SUBSPORT Specific Substances Alternatives Assessment – Nonylphenols and Nonylphenol ethoxylates

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1. Profiling nonylphenols and nonylphenol ethoxylates

1.1 Chemical identification

Profiling a chemical, under this chapter, means establishing its basic characteristics: identity and physico- chemical hazards. Uses and functions will be described in the chapter 2.

For groups of substances, as it is the case for nonylphenols and their ethoxylates, it is often hard to presented exhaustive information for all the members of the group. In this chapter information is generally focused on the most representative members of the group.

Nonylphenols and nonylphenol ethoxylates are both groups of chemicals, members of the large families of alkyl phenols (AP) and alkyl phenol ethoxylates (APE), respectively.
Nonylphenols (NP) have a phenolic ring on which a nine carbon alkyl chain is attached. The various nonylphenols are differentiated by the position in which the alkyl chain is attached to the phenolic ring and also by the structure of the alkyl chain (linear or branched).
Nonylphenols ethoxilates (NPE) result form the reaction of nonylphenol with ethylene oxide (EO). The degree of ethoxylation for commercially available ranges from four moles of ethoxylates (NPE4) to eighty moles of ethoxylates (NPE80) [1].
Industry production of nonylphenols and nonylphenol ethoxylates results in mixtures of isomers, containing also impurities like unreacted ethylene oxide, gycol ethers [2]

Nonylphenols and nonylphenol ethoxylates are largely used in industry, in grater quantities then other members of the APE family [1].

According to the Alkylphenols & Ethoxylates Research Council (APERC, 2002) [7] CAS number 84852-15-3 is the most descriptive of commercially available nonylphenols. The CAS numbers 25154-52-3 and 04-40-5 are considered by APERC less descriptive with respect to the branching and position of the nonyl group. Also, 'linear, or normal, n-NP is difficult to produce and is therefore less likely to be commercially relevant' [3].

For NPE, there are some CAS registration numbers specific to certain levels of ethoxylates, however, all degrees of ethoxylation may be manufactured under the CAS number for poly-ethoxylates (CAS 127087-87-0), as long as they are synthesized via polymerization reaction between NP and EO, according to US EPA [1].

In tables 1 and 2, examples of nonylphenols and nonylphenol ethoxylates are not exhaustive but include the most used ones [1, 2, 4, 5, 7].

Table 1. Substance identification: non exhaustive examples of nonylphenols

Group name: nonylphenols	
Chemical name	**4-Nonylphenol, branched**
Identification number	CAS: 84852-15-3 * EC : 284-325-5
Other names	Phenol, 4-nonyl-, branched
Chemical name (IUPAC)	**4-Nonylphenol**
Identification number	CAS: 104-40-5 EC : 203-199-4
Other names	Phenol, 4-nonyl-; p-nonylphenol
Chemical name (IUPAC)	**p-Isononylphenol**
Identification number	CAS: 26543-97-5 EC : 247-770-6
Other names	Phenol, 4-isononyl- n-Nonylphenol (mixed isomers)
Chemical name	**Nonylphenol**
Identification number	CAS: 25154-52-3** EC : 246-672-0
Other names	n-Nonylphenol (mixed isomers)
Chemical name (IUPAC)	4-(1,1- Dimethylheptyl)phenol
Identification number	CAS: 30784-30-6 EC : 250-339-5
Other names	p-(1,1-dimethylheptyl)phenol; phenol, 4-(1,1-dimethylheptyl)-
Chemical name (IUPAC)	**4-(1-Methyloctyl)phenol**
Identification number	CAS: 17404-66-9 EC: 241-427-4
Other names	p-(1-methyloctyl)phenol
Chemical name (IUPAC)	**4-(1-Ethyl-1-methylhexyl)phenol**
Identification number	CAS: 52427-13-1 EC: 257-907-1
Other names	Phenol, 4-(1-ethyl-1-methylhexyl)-

*) Initially it was not clearly differentiated from linar Nonylphenol in ESIS

**) It used to cover all nonylphenols but is currently used for linear ones.

Table 2. Substance identification: non exhaustive examples of nonylphenol ethoxylates

Group name: nonylphenols ethoxylates	
Chemical name	**2-(p-Nonylphenoxy) ethanol**
Identification number	CAS: 104-35-8 EC: -
Other names	-
Chemical name	**2-[2-(4-nonylphenoxy)ethoxy] ethanol**
Identification number	CAS: 20427-84-3 EC: 243-816-4
Other names	2-(2-(p-Nonylphenoxy)ethoxy) ethanol
Chemical name	**p-Nonylphenol polyethylene glycol ether**
Identification number	CAS: 26027-38-3 EC: 500-045-0
Other names	4-Nonylphenol, ethoxylated
Chemical name	**Nonylphenol hepta(oxyethylene)ethanol**
Identification number	CAS: 27177-05-5 EC: 248-293-6
Other names	23-(nonylphenoxy)-3,6,9,12,15,18,21-heptaoxatricosan-1-ol
Chemical name	**Nonylphenol nona(oxyethylene)ethanol**
Identification number	CAS: 27177-08-8 EC: 248-294-1
Other names	29-(nonylphenoxy)-3,6,9,12,15,18,21,24,27-nonaoxanonacosanol
Chemical name	**1-ethoxy-3-nonylbenzene**
Identification number	CAS: 28679-13-2 EC:-
Other names	Ethoxynonyl-benzene
Chemical name	**Nonylphenoxy ethanol**
Identification number	CAS: 27986-36-3 EC: 248-762-5
Other names	2-(nonylphenoxy)ethanol
Chemical name	**Nonylphenol polyethylene glycol ether**
Identification number	9016-45-9 500-024-6
Other names	Nonylphenol, ethoxylated
Chemical name	Ethanol, 2-[2-(nonylphenoxy)ethoxy]-
Identification number	27176-93-8 248-291-5
Other names	2-[2-(nonylphenoxy)ethoxy]ethanol
Chemical name	Nonylphenol ethoxylate
Identification number	37340-60-6
Chemical name	Poly(oxy-1,2-ethanediyl), alpha-(2-nonylphenyl)-omega-hydroxy-
Identification number	51938-25-1
Chemical name	Nonylphenol ethoxylate
Identification number	68412-53-3

1.2 Hazard identification

Characterising a substance based on its hazards is essential in alternatives assessment, when comparing it to the substitute.

Hazards are intrinsic to the chemical, which means that regardless of the way a chemical is used, these characteristics do not change. The goal of the substitution processes is to advance inherently safer chemicals and products, consistent with the principles of green chemistry.
This approach allows the reviewer to assess whether or not an alternative is indeed preferable from an environmental, health and safety perspective.

The wide range of substances included in the two studied groups (nonylphenol and NPE) is not easy to describe in terms of properties and hazards.

In table 3, hazards for representative examples of nonylphenols are provided. Initially CAS 25154-52-3 inlcuded linear and branched species, but was revised to refer only to linear ones. Hazards for the two groups are generally presented together.

Table 3. Hazard characteristics of nonylphenols

Properties