters
1338-41-6	Sorbitan monostearate	Sorbitan esters
246159-33-1	Cetearyl polyglucoside	Alkyl polyglucosides
68439-49-6	Alcohols, C16-18, ethoxylated	Alcohol ethoxylates
9004-95-9	Alcohols, C16, ethoxylated	Alcohol ethoxylates
9005-65-6	Sorbitan monooleate, ethoxylated	Sorbitan ester ethoxylates
9005-64-5	Sorbitan monolaurate, ethoxylated	Sorbitan ester ethoxylates
9004-99-3	Poly(oxy-1,2-ethanediyl), .alpha.-(1-oxooctadecyl)-.omega.-hydroxy-	Fatty alcohol ethoxylates

A list of PCPs containing APE alternatives that are used in hospitality businesses, such as hotels, in Washington state is shown in Table 21. These were obtained from SDS information from distributors who serve the state (Walter E. Nelson Co. 2020).

Table 21. APE alternatives used in industrial personal care products in Washington.

CAS number	Chemical name	Class	Function	Product type
9004-82-4	Sodium laureth sulfate	Alkyl ether sulfates	Surfactant	Shampoo; body wash; conditioner
151-21-3	Sodium lauryl sulfate	Alkyl sulfates	Surfactant	Shampoo; body wash
68140-00-1	Coco monoethanolamide	Cocamides	Surfactant	Shampoo; body wash
111-60-4	Ethylene glycol stearate	Fatty acid ester	Emulsifier	Shampoo; body wash
61789-40-0	Cocamidopropyl betaine	Cocamides	Surfactant	Conditioner
68604-71-7	Disodium cocoamphodipropionate	Coco esters	Emulsifier	Soaps, lotions, shampoos

Fire Fighting Gels and Foams

State of the market

APEs are used as surfactants in fire-fighting gels and foams. Hydrocarbon surfactants are present in aqueous film-forming foams (AFFFs) at higher concentrations (5-10% w/w) than per- and polyfluoroalkyl substances (0.9-1.5% w/w) (Garcia et al. 2019). In 2010, the EPA stated that they will support and encourage manufacturers to eliminate the use of APEs in fire-fighting gels and foams (EPA 2010).

In a screening study of eight commercial AFFFs manufactured between 1988 and 2012, nine surfactants were detected. These included OPEs, alcohol ethoxylates, ethoxylated cocamines, alkyl ether sulfates, alkyl amido dipropionates, alkyl benzenesulfonates, alkyl sulfates, and polyethylene glycols (Garcia et al. 2019).

Use of AFFFs can contaminate groundwater and surface water. Treatment of AFFF-contaminated water is mostly directed at the removal of per- and polyfluoroalkyl substances (PFASs); however, APEs present in AFFFs will also be released during use and should be considered as a priority contamination substance (Garcia et al. 2019)

Through the Health Product Declarations (HBD) Public Repository (HPDC 2020), various products related to fire protection were found. Among these were 3M™ Fire Barrier Sealant, a latex sealant that can be applied with a caulk gun to form a flexible firestop seal, which contained APEs.

Further information on the use of APEs in this market sector could not be located.

Alternatives

Data on APE alternatives in fire-fighting foams and gels were not readily available. APE alternatives that have been detected in AFFFs were alcohol ethoxylates, ethoxylated cocamines, alkyl ether sulfates, alkyl amido dipropionates, alkyl benzenesulfonates, alkyl sulfates, and polyethylene glycols (Garcia et al. 2019). However, it is unknown if these are used as direct APE replacements.

WF300 Intumescent Firestop Caulk by Specified Technologies Inc. lists alcohol, C8-22, ethoxylated (CAS 69013-19-0) as a surfactant. There are also undisclosed ingredients, so it is possible that this product also contains APEs. Air-Bloc® 17MR from Henry Company is a fire-resistant elastomeric membrane barrier that lists fatty acids, soya, epoxidized, methyl esters (CAS 68082-35-9) as its surfactant (HPDC 2020).

In addition, EnergyGuard™ Polyiso Insulation fire rated barriers by GAF that contain isocyanurate foams, listed 1,2-propanediol, polymer with 2-ethyloxirane and oxirane, potassium salt (CAS 134737-27-2) as the surfactant (HPDC 2020).

Cooling Towers

State of the market

APEs are used as dispersants in combination with biocides for antifouling in cooling towers and water treatment. APEs may be present in these products at up to 5% (Bhole et al. 2018; Corbin 2017).

Cooling tower water that is removed from the system is called blowdown. Blowdown can contain chemical additives that were added to the cooling tower water, such as APEs. Options for management of blowdown include discharge to WWTPs (may require pretreatment) or treatment (reverse osmosis) and reuse (Lenntech 2020).

No further information concerning the use of APEs in cooling towers could be located.

Alternatives

There are alternatives in this market, such as C6-20 alcohol ethoxylates, glycol ethers, and EO/PO block polymers. These are often used in combination with each other. APE alternatives for cooling tower applications are shown in Table 22 (Bhole et al. 2018; Corbin 2017; Accepta 2013a, 2013b, 2018, 2019).

Table 22. APE alternatives in cooling towers.

CAS number	Chemical name	Surfactant class
9004-78-8	Polyoxyethylene phenol ether	Alcohol ethoxylates
577-11-7	Bis(2-ethylhexyl) sodium sulfosuccinate	Alkyl sulfosuccinates
111-76-2	2-Butoxyethanol	Glycol ethers
9003-11-6	Polyethylene/polypropylene glycol	Polyalkylene glycol
61791-54-6	Amines, N-tallow alkyltrimethylenedi-, acetates	Tallow amines
68439-50-9	Alcohols, C12-14, ethoxylated	Alcohol ethoxylates

5. Alternatives

Availability

The ability of alternatives to replace an APE surfactant will depend on performance demands and functional characteristics. Typically, surfactants are substituted by type (e.g., anionic for an anionic); however, it is possible to reformulate a product with another, or with a mixture of types. Since APEs are nonionic, the most likely alternatives are other nonionic surfactants. However, not all alternatives can act as “drop in” alternatives. Formulations may need significant alterations in order to function at the same performance level as the APE-containing product under its conditions of use. Where a single drop-in alternative is unavailable, a blend of multiple surfactants may provide the necessary functionality. Substitution of surfactants may also lead to differences in the relative percentages in composition in order to achieve the same performance (BizNGO 2013; Cassell 2020; Losey 2019).

Alternatives exist for most major market sectors that have previously relied on APEs, although substitution of APEs is more fully implemented in some sectors, such as detergents and cleaning products, than others. Some market areas use more specialized formulations for specific conditions of use where APEs may be more difficult to replace. Therefore, reformulating products or substitution in some market sectors will be more costly and time-consuming (Losey 2019). There is limited information about the market share of APEs and alternatives for each market segment, so it is difficult to determine the percentage of APEs versus non-APE products currently in use.

The main APE alternatives in use are alcohol ethoxylates, glucose-based carbohydrates such as alkylpolyglucoside, glucamides, and glucamine oxides (EPA 2010). Plant-derived surfactants derived from renewable palm and coconut oils are becoming popular for multiple reasons. One reason is the diminished dependence of fossil fuels and reduction in greenhouse gases. Another reason is consumer demand for more “natural” products, as they assume this equates to “healthier”. These plant-derived surfactants include used cetearyl-, cetyl-, cetyl oleyl- lauryl-, stearyl- alcohol ethoxylates, castor oil ethoxylates, and lauramine oxides (Oxiteno 2020a).

Alcohol ethoxylates are becoming some of the most commonly used nonionic surfactants in the United States, with a total use concentration of 840 million pounds reported in 2008 (Sanderson et al. 2013), compared to the annual estimated consumption of 300 to 400 million pounds per year for APEs (EPA 2010). It is estimated that the global alcohol ethoxylate market will grow by $1.2 billion by 2024 (MarketWatch 2020). One of the most common alcohol ethoxylates in use is alcohols, C9-11, ethoxylates (CAS 68439-46-3). This surfactant provides desirable properties such as high surface activity, low aquatic toxicity, and biodegradability, making it popular in industrial and institutional, home care, paints and coatings, and agrochemical applications. The surfactant manufacturer, Oxiteno, recently built a new facility in

Pasadena, Texas to manufacture alcohols, C9-11, ethoxylates and can produce up to 375 million pounds per year (Oxiteno 2019).

The main alternatives for NPEs in Europe, which has restricted all use of APEs, include linear and branched alcohol ethoxylates, and glucose-based carbohydrates such as alkylpolyglucoside (Priac et al. 2017).

The EPA's DfE Safer Choice Program offered an Alternatives Assessment for NPE surfactants (EPA 2012a) and has identified safer alternative surfactants through partnerships with industry and environmental advocates. These safer alternatives are comparable in cost and are readily available (see Table 4).

Chemical manufacturers have also provided documents listing their typical APE alternatives. These provide a good example of the most common APE alternatives on the market. A few examples are summarized below.

The Dow Chemical Company released a guide of alternatives products to their TERGITOL™ NP and TRITON™ X APE surfactant products (Dow 2019a,b). Their alternative product lines include ECOSURF™ EH Series, ECOSURF™ SA Series, ECOSURF™ LF Series, TERGITOL™ 15-S Series, TERGITOL™ TMN Series, TRITON™ CG Series, and TERGITOL™ L Series. The alternative surfactants used in these products are shown in Table 23. The Dow® document provides tables that contain suggested alternatives to each TERGITOL™ NP and TRITON™ X product, as well as properties comparisons for each.

The Dow Chemical Company also provides a helpful reference document outlining all of their surfactant products and in what markets and applications they are applicable. The document breaks down features and applications for each product with the associated average amount of EO (DOW 2014).

Table 23. Alternatives used in Dow® product lines.

Product series	CAS number	Chemical name	Surfactant class
ECOSURF™ EH	64366-70-7	2-Ethylhexanol, ethoxylated, propoxylated	Alcohol alkoxylates
ECOSURF™ SA	68937-66-6	Alcohols, C6-C12, ethoxylated, propoxylated	Alcohol alkoxylates
ECOSURF™ SA	69277-22-1	Alcohols, C10-16, ethoxylated, propoxylated	Alcohol alkoxylates
ECOSURF™ LF	1013910-41-2	Oxirane, 2-ethyl-, polymer with oxirane, mono-C12-14-sec-alkyl ethers	Alcohol ethoxylates
TERGITOL™ 15-S	84133-50-6	Alcohols, C12-14-secondary, ethoxylated	Alcohol ethoxylates
TERGITOL™ TMN	60828-78-6	Polyoxyethylene 2,6,8- trimethyl-4-nonyl ether	Alcohol ethoxylates

Product series	CAS number	Chemical name	Surfactant class
TRITON™ CG	68515-73-1	D-Glucopyranose, oligomeric, decyl octyl glycoside	Alkyl polyglucosides
TRITON™ CG	110615-47-9	D-Glucopyranose, oligomeric, C10-16-alkyl glycosides	Alkyl polyglucosides
TERGITOL™ L	9003-11-6	Polyethylene/polypropylene glycol	Polyalkylene glycol

Stepan Company provided a list of APE alternatives to use as a starting point when selecting them for certain applications. The list is not all inclusive. The product lines and chemicals are shown in Table 24.

Table 24. Alternatives used in Stepan Company product lines.

Product series	CAS number	Chemical name	Surfactant class
BIO-SOFT®	68439-46-3	Alcohols, C9-11, ethoxylated	Alcohol ethoxylates
BIO-SOFT®	34398-01-1	Alcohols, C11, ethoxylated	Alcohol ethoxylates
BIO-SOFT®	66455-14-9	Alcohols, C12-13, ethoxylated	Alcohol ethoxylates
BIO-SOFT®	68131-39-5	Alcohols, C12-15, ethoxylated	Alcohol ethoxylates
BIO-SOFT®	9002-92-0	Alcohols, C12-14, ethoxylated	Alcohol ethoxylates
BIO-SOFT®; MAKON®	24938-91-8	Alcohols, C13, ethoxylated	Alcohol ethoxylates
BIO-SOFT®	61791-26-2	Tallowamine ethoxylated	Amine ethoxylates
MAKON®	61827-42-7	Isodecylalcohol, ethoxylated	Alcohol ethoxylates
MAKON®	64175-88-8	Monoisopropanolamide alkoxylate	Alcohol alkoxylates
MAKON®	68154-97-2	Alcohols, C10-12, ethoxylated propoxylated	Alcohol alkoxylates
NINEX®	67784-86-5	Fatty acids, tall oil, ethoxylated propoxylated	Alcohol alkoxylates
STEPANTEX®	61791-12-6	Ethoxylated castor oil	Ethoxylated seed oils
STEP-FLOW®	9003-11-6	Polyethylene/polypropylene glycol	Polyalkylene glycol
TOXIMUL®	9038-95-3	Oxirane, 2-methyl-, polymer with oxirane, monobutyl ether	Alcohol alkoxylates

Safety

Similar to APEs, the alternatives to APEs also exhibit high aquatic toxicity in general, as is characteristic of most surfactants due to how they function. However, they are often less persistent in the environment and their degradation products demonstrate lower persistence and aquatic toxicity than the parent surfactants. A summary of the persistence and aquatic toxicity of APEs and the eight alternatives identified in EPA's DfE Alternatives Assessment for Nonylphenol Ethoxylates (EPA 2012a) can be seen in Table 25. The persistence and hazard designations were based on DfE Alternative Assessment criteria.

Table 25. Summary of persistence and aquatic toxicity of APEs and alternatives (EPA, 2012a).

CAS number	APE or alternative to APEs	Chemical name	Persistence	Degradation products of concern	Acute aquatic toxicity	Chronic aquatic toxicity
127087-87-0	APE	Nonylphenol ethoxylate (NP9EO)	Moderate	Yes	High	Moderate
9036-19-5	APE	Octylphenol ethoxylate (OP10EO)	High	Yes	High	Very high
68411-30-3	Alternatives to APEs	Benzenesulfonic acid, C10-10-alkyl derivatives, sodium salts	Very low	No	High	High
68515-73-1	Alternatives to APEs	D-glucopyranose, oligomeric, decyloctyl glycosides	Very low	No	Moderate	Moderate
151-21-3	Alternatives to APEs	Sodium lauryl sulfate	Very low	No	High	High
68439-46-3	Alternatives to APEs	C9-11 alcohols, ethoxylated (6EO)	Very low	No	High	High
68131-39-5	Alternatives to APEs	C12-15 alcohols, ethoxylated (9EO)	Very low	No	Very High	High
1138-41-6	Alternatives to APEs	Sorbitan monostearate	Low	No	High	High
64366-70-7	Alternatives to APEs	Oxirane, methyl-, polymer with oxirane, mono(2-ethylhexyl ether)	Low	No	Moderate	Moderate
9004-82-4	Alternatives to APEs	Poly(oxy-1,2-ethanediyl), alpha-sulfo-omegadodexcyloxy-, sodium salt	Low	No	High	High

A high-level hazards screening was conducted for the identified APE alternatives listed in this document (except for agricultural chemicals) using the automated GreenScreen® List Translator™ scoring or publicly available GreenScreen Benchmark scores in Pharos

(GreenScreen 2020; HBN 2019). Along with this, the Safer Choice Program's SCIL was searched to identify alternatives that have been recognized by the EPA for safer chemistry (EPA 2019b). The results of this screening are presented in Appendix III. Eighty-four alternatives were identified in this report. Of the 74 alternatives listed in this report, 46 are listed on SCIL. GreenScreen® List Translator labelled two alternatives as Benchmark 2 (use but search for safer substitutes), 23 as LT-P1 (possible high concern), and 49 as LT-UNK of NoGSLT (unknown concern). It is worth noting that 17 of the LT-P1 chemicals are on SCIL.

Consumers are exposed to alcohol ethoxylates mostly through the dermal route through their presence in household laundry and cleaning products. Small amounts of inhalation exposure may occur due to their use in spray cleaners. A maximum consumer aggregate exposure estimate of 6.48 μg/kg body weight/day has been reported (HERA 2009).

6. Barriers to Adoption of Alternatives

Although the use of APEs appears to be decreasing due to regulations in other regions, retailer restrictions, and adoption of environmentally sustainable corporate policies, it is apparent that some market sectors are still driving continued demand for these substances. According to stakeholder discussions, reformulation of a product requires an initial cost investment in order to evaluate the performance of alternatives, restructure the supply chain, and possibly change the production process. As markets shift and the supply chain stabilizes, the cost of moving to alternatives should decrease, but large up-front investments and uncertainty regarding return on investment pose a barrier to developing and adopting these alternatives. Any data that can demonstrate downward trends in cost in conjunction with procedures used to phase out NPEs would be highly informative and may encourage other facilities to also reduce their use of NPEs.

Chemical alternatives to APEs are readily available for many market applications; however, APEs may still be used since they are not specifically banned or restricted in the US. An example product sector is laundry detergents. Although use of NPEs in consumer laundry detergent products has largely been phased out, it has been shown that on-premises launderers still use the NPE-containing products. The reasons for this include the low cost and high performance of APEs and the fact that there is no regulatory or economic incentive for them to substitute. According to one stakeholder, manufacturers have stated that they will keep making APEs until they are required to stop.

For future work, Ecology may seek to survey key businesses to collect information on the cost associated with switching to non-APE surfactant alternatives in various markets.

7. Data Gaps

APEs are present in a multitude of products and market sectors. There is limited publicly available information on which products contain APEs, mostly due to CBI claims, and, therefore, their potential to impact and contribute to environmental and human health exposures is uncertain. In addition, limited stakeholder response was a barrier to obtaining critical data and perspectives. APEs are ubiquitous in environmental media; however, a clear picture of source and product specific information is unavailable at this time. This report may be used as a starting point to gain a better understanding the role of APEs in consumer and industrial markets and their possible pathways to the aquatic environment.

While a multitude of APE alternatives were presented in this document, it would be helpful to have a better understanding of which alternatives serve as the best performing and cost-efficient replacements to APEs in different types of product formulations.

Recent data of the current market shares of APEs were not available. This information would be useful in determining if a decrease in use of NPE compounds has led to an increase in the use of OPEs or other regrettable substitutes. It is also difficult to determine the percentage of APEs versus non-APE products currently in use. MarketWatch created a global Alcohol Ethoxylate 2020 market report that may provide useful information on the use of these widely used alternatives in various market (MarketWatch 2020). Ecology may want to consider purchasing this document for more information.

There were no publicly available data related to cost changes in the supply chain for substitution of APE alternatives in products. Surveys of impacted businesses to collect such information would be helpful in informing the cost involved in switching to non-APE surfactant alternatives in various markets.

8. References

Abdullah K, Malloy T, Stenstrom MK, et al. 2017. Toxicity of acidization fluids used in California oil exploration. Toxicol Environ Chem 99(1):78-94.

Accepta, 2013a. Accepta 2615. MSDS. Accepta Water Ltd.

Accepta, 2013b. Accepta 2617. MSDS. Accepta Water Ltd.

Accepta, 2018. Accepta 2306. MSDS. Accepta Water Ltd.

Accepta, 2019. Accepta 2321. MSDS. Accepta Water Ltd.

Agrian®, 2020. Dyne-AMIC product information. Helena Agri-Enterprises, LLC. Agrian®. Available online at; https://www.agrian.com/labelcenter/results.cfm?quicksearch=dyne-amic

AHLA, 2020. Washington's Hotel Industry by the Numbers. American Hotel & Lodging Association. Available online at: https://www.ahla.com/statefacts

APERC, 2017 Alkylphenols & Ethoxylates Research Council (APERC). Comment letter - regarding DTSCs Background Document on Potential Aquatic Impacts and Continued Uses of Nonylphenol Ethoxylates and Triclosan. Available online at: https://calsafer.dtsc.ca.gov/documentitem/index/?guid=2a5142a3-7488-48fa-996f-41da92ed3f21

Arkema, 2020. EnVia® Products. Arkema Group Coating Resins. Available online at: https://americas.arkemacoatingresins.com/en/products/spotlights/envia-products/

Bakke D, 2013. Human and Ecological Risk Assessment of Nonylphenol Polyethoxylate-based (NPE) Surfactants in Forest Service Herbicide Applications. USDA Forest Service. Available online at: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5346866.pdf

BASF, 2013. Lutensit® A types. Technical Information. BASF Care Chemicals Division Available online at: https://chemical.carytrad.com.tw/uploads/1/2/3/8/123848866/tds_lutensit_a_types_en.pdf

BASF, 2015. Lutensol® TO 5. Safety Data Sheet. BASF. Available online at: https://www.stobec.com/DATA/PRODUIT/1961~v~msds_8673.pdf

BASF, 2020a. Emulsion Polymerization. Formulation Technologies. BASF. Available online at: https://www.formulation-technologies.basf.com/applications/emulsion-polymerization

BASF, 2020b. Pulp and Paper. Formulation Technologies. BASF. Available online at: https://www.formulation-technologies.basf.com/applications/pulp-and-paper

BAuA, 2012. Proposal for Identification of a Substance as a CMR 1A or 1B, PBT, vPvB or a Substance of an Equivalent Level of Concern. Annex XV dossier – Identification of 4-tert-Octylphenol Ethoxylates as SVHC. BauA, Federal Office for Chemicals, Germany. Available online at: https://echa.europa.eu/documents/10162/728c29b1-8ce3-1d99-b128-8c54ca7f5d1f

Bhole Y, Singh M, Finision J, Meier D, 2018. Nonylphenol Ethoxylate-Free Oil Dispersant Formulation. Patent 20180355284. Free Patents Online. Available at: http://www.freepatentsonline.com/y2018/0355284.html

BizNGO, 2013. Nonylphenol Ethoxylates (NPE) in All-Purpose Cleaners. Final Alternatives Assessment. BizNGO. Available online at: https://www.bizngo.org/images/ee_images/uploads/resources/Final_text_for_CPA_review_Combined_NPE_STAGE_1_and_2_REPORT_20180116.pdf

Bluesign, 2019. Bluesign® System Substances List (BSSL). Consumer safety limit. Version 10.0. bluesign technologies ag. Available online at: https://www.bluesign.com/downloads/bssl/bssl-v10.0.pdf

Cassell, C, 2020. Lowe's. Personal Communication. 2/12/2020.

CBA, 2020. Smartlabel® Product Search. The Consumer Brands Association and Food & Consumer Products of Canada. Available online at: http://www.smartlabel.org/products

Challener, C, 2020. Waterbourne Coating Technologies Steadily Advance Despite Challenges. Coatings Tech 17(1). American Coatings Association. Available online at: https://www.paint.org/coatingstech-magazine/articles/waterborne-coating-technologies-steadily-advance-despite-challenges/

CIR, 2015. Safety Assessment of Nonoxynols as Used in Cosmetics. Cosmetic Ingredient Review. Available online at: http://www.cir-safety.org/sites/default/files/nonoxynols_0.pdf

Clariant, 2015. Process Aids and Intermediates for the Chemical Industry. Surfactants. Clariant International Ltd. Available online at: https://biokhimact.com.ua/images/catalogs/Surfactants.pdf

Clariant, 2020a. How Care Chemicals Creates Vale. Integrated Report 2019. Clariant. Available online at: http://reports.clariant.com/2019/integrated-report/business-areas/care-chemicals.html

Clariant, 2020b. Dispersant for Waterborne Pigment Concentrates Dispersogen® PLF 100. Clariant International Ltd. Available online at: https://www.clariant.com/-

/media/Files/Business-Units/ICS/Paints-and-Coatings/dispersogen_plf_100/Clariant-Brochure-Dispersogen-PLF-100-2020-EN.pdf

Clariant 2020c. Runway De-Icing. Safeway- An Efficient Way of Runway Deicing. Clariant. Available online at: https://www.clariant.com/en/Business-Units/Industrial-and-Consumer-Specialties/Aviation/Runway-De-Icing

Cognis, 2009. Disponil® SDS 15. Safety Data Sheet. Cognis Functional Products. Available online at: https://e-applications.basf-ag.de/data/basf-pcan/pds2/pds2-web.nsf/5AAE6D552E5CE6B1C125757700445088/$File/DISPONIL_r_SDS_15__E.pdf

Corbin B, 2017. Biofouling Control in Industrial Water Systems. CTI Journal 38(2), p.8. Available online at: https://www.cti.org/downloads/2017SummerJournalCTI.pdf

Corsi SR, Zitomer DH, Field JA, Cancilla D, 2003. Nonylphenol ethoxylates and other additives in aircraft deicers, antiicers, and waters receiving airport runoff. Environ. Sci. Technol. 37(18):4031-4037. Available online at: https://www.researchgate.net/publication/9068313_Nonylphenol_Ethoxylates_and_Other_Additives_in_Aircraft_Deicers_Antiicers_and_Waters_Receiving_Airport_Runoff

Corsi SR, Geis SW, Loyo-Rosales JE, et al., 2006. Characterization of aircraft deicer and anti-icer components and toxicity in airport snowbanks and snowmelt runoff. Environ Sci. Technol. 40(10):3195-3202. Available online at: https://www.ncbi.nlm.nih.gov/pubmed/16749681

DEPA, 2013. Survey of Alkylphenols and Alkylphenol Ethoxylates. The Danish Environmental Protection Agency. Available online at: https://www2.mst.dk/Udgiv/publications/2013/04/978-87-92903-99-0.pdf

DNR, 2018. Invitation for Bid (IFB) #1724, Site Preparation – Ground Herbicide Contract Northwest Region. Washington State Department of Natural Resources. Available online at: https://www.dnr.wa.gov/programs-and-services/forest-resources/silviculture-state-lands

DNR, 2019. Invitation for Bid (IFB) #1791, Site Preparation – Ground Herbicide Contract Northeast Region. Washington State Department of Natural Resources. Available online at: https://www.dnr.wa.gov/programs-and-services/forest-resources/silviculture-state-lands

Doherty A, Ernst M, 2019. DTSC, California. Personal Communication. 12/5/2019.

Dollar Tree, 2017. Commitment to Eliminate Priority Chemicals. Dollar Tree. Available online at: https://www.dollartree.com/file/general/Priority_Chemicals_Commitment.pdf

Dow, 2010. DOW™ Nonylphenol Ethoxylate Surfactants. Product Safety Assessment. The Dow Chemical Company. Available online at:

http://msdssearch.dow.com/PublishedLiteratureDOWCOM/dh_096d/0901b8038096dad7.pdf?filepath=productsafety/pdfs/noreg/233-00257.pdf&fromPage=GetDoc

Dow, 2013. TERGITOL™ NP Series and TRITON™ X Series Surfactants. Applications for APE-based Surfactants. The Dow Chemical Company. Available online at: https://dowservice.custhelp.com/ci/fattach/get/1690988/0/filename/TERGITOL%C2%99_NP_Series%26TRITON%C2%99_X_Series+_Applications_Aug2013.pdf

Dow, 2014. Surfactants Reference Chart. A Broad Range of Anionic and Nonionic Products. Dow Surfactants. The Dow Chemical Company. Available online at: https://www.dow.com/en-us/document-viewer.html?ramdomVar=6401589459999199552&docPath=/content/dam/dcc/documents/en-us/catalog-selguide/119/119-01491-01-dow-surfactants-selection-guide.pdf

Dow, 2015. Product Safety Assessment. DOW™ Octylphenol Ethoxylate Surfactants. The Dow Chemical Company. Available online at: http://msdssearch.dow.com/PublishedLiteratureDOWCOM/dh_096d/0901b8038096dada.pdf?filepath=productsafety/pdfs/noreg/233-00258.pdf&fromPage=GetDoc

Dow, 2019a. Alternatives to Alkyl Phenol Ethoxylate (APE, APEO) Surfactants. Dow Surfactants. The Dow Chemical Company. Available online at: https://www.dow.com/content/dam/dcc/documents/en-us/catalog-selguide/119/119-02307-01-dow-surfactants-selection-guide.pdf?iframe=true

Dow, 2019b. Tergitol™ L-64 E Surfactant. Safety Data Sheet. The Dow Chemical Company. Available online at: https://www.dow.com/en-us/document-viewer.html?docType=SDS&contentType=SDS&product=121010z&tradeProduct=000000121010&selectedCountry=US&selectedLanguage=EN&recordNumber=34633618

DTSC, 2018. Product-Chemical Profile for Nonylphenol Ethoxylates in Laundry Detergents. Department of Toxic Substances Control. State of California. Available online at: https://dtsc.ca.gov/wp-content/uploads/sites/31/2018/10/Internal_Profile_for-NPEs_Laundry_Detergent.pdf

ECHA, 2009. Substances Restricted Under REACH. Registration Evaluation Authorisation and Restriction of Chemicals (REACH), Annex XVII, Entry 46. European Chemicals Agency. Available online at: https://echa.europa.eu/substances-restricted-under-reach

ECHA, 2016. Substances Restricted Under REACH. Registration Evaluation Authorisation and Restriction of Chemicals (REACH), Annex XVII, Entry 46a. European Chemicals Agency. Available online at: https://echa.europa.eu/documents/10162/7dcd73a4-e80d-47c5-ba0a-a5f4361bf4b1

Ecology, 2015. Pollution Prevention Practices for Metal Machining. Washington State Department of Ecology, Olympia, WA. Available online at: https://apps.ecology.wa.gov/publications/SummaryPages/99412.html

Ecology, 2019. Aquatic Plant and Algae Management General Permit. Washington State Department of Ecology, Olympia, WA. Available online at: https://apps.ecology.wa.gov/paris/DownloadDocument.aspx?id=274757

Ecology, 2020a. Industrial Facility Permits and Regulation. Washington State Department of Ecology, Olympia, WA. Available online at: https://ecology.wa.gov/Regulations-Permits/Permits-certifications/Industrial-facilities-permits

Ecology, 2020b. Reclaimed Water. Washington State Department of Ecology, Olympia, WA. Available online at: https://ecology.wa.gov/Water-Shorelines/Water-quality/Reclaimed-water

Ecology, 2020c. Biosolids. Washington State Department of Ecology, Olympia, WA. Available online at: https://ecology.wa.gov/Waste-Toxics/Reducing-recycling-waste/Organic-materials/Biosolids/Learn-about-biosolids

Ecology, 2020d. Water Quality Permitting and Reporting Information System (PARIS). Washington State Department of Ecology, Olympia, WA. Available online at: https://apps.ecology.wa.gov/paris/PermitLookup.aspx

Ecology and King County, 2011. Control of Toxic Chemicals in Puget Sound: Assessment of Selected Toxic Chemicals in the Puget Sound Basin, 2007-2011. Washington Department of Ecology, Olympia, WA and King County Department of Natural Resources, Seattle, WA. Ecology Publication No. 11-03-055. www.ecy.wa.gov/biblio/1103055.html

EnviroVision Corporation, 2008. Phase 2: Improved Estimates of Toxic Chemical Loadings to Puget Sound from Surface Runoff and Roadways. Herrera Environmental Consultants, Inc. Washington Department of Ecology, Olympia, WA. Publication Number 08-10-084. Available online at: https://apps.ecology.wa.gov/publications/SummaryPages/0810084.html

EPA, 2005. Aquatic Life Ambient Water Quality Criteria – Nonylphenol. US Environmental Protection Agency, Office of Water, Washington, DC. EPA-822-R-05-005. Available online at: https://www.epa.gov/sites/production/files/2019-03/documents/ambient-wqc-nonylphenol-final.pdf

EPA, 2010. Nonylphenol (NP) and Nonylphenol Ethoxylates (NPEs) Action Plan. US Environmental Protection Agency, Washington, DC. Available online at: https://www.epa.gov/sites/production/files/2015-09/documents/rin2070-za09_np-npes_action_plan_final_2010-08-09.pdf

EPA, 2012a. DfE Alternatives Assessment for Nonylphenol Ethoxylates. US Environmental Protection Agency. Available online at: https://www.epa.gov/sites/production/files/2014-06/documents/npe_final.pdf

EPA, 2012b. Environmental Impact and Benefit Assessment for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category. US Environmental Protection Agency. Available online at: https://www.epa.gov/sites/production/files/2015-06/documents/airport-deicing_environmental-impact-and-benefit-assessment-final-2012.pdf

EPA, 2015. Analysis of Hydraulic FracturingFluid Data from the FracFocus Chemical Disclosure Registry 1.0. (EPA/601/R-14/003). US Environmental Protection Agency. Washington DC: Office of Research and Development. Available online at: https://www.epa.gov/sites/production/files/2015-03/documents/fracfocus_analysis_report_and_appendices_final_032015_508_0.pdf

EPA, 2016a. Summary of Nominations for the Fourth Contaminant Candidate List (CCL4). US Environmental Protection Agency, Office of Water, Washington, DC. EPA-815-R-16-006. Available online at: https://www.epa.gov/sites/production/files/2016-11/documents/815r16006.pdf

EPA, 2016b. Safer Choice Criteria for Surfactants. Safer Choice Program. US Environmental Protection Agency. Available online at: https://www.epa.gov/saferchoice/safer-choice-criteria-surfactants

EPA, 2018a. Addition of NPEs Category to TRI List Final Rule. Toxics Release Inventory (TRI) Program. US Environmental Protection Agency. Available online at: https://www.epa.gov/toxics-release-inventory-tri-program/addition-npes-category-tri-list-final-rule

EPA, 2018b. Addition of Nonylphenol Ethoxylates Category; Community Right-to-Know Toxic Chemical Release Reporting. Federal Register, Vol 83 (113): 27291, June 12, 2018. 40 CFR Part 372 [EPA–HQ–TRI–2016–0222; FRL–9979–16]. Available online at: https://www.govinfo.gov/content/pkg/FR-2018-06-12/pdf/2018-12628.pdf

EPA, 2019a. Design for the Environment Safer Detergents Stewardship Initiative (SDSI). Safer Choice. US Environmental Protection Agency. Available online at: https://www.epa.gov/saferchoice/design-environment-safer-detergents-stewardship-initiative

EPA, 2019b. Safer Chemicals Ingredients List. Safer Choice Program. US Environmental Protection Agency. Available online at: https://www.epa.gov/saferchoice/safer-ingredients

EWG, 2020a. EWG's Guide to Healthy Cleaning. Environmental Working Group. Available online at: https://www.ewg.org/guides/cleaners/

EWG, 2020b. EWG's Skin Deep®. Environmental Working Group. Available online at: https://www.ewg.org/skindeep/

Feinstein, D, 2019. Personal Care Products Safety Act. S.726. 116th Congress. Available online at: https://www.congress.gov/bill/116th-congress/senate-bill/726/text

Fink, J, 2013. Hydraulic Fracturing Chemicals and Fluids Technology. Gulf Professional Publishing. P.62. Available online at: https://books.google.com/books?id=9gUjTLy5l18C&pg=PA62&lpg=PA62&dq=myrcene+surfactant&source=bl&ots=yQ0RfR_WDJ&sig=ACfU3U2Jsc3IzayxWHKUh_SZ9ckd9aHazQ&hl=en&sa=X&ved=2ahUKEwjolJCUzPLoAhWnUt8KHR6eAxUQ6AEwBXoECAoQKQ#v=onepage&q=myrcene%20surfactant&f=false

Foss S, 2019. Email to Craig Manahan RE: Response to Request from Ecology – APE's.

Franklin K (ed), 2016. Walmart releases high priority chemical list. Chemical Watch. CW Research Ltd. Available online at: https://chemicalwatch.com/48724/walmart-releases-high-priority-chemical-list#overlay-strip

Garcia RA, Chiaia-Hernandez AC, Lara-Martin PA, et al., 2019. Suspect screening of hydrocarbon surfactants in AFFFs and AFFF-contaminated groundwater by high-resolution mass spectrometry. Environ Sci Technol 53(14): 8068-8077. Available online at: https://pubs.acs.org/doi/10.1021/acs.est.9b01895

GOTS, 2016. Spotlight on the Use of NPEs. Global Organic Textile Standard. Global Standard gGmbH. Available online at: https://www.global-standard.org/information-centre/news/120-spotonnpes.html

GreenScreen, 2020. GreenScreen® List Translator™. GreenScreen® for Safer Chemicals. Available online at: https://www.greenscreenchemicals.org/learn/greenscreen-list-translator

Green Seal, 2015. GS-11, Green Seal™ Standard for Paints, Coatings, Stains, and Sealers. Green Seal, Inc. Available online at: https://www.greenseal.org/storage/standards/August2019/GCc7b2DO1dc2Dk68ySd2.pdf

GWPC & IOGCC, 2020. FracFocus Chemical Disclosure Registry. Groundwater Protection Council & Interstate Oil and Gas Compact Commission. Available online at: http://fracfocus.org/

HBN, 2018. It's Not Just About VOCs: Select APE-free Paint, Too. Home Free. Healthy Building Network. Available online at: https://homefree.healthybuilding.net/news/47-its-not-just-about-vocs-select-ape-free-paint-too

HBN, 2019. Pharos. Healthy Building Network. Available online at: https://pharosproject.net/

HERA, 2009. Alcohol Ethoxylates. Human & Environmental Risk Assessment on Ingredients of European Household Cleaning Products. HERA Project. Available online at: https://www.heraproject.com/files/34-F-09%20HERA%20AE%20Report%20Version%202%20-%203%20Sept%2009.pdf

HLAC, 2020. Healthcare Laundries Accredited for Patient Safety. Healthcare Laundry Accreditation Council. Available online at: https://www.hlacnet.org/sort-by-state

Hillyard, 2020. Icon® Gym Finish Ingredient List. Hillyard. Available online at: https://productingredientweb.hillyard.com/ingredient?formula=HIL0027400

HPDC, 2020. Health Product Declaration Public Repository. Health Product Declaration® Collaborative. Available online at: https://www.hpd-collaborative.org/hpd-public-repository/

Huntsman, 2005. Metalworking Chemicals. Huntsman Performance Products. Available online at: http://www.huntsman.com/performance_products/Media%20Library/a_MC348531CFA3EA9A2E040EBCD2B6B7B06/Products_MC348531D0B9FA9A2E040EBCD2B6B7B06/Amines_MC348531D0BECA9A2E040EBCD2B6B7B06/Morpholine%20%20%20DGA_R_MC348531D0D20A9A2E040EBCD2B6B7B06/DIGLYCOLAMINE_R%20agen_MC348531D0DBAA9A2E040EBCD2B6B7B06/files/metalworking_brochure.pdf

Huntsman, 2013. Textile Effects. Huntsman positive list for ZDHC and H&M RSL. Huntsman International. Available online at: http://www.huntsman.com/textile_effects2/Media%20Library/global/files/ZDHC_HM_0407131032a_HR.pdf

Huntsman, 2017. Surfonic® Performance Emulsifiers for Metalworking Fluids. Huntsman Performance Products. Available online at: https://www.huntsman.com/performance_products/Media%20Library/global/files/SURFONIC%C2%AE%20Emulisfer%20for%20Metalworking%20Fluids_EN_20170517.pdf

Huntsman, 2018. Metalworking Chemicals. Huntsman Performance Products. Available online at: http://www.huntsman.com/performance_products/Media%20Library/global/files/Metalworking_EN_May%202018_A4.pdf

Hurd P, 2019. Email to Craig Manahan RE: List of Pesticide/Adjuvant Components

James CA, Lanksbury J, Khangaonkar T, et al. 2020. Evaluating exposures of bay mussels (Mytilus tossulus) to contaminants of emerging concern through environmental sampling and hydrodynamic modeling. Sci Total Environ 709:136098.

Jennings J, 2019. Email to Craig Manahan RE: List of Pesticide/Adjuvant Components

KFF, 2017. Total Number of Residents in Certified Nursing Facilities. State Health Facts. Kaiser Family Foundation. Available online at: https://www.kff.org/other/state-indicator/number-of-nursing-facility-residents/?currentTimeframe=0&selectedRows=%7B%22states%22:%7B%22washington%22:%7B%7D%7D%7D&sortModel=%7B%22colId%22:%22Location%22,%22sort%22:%22asc%22%7D

KFF, 2018. Hospital Inpatient Days per 1,000 Population by Ownership Type. State Health Facts. Kaiser Family Foundation. Available online at: https://www.kff.org/other/state-indicator/inpatient-days-by-ownership/?currentTimeframe=0&selectedRows=%7B%22states%22:%7B%22washington%22:%7B%7D%7D%7D&sortModel=%7B%22colId%22:%22Location%22,%22sort%22:%22asc%22%7D

Lenntech, 2020. Cooling Tower Blowdown (CTBD) Treatment. Lenntech B.V. Available online at: https://www.lenntech.com/applications/process/cooling-tower-blowdoen.htm

Losey, B, 2019. Director at Alkylphenols & Ethoxylates Research Council (APERC). Personal Communication. 10/21/2019.

Lowe's, 2019. Safer Chemicals Policy. Lowe's. Available online at: https://newsroom.lowes.com/policies/safer-chemicals/

Lubliner B, Redding M, Ragsdale D, 2010. Pharmaceuticals and Personal Care Products in Municipal Wastewater and Their Removal by Nutrient Treatment Technologies. Washington Department of Ecology, Olympia, WA. Publication Number 10-03-004. Available online at: www.ecy.wa.gov/biblio/1003004.html

MarketWatch, 2020. Alcohol Ethoxylate Market 2020 Analysis, Growth by Top Companies, Trends by Types and Application, Forecast to 2025. MarketWatch. Available online at: https://www.marketwatch.com/press-release/alcohol-ethoxylate-market-2020-analysis-growth-by-top-companies-trends-by-types-and-application-forecast-to-2025-2020-04-06?tesla=y

Mathieu C, Wong S, 2016. Brominated Flame Retardants, Alkylphenolic Compounds, and Hexabromocyclododecane in Freshwater Fish of Washington state Rivers and Lakes. Washington Department of Ecology, Olympia, WA. Publication Number 16-03-012. Available online at: https://apps.ecology.wa.gov/publications/SummaryPages/1603012.html

Meador JP, Yeh A, Young G, et al. 2016. Contaminants of emerging concern in a large temperate estuary. Environ Pollut 213:254-267.

MediCleanse, 2020. Environment. MediCleanse Medical Linen Service. Available online at: https://www.medicleanse.com/about-us/environment/

MPCA, 2020. NPE in detergents. Safer Product Chemistry Program. Minnesota Pollution Control Agency. Available online at: https://www.pca.state.mn.us/quick-links/green-chemistry-and-design-npe-detergents-project

Muller A, Osterlund H, Nordqvist K, et al. 2019. Building surface materials as sources of micropollutants in building runoff: A pilot study. Sci Total Environ 680:190-197.

Nilsen E, Furlong ET, Rosenbauer R. 2014. Reconnaissance of pharmaceuticals and wastewater indicators in streambed sediments of the Lower Columbia River Basin, Oregon and Washington. JAWRA Journal of the American Water Resources Association 50(2):291-301.

NPSC, 2019. Washington Enacts Law Creating New Paint Recycling Program. Northwest Product Stewardship Council. Available online at: http://productstewardship.net/news/washington-enacts-law-creating-new-paint-recycling-program

NPSC, 2020. Paint; The Problem: Volume, Cost, Waste, and Toxicity. Northwest Product Stewardship Council. Available online at: http://productstewardship.net/products/paint

OECD SIDS, 2005. Linear Alkylbenzene Sulfonate (LAS). SIDS Initial Assessment Report for 20th SIAM. Available online at: https://hpvchemicals.oecd.org/ui/handler.axd?id=5b837fb0-350c-4742-914e-5f6513df120a

OEKO-TEX, 2020. Standard 100 by OEKO-TEX®. International Association for Research and Testing in the Field of Textile and Leather Ecology. OEKO-TEX® Association. Available online at: https://www.oeko-tex.com/importedmedia/downloadfiles/STANDARD_100_by_OEKO-TEX_R__-_Standard_en.pdf

Oxiteno, 2019. C9-C11 Alcohol Ethoxylates; Uses of CAS 68439-46-3. Oxiteno. Available online at: https://www.oxiteno.us/alcohols-c9-11-ethoxylated-cas-no-68439-46-3/

Oxiteno, 2020a. Plant-Derived and Natural Surfactants. Oxiteno. Available online at: https://www.oxiteno.us/plant-derived-and-natural-surfactants/

Oxiteno, 2020b. Products. Oxiteno. Available online at: https://www.oxiteno.us/products/

Peter KT, Tian Z, Wu C, et al. 2018. Using high-resolution mass spectrometry to identify organic contaminants linked to urban stormwater mortality syndrome in Coho salmon. Environ Sci Technol 52(18):10317-10327.

Potucek F, Skotnicova I, 2012. Displacement washing of Kraft pulp with aqueous solutions of surfactants. Cellulose Chemistry and Technology 47(9-10):777-782. Available online at: http://www.cellulosechemtechnol.ro/pdf/CCT9-10(2013)/p.777-782.pdf

PRI, 2015. Nonylphenol Ethoxylates. Technical Evaluation Report. Pesticide Research Institute. Agricultural Marketing Service. US Department of Agriculture National Organic Program. Available online at: https://www.ams.usda.gov/sites/default/files/media/NPE%20Technical%20Evaluation%20Report%20%282015%29.pdf

Priac A, Morin-Crini N, Druart C, et al. 2017. Alkylphenol and alkylphenol polyethoxylates in water and wastewater: A review of options for their elimination. AJOC 10(2): S3749-73. Available online at: https://www.sciencedirect.com/science/article/pii/S1878535214000872

RIKZ, 2001. Chemical Study on Alkylphenols. Rijksinstituut voor Kust en Zee. Available online at: https://edepot.wur.nl/174304

Rust D, Wildes S, 2008. Surfactants. A Market Opportunity Study Update. Omni Tech International, LTD. Prepared for the United Soybean Board. Available online at: https://soynewuses.org/wp-content/uploads/Surfactants-MOS-Jan-2009.pdf

SAE, 2018. Liquid Runway Deicing/Anti-Icing Product AMS1435D. SAE International. Available online at: https://www.sae.org/standards/content/ams1435d/

Sanderson H, van Compernolle R, Dyer SD, et al. 2013. Occurrence and risk screening of alcohol ethoxylate surfactants in three U.S. river sediments associated with wastewater treatment plants. Sci Total Environ 463-4: 600-610. Available online at: https://www.sciencedirect.com/science/article/pii/S0048969713005901?via%3Dihub

Sasol, 2015a. Study of Alkylphenol Ethoxylate-free Ether Sulfates for Emulsion Polymerization. Sasol Performance Chemicals. Available online at: https://sasoldcproducts.blob.core.windows.net/documents/Product%20Brochures/APEO-free%20ether%20sulfates%20for%20emulsion%20polymerization.pdf

Sasol, 2015b. Alcohol Ethoxylates. Versatile alternatives for technical applications. Sasol Performance Chemicals. Available online at: http://www.sasoltechdata.com/MarketingBrochures/Alcohol_Ethoxylates.pdf

Sasol, 2019. SAFOL 23E& Ethoxylate. Safety Data Sheet. Available online at: http://www.sasoltechdata.com/MSDS/SAFOL23E7.pdf

SCA, 2013. Nonylphenol and Nonylphenolethoxylates in Textiles. Annex XV Restriction Report. Proposal for a Restriction. European Chemicals Agency. Available online at: https://www.echa.europa.eu/documents/10162/77e0a60d-fc25-5258-d2f8-a80a9576023a

Schade M, Belliveau M, 2020. The Right Chemistry, Dollar General, Sephora, Lowe's among 7 most improved retailers addressing toxic chemicals. GreenBiz Group Inc. Available online at:

https://www.greenbiz.com/article/dollar-general-sephora-lowes-among-7-most-improved-retailers-addressing-toxic-chemicals

Schreder E, 2020. Toxic Free Future. Personal Communication. 2/6/2020.

S.C. Johnson, 2020a. Not Allowable Materials. Principles for Restrictions and Use. S.C. Johnson & Son, Inc. Available online at: https://www.whatsinsidescjohnson.com/us/en/not-allowable-materials

S.C. Johnson, 2020b. What's Inside. Product Search. Available online at: https://www.whatsinsidescjohnson.com/us/en

Sharp K, Sharp M, Matheson L, 2008. Alkylphenol Ethoxylate Replacement for Emulsion Polymerization. Sasol North America. Available online at: http://sasolnorthamerica.com/Images/Interior/productsearchdocuments/sasol%20alkylphenol%20ethoxylate%20replacement%20for%20emulsion%20polymerization%20-%20final.pdf

Silver Fern, 2020. All Surfactants Products. Silver Fern Chemical Inc. Available online at: https://www.silverfernchemical.com/product-category/surfactants/

Stepan, 2019a. BIO-SOFT D-40. Safety Data Sheet. Stepan Company. Available online at: https://www.stepan.com/msds/00037900.pdf

Stepan, 2019b. BIO-SOFT N91-6. Safety Data Sheet. Stepan Company. Available online at: https://www.stepan.com/msds/00588900.pdf

Target, 2016. Chemicals@Target: Chemicals Policy & Goals. Available online at: https://corporate.target.com/_media/TargetCorp/csr/pdf/Target-Chemicals-Policy-and-Goals.pdf

TERC, 2020. Metalworking Fluids. Transportation Environmental Resource Center. National Center for Manufacturing Sciences. Available online at: https://www.tercenter.org/metalworking.php

The Home Depot. 2017. Chemical Strategy. Available online at: https://corporate.homedepot.com/sites/default/files/image_gallery/PDFs/Chemical%20Strategy%2010_2017.pdf

Tian Z, Peter KT, Gipe AD, et al. 2020. Suspect and Nontarget Screening for Contaminants of Emerging Concern in an Urban Estuary. Environ Sci Technol 54(2):889-901.

Toxic-Free Future, 2019. Priority Classes of Chemicals of Significant Concern to Vulnerable Populations and Orcas. A Toxic-Free Future Factsheet. Available online at:

https://48h57c2l31ua3c3fmq1ne58b-wpengine.netdna-ssl.com/wp-content/uploads/2019/01/Table-of-Chemicals-Final-1-7-19.pdf

TRSA, 2010. Commitment to Phase out Use of Industrial Laundry Detergents Containing Nonylphenol Ethoxylates ("NPE"). Textile Rental Services Association of America. Available online at: https://www.epa.gov/sites/production/files/2015-09/documents/trsa_npe_phase_out_commitment_letter.pdf

US Census Bureau, 2019. State Population Totals: 2010-2019. US Department of Commerce. Available online at: https://www.census.gov/data/datasets/time-series/demo/popest/2010s-state-total.html

Venkatesan AK, Halden RU, 2013. National inventory of alkylphenol ethoxylate compounds in U.S. sewage sludges and chemical fate in outdoor soil mesocosms. Environ Pollut 174:189-193. Available online at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3552055/

Walter E. Nelson Co., 2020. Product Ingredient Disclosure. Available online at: https://www.walterenelson.com/wp-content/uploads/WENCO-CA-RTK-Ingredient-Disclosures-1-7-20.pdf

Washington State Legislature, 2019a. SB 5135 – 2019-20. Preventing Toxic Pollution that Affects Public Health or the Environment. Available online at: https://app.leg.wa.gov/RCW/default.aspx?cite=70.365&full=true

Washington State Legislature, 2019b. SB 5145 – 2019-20. Concerning Use of Hydraulic Fracturing in the Exploration for and Production of Oil and Natural Gas. Available online at: https://app.leg.wa.gov/billsummary?BillNumber=5145&Initiative=false&Year=2019

Washington State Office of the Governor, 2020. Office of Aerospace. Access Washington. Available online at: https://www.governor.wa.gov/issues/issues/economy/aerospace

WCP Solutions, 2020. Chemicals. Facility Supplies Product Catalog. Available online at: https://wcponline.wcpsolutions.com/products?webcode=CHEM

WSDA, 2011. WSDA Criteria for Registration of Spray Adjuvants for Aquatic Use. Washington State Department of Agriculture. Available online at: https://cms.agr.wa.gov/getmedia/feb21948-b097-4d3a-805e-2107045cd2a9/DefinitionCriteriaRegistrationSprayAdjuvantsAquatic.pdf

WSDA, 2019. Partial List of Spray Adjuvant Ingredients. Washington State Department of Agriculture. Available online at: https://cms.agr.wa.gov/WSDAKentico/Documents/PM/Registration/PartialListSprayAdjuvantIngredients_1.pdf?/PartialListSprayAdjuvantIngredients_1

WSDOT, 2020. All Washington State Airports. Washington State Department of Transportation. Available online at: https://www.wsdot.wa.gov/aviation/AllStateAirports/default.htm

WSU, 2020. Pesticide Information Center OnLine (PICOL) Database. Washington state Pest Management Resource Service. Washington State University. Available online at: https://picol.cahnrs.wsu.edu/Home/Index

Yamazaki S, 2020. Email to Craig Manahan RE: Industrial Chemical Reporting Values.

Appendix I. APEs CAS Numbers and Chemical Names

Table 26. Chemical names and CAS numbers for APEs in this assessment.

CAS number	NPE or OPE	Chemical name
104-35-8	NPE	2-(4-nonylphenoxy)ethanol
7311-27-5	NPE	Ethanol, 2-[2-[2-[2-(4-nonylphenoxy)ethoxy]ethoxy]ethoxy]-
9016-45-9	NPE	Poly(oxy-1,2-ethanediyl), α-(nonylphenyl)-ω-hydroxy-
14409-72-4	NPE	3,6,9,12,15,18,21,24-Octaoxahexacosan-1-ol, 26-(4-nonylphenoxy)-
20427-84-3	NPE	Ethanol, 2-[2-(4-nonylphenoxy)ethoxy]-
26027-38-3	NPE	Poly(oxy-1,2-ethanediyl), α-(4-nonylphenyl)-ω-hydroxy-
26571-11-9	NPE	3,6,9,12,15,18,21,24-Octaoxahexacosan-1-ol, 26-(nonylphenoxy)-
27176-93-8	NPE	Ethanol, 2-[2-(nonylphenoxy)ethoxy]-
27177-05-5	NPE	3,6,9,12,15,18,21-Heptaoxatricosan-l-ol, 23-(nonylphenoxy)-
27177-08-8	NPE	3,6,9,12,15,18,21,24,27-Nonaoxanonacosan-1-ol, 29-(nonylphenoxy)-
27942-27-4	NPE	3,6,9,12,15,18-Hexaoxaeicosan-1-ol, 20-(4-nonylphenoxy)-
27986-36-3	NPE	Ethanol, 2-(nonylphenoxy)-
34166-38-6	NPE	3,6,9,12,15-Pentaoxaheptadecan-1-ol, 17-(4-nonylphenoxy)-
37205-87-1	NPE	Poly(oxy-1,2-ethanediyl), α-(isononylphenyl)-ω-hydroxy-
51938-25-1	NPE	Poly(oxy-1,2-ethanediyl), α-(2-isononylphenyl)-ω-hydroxy-
68412-54-4	NPE	Poly(oxy-1,2-ethanediyl), α-(nonylphenyl)-ω-hydroxy-, branched
127087-87-0	NPE	Poly(oxy-1,2-ethanediyl), α-(4-nonylphenyl)-ω-hydroxy-, branched
156609-10-8	NPE	4-t-Nonylphenol-diethoxylate
2315-67-5	OPE	Ethanol, 2-[4- (1,1,3,3- tetramethylbutyl)phenoxy]-
2315-61-9	OPE	Ethanol, 2-[2- [4-(1,1,3,3- tetramethylbutyl)phenoxy] ethoxy]-
9002-93-1	OPE	Poly(oxy-1,2- ethanediyl), α-[4-(1,1,3,3-tetramethylbutyl)phenyl]- ω-hydroxy
2497-59-8	OPE	3,6,9,12,15,18- Hexaoxaeicosan-1-ol, 20- [4-(1,1,3,3-tetramethylbutyl)phenoxy]-
9036-19-5	OPE	Polyethylene glycol mono(octylphenyl) ether
9014-92-0	Other	Dodecylphenol ethoxylate

Appendix II. Alternative Pesticide Spray Adjuvants Registered in the United States

Table 27. Alternative pesticide spray adjuvants registered in the U.S.

CAS number	Chemical name	Surfactant class
64366-70-7	2-Ethylhexanol, ethoxylated, propoxylated	Alcohol alkoxylates
127036-24-2	Alcohol, C11, branched, ethoxylated	Alcohol ethoxylates
34398-01-1	Alcohols, C11, ethoxylated	Alcohol ethoxylates
9002-92-0	Alcohols, C12, ethoxylated	Alcohol ethoxylates
68154-97-2	Alcohols, C10-12, ethoxylated propoxylated	Alcohol alkoxylates
66455-15-0	Alcohols, C10-14, ethoxylated	Alcohol ethoxylates
68002-97-1	Alcohols, C10-16, ethoxylated	Alcohol ethoxylates
78330-21-9	Alcohols, C11-14-iso-, C13-rich, ethoxylated	Alcohol ethoxylates
68131-40-8	Alcohols, C11-15-secondary, ethoxylated	Alcohol ethoxylates
66455-14-9	Alcohols, C12-13, ethoxylated	Alcohol ethoxylates
68439-50-9	Alcohols, C12-14, ethoxylated	Alcohol ethoxylates
84133-50-6	Alcohols, C12-14-secondary, ethoxylated	Alcohol ethoxylates
68131-39-5	Alcohols, C12-15, ethoxylated	Alcohol ethoxylates
68551-13-3	Alcohols, C12-15, ethoxylated propoxylated	Alcohol alkoxylates
68551-12-2	Alcohols, C12-16, ethoxylated	Alcohol ethoxylates
68439-49-6	Alcohols, C16-18, ethoxylated	Alcohol ethoxylates
71243-46-4	Alcohols, C8-16, ethoxylated	Alcohol ethoxylates
69013-18-9	Alcohols, C8-18, ethoxylated propoxylated	Alcohol alkoxylates
68439-46-3	Alcohols, C9-11, ethoxylated	Alcohol ethoxylates
78330-20-8	Alcohols, C9-11-iso-, C10-rich, ethoxylated	Alcohol ethoxylates
26402-22-2	Decanoic acid, monoester with 1,2,3-propanetriol	Glycerides of fatty acids
110615-47-9	D-Glucopyranose, oligomeric, C10-16-alkyl glycosides	Alkyl polyglucosides
132778-08-6	D-Glucopyranose, oligomeric, C9-11-alkyl glycosides	Alkyl polyglucosides
68515-73-1	D-Glucopyranose, oligomeric, decyl octyl glycosides	Alkyl polyglucosides
61791-12-6	Ethoxylated castor oil	Ethoxylated seed oils
61791-23-9	Ethoxylated soybean oil	Ethoxylated seed oils
518299-31-5	Fatty acids, C16-18 and C18- unsaturated, esters with polyethylene glycol monomethyl ether	Ethoxylated fatty acid methyl esters
68424-61-3	Glycerides, C16-18 and C18- unsaturated, mono- and di	Glycerides
26402-26-6	Glyceryl monooctanoate	Glycerides

CAS number	Chemical name	Surfactant class
8002-43-5	Lecithins	Naturals
8030-76-0	Lecithins, soya	Naturals
85637-75-8	Oxirane, methyl-, polymer with oxirane, mono[2-(2- butoxyethoxy)ethyl] ether	Alcohol alkoxylates
34398-00-0	Poly(oxy-1,2-ethanediyl), alpha- (1-oxodecyl)-omega-methoxy	Ethoxylated fatty acid methyl esters
9006-27-3	Poly(oxy-1,2-ethanediyl), alpha- (1-oxododecyl)-omegamethoxy-	Ethoxylated fatty acid methyl esters
194289-64-0	Poly(oxy-1,2-ethanediyl), alpha- (1-oxooctyl)-omega-methoxy-	Ethoxylated fatty acid methyl esters
32761-35-6	Poly(oxy-1,2-ethanediyl), alpha- (1-oxotetradecyl)-omegamethoxy-	Ethoxylated fatty acid methyl esters
9041-33-2	Poly(oxyethylene) poly(oxypropylene) glycol monoallyl ether	Alcohol alkoxylates
9005-02-1	Polyethylene glycol dilaurate	Ethoxylated fatty acids
9005-07-6	Polyethylene glycol dioleate	Ethoxylated fatty acids
61791-01-3	Polyethylene glycol ditallate	Ethoxylated fatty acids
27274-31-3	Polyethylene glycol monoallyl ether	Alcohol ethoxylates
9004-96-0	Polyethylene glycol oleate	Ethoxylated fatty acids
9005-00-9	Polyethylene glycol stearyl ether	Alcohol ethoxylates
61791-00-2	Polyethylene glycol tallate	Ethoxylated fatty acids
9007-48-1	Polyglyceryl oleate	Polyglycerol esters of fatty acids
9038-95-3	Polyoxyethylene - polyoxypropylene monobutyl ether	Alcohol alkoxylates
60828-78-6	Polyoxyethylene 2,6,8- trimethyl-4-nonyl ether	Alcohol ethoxylates
27252-80-8	Polyoxyethylene glycol allyl methyl ether	Alcohol ethoxylates
9005-64-5	Polyoxyethylene sorbitan monolaurate	Sorbitan esters
9005-65-6	Polyoxyethylene sorbitan monooleate	Sorbitan esters
9005-67-8	Polyoxyethylene sorbitan monostearate	Sorbitan esters
9005-70-3	Polyoxyethylene sorbitan trioleate	Sorbitan esters
9005-71-4	Polyoxyethylene sorbitan tristearate	Sorbitan esters
57171-56-9	Polyoxyethylene sorbitol hexaoleate	Sorbitol esters
9004-99-3	Polyoxyethylene stearate	Ethoxylated fatty acids
1393-03-9	Soapbark	Naturals
1338-43-8	Sorbitan monooleate	Sorbitan esters
1338-41-6	Sorbitan monostearate	Sorbitan esters
26266-58-0	Sorbitan trioleate	Sorbitan esters

Appendix III. APE Alternatives List Screening

Notes:

- * = List Translator Scores: LT-1 = Known High Concern; LT-P1 = Possible High Concern; LT-UNK or NoGSLT = Unknown Concern; BM2 = Use but search for safer substitutes
- ^ = If is chemical is not on SCIL, this does not necessarily mean it does not pass the criteria. It may not have yet been assessed by SCIL.

Table 28. APE alternatives list screening.

CAS number	Chemical name	Surfactant class	GreenScreen® List Translator *	SCIL listed ^
30364-51-3	Sodium myristol sarcosinate	Acyl sarcosinates	LT-UNK	Yes
204336-40-3	1-Hexanol, 3,5,5-trimethyl-, ethoxylated, propoxylated	Alcohol alkoxylates	LT-UNK	No
64175-88-8	Monoisopropanolamide alkoxylate	Alcohol alkoxylates	LT-UNK	No
64366-70-7	2-Ethylhexanol, ethoxylated, propoxylated	Alcohol alkoxylates	LT-UNK	Yes
67784-86-5	Fatty acids, tall oil, ethoxylated propoxylated	Alcohol alkoxylates	LT-UNK	No
68154-97-2	Alcohols, C10-12, ethoxylated, propoxylated	Alcohol alkoxylates	LT-UNK	Yes
68439-51-0	Alcohols, C12-14, ethoxylated, propoxylated	Alcohol alkoxylates	LT-P1	Yes
68649-29-6	Alcohols, C10-16, ethoxylate propoxylate phosphoric acid	Alcohol alkoxylates	NoGSLT	No
68937-66-6	Alcohols, C6-C12, ethoxylated, propoxylated	Alcohol alkoxylates	NoGSLT	Yes
68987-81-5	Alcohols, C6-10, ethoxylated propoxylated	Alcohol alkoxylates	NoGSLT	Yes
69277-22-1	Alcohols, C10-16, ethoxylated, propoxylated	Alcohol alkoxylates	NoGSLT	No
9038-95-3	Oxirane, 2-methyl-, polymer with oxirane, monobutyl ether	Alcohol alkoxylates	LT-UNK	No
68439-46-3	C9-11 Alcohols, ethoxylated (6EO)	Alcohol ethoxylates	LT-P1	Yes

CAS number	Chemical name	Surfactant class	GreenScreen® List Translator *	SCIL listed ^
1013910-41-2	Oxirane, 2-ethyl-, polymer with oxirane, mono-C12-14-sec-alkyl ethers	Alcohol ethoxylates	NoGSLT	No
24938-91-8	Alcohols, C13, ethoxylated	Alcohol ethoxylates	LT-P1	Yes
34398-01-1	Alcohols, C11, ethoxylated	Alcohol ethoxylates	NoGSLT	Yes
60828-78-6	Polyoxyethylene 2,6,8-trimethyl-4-nonyl ether	Alcohol ethoxylates	LT-UNK	No
61827-42-7	Isodecylalcohol, ethoxylated	Alcohol ethoxylates	LT-UNK	No
66455-14-9	Alcohols, C12-13, ethoxylated	Alcohol ethoxylates	LT-UNK	Yes
67254-71-1	Alcohols, C10-12, ethoxylated	Alcohol ethoxylates	NoGSLT	No
68002-97-1	Alcohols, C10-16, ethoxylated	Alcohol ethoxylates	LT-UNK	Yes
68131-39-5	Alcohols, C12-15, ethoxylated	Alcohol ethoxylates	LT-P1	Yes
68439-46-3	C9-11Alcohols, ethoxylated (6EO)	Alcohol ethoxylates	LT-P1	Yes
68439-49-6	Alcohols, C16-18, ethoxylated	Alcohol ethoxylates	LT-P1	Yes
68439-50-9	Alcohols, C12-14, ethoxylated (9EO)	Alcohol ethoxylates	LT-P1	Yes
68551-12-2	Alcohols, C12-16, ethoxylated	Alcohol ethoxylates	LT-UNK	Yes
68911-48-0	Alcohols, C7-21, ethoxylated	Alcohol ethoxylates	NoGSLT	No
68920-66-1	Alcohols, C16-18 and C18-unsatd., ethoxylated	Alcohol ethoxylates	LT-UNK	No
68951-67-7	Alcohols, C14-15, ethoxylated	Alcohol ethoxylates	LT-UNK	Yes
69011-36-5	Isotridecanol ethoxylate	Alcohol ethoxylates	LT-UNK	Yes
84133-50-6	Alcohols, C12-14-secondary, ethoxylated	Alcohol ethoxylates	LT-UNK	Yes
9002-92-0	Alcohols, C12, ethoxylated	Alcohol ethoxylates	LT-P1	Yes
9004-78-8	Polyoxyethylene phenol ether	Alcohol ethoxylates	LT-UNK	No

CAS number	Chemical name	Surfactant class	GreenScreen® List Translator *	SCIL listed ^
9004-95-9	Alcohols, C16, ethoxylated	Alcohol ethoxylates	LT-P1	Yes
9014-85-1	2,4,7,9-Tetramethyldec-5-yne-4,7-diol, ethoxylated	Alcohol ethoxylates	LT-P1	No
9043-30-5	Isotridecanol, ethoxylated	Alcohol ethoxylates	LT-UNK	Yes
134180-76-0	Oxirane, methyl-, polymer with oxirane, mono(3-(1,3,3,3-tetramethyl-1-((trimethylsilyl)oxy)disiloxanyl)propyl) ether	Alkoxylated siloxanes	NoGSLT	Yes
68603-58-7	t-Alkylamines, C12-14, ethoxylated	Alkyl amine ethoxylates	LT-UNK	No
9004-82-4	Polyoxy(1,2-ethanediyl), alpha-sulfo-omega-dodecyloxy-, sodium salt	Alkyl ether sulfates	LT-P1	Yes
110615-47-9	Lauryl glucoside	Alkyl polyglucosides	LT-UNK	Yes
246159-33-1	Cetearyl polyglucoside	Alkyl polyglucosides	NoGSLT	Yes
68515-73-1	D-Glucopyranose, oligomeric, decyl octyl glycosides	Alkyl polyglucosides	LT-UNK	Yes
126-92-1	Sodium ethylhexyl sulfate	Alkyl sulfates	LT-UNK	Yes
151-21-3	Sodium lauryl sulfate	Alkyl sulfates	LT-P1	Yes
5324-84-5	Sodium caprylyl sulfonate	Alkyl sulfonate	LT-UNK	Yes
68439-57-6	Alkenes, C14-16 alpha-, sulfonated, sodium salts	Alkyl sulfonates	LT-UNK	Yes
1639-66-3	Sodium dioctyl sulfosuccinate	Alkyl sulfosuccinates	LT-UNK	No
577-11-7	Bis(2-ethylhexyl) sodium sulfosuccinate	Alkyl sulfosuccinates	LT-P1	No
25155-30-0	Sodium dodecylbenzenesulfonate	Alkylbenzene sulfonates	LT-P1	Yes
27176-87-0	Dodecylbenzene sulfonic acid	Alkylbenzene sulfonates	LT-P1	Yes
68411-30-3	Benzenesulfonic acid, C10-13-alkyl derivs., sodium salt	Alkylbenzene sulfonates	LT-P1	No
85480-57-5	Potassium alkyl benzene sulfonate	Alkylbenzene sulfonates	LT-UNK	No

CAS number	Chemical name	Surfactant class	GreenScreen® List Translator *	SCIL listed ^
119345-04-9	Benzene, 1,1'-oxybis-, tetrapropylene derivatives, sulfonate	Alkyldiphenyloxide disulfonate	LT-P1	No
36445-71-3	Benzenesulfonic acid, decyl(sulfophenoxy)-, disodium salt	Alkyldiphenyloxide disulfonate	NoGSLT	No
61791-26-2	Tallow amine ethoxylated	Amine ethoxylates	LT-P1	No
1643-20-5	Lauramine oxide	Amine oxide	BM-2	Yes
61789-40-0	Cocamidopropyl betaine	Cocamides	LT-P1	Yes
68140-00-1	Coco monoethanolamide	Cocamides	LT-P1	No
61788-90-7	Cocamine oxide	Cocamine oxide	LT-P1	Yes
68604-71-7	Disodium cocoamphodipropionate	Coco esters	NoGSLT	Yes
61791-12-6	Castor oil, ethoxylated	Ethoxylated seed oil	LT-UNK	Yes
111-60-4	Ethylene glycol stearate	Fatty acid ester	LT-UNK	Yes
9004-99-3	Poly(oxy-1,2-ethanediyl), .alpha.-(1-oxooctadecyl)-.omega.-hydroxy-	Fatty alcohol ethoxylates	LT-UNK	Yes
70750-46-8	Tallow dihydroxyethyl betaine	Glyceride betaines ethoxylated	NoGSLT	No
111-76-2	2-Butoxyethanol	Glycol ethers	BM-2	No
532-02-5	Sodium alkylnaphthalene sulfonate	Naphthalene sulfonates	LT-UNK	No
68608-26-4	Sodium C10-18 secondary alkyl sulfonate	Petroleum sulfonates	LT-P1	Yes
9003-11-6	Polyethylene/polypropylene glycol	Polyalkylene glycol	LT-UNK	Yes
9005-64-5	Sorbitan monolaurate, ethoxylated	Sorbitan ester ethoxylates	LT-UNK	Yes
9005-65-6	Sorbitan monooleate, ethoxylated	Sorbitan ester ethoxylates	LT-P1	Yes
1338-41-6	Sorbitan monostearate	Sorbitan esters	LT-UNK	Yes
1338-43-8	Sorbitan monoloeate	Sorbitan esters	LT-UNK	Yes
71902-01-7	Sorbitan isostearate	Sorbitan esters	LT-UNK	No
61791-54-6	Amines, N-tallow alkyltrimethylenedi-, acetates	Tallow amines	NoGSLT	No

Appendix IV. Acknowledgements

Contributors and reviewers

- Courtney Hard, Project Lead, SRC, Inc.
- Catherine Rudisill, QC Reviewer, SRC, Inc.
- Laura Morlacci, QC Reviewer, SRC, Inc.
- Chrissy Coley, Contributor, SRC, Inc.
- Heather Printup, Contributor, SRC, Inc.

Acknowledgments

The authors of this report would like to thank the following people for their contributions to this study:

- Craig Manahan – Washington Department of Ecology
- Saskia van Bergen – Washington Department of Ecology
- Jon Jennings – Washington Department of Ecology
- Shingo Yamazaki – Washington Department of Ecology
- Barbara Losey – Alkylphenols & Ethoxylates Research Council
- Erika Schreder – Toxic-Free Future
- Mike Schade – Mind the Store
- Chris Cassell – Lowe's
- Shari Franjevic – Clean Production Action
- Pete Hurd – Washington State Department of Natural Resources
- Christoph Krumm – Sironix Renewables
- Michael Ernst – California Department of Toxic Substances Control
- Anne Doherty – California Department of Toxic Substances Control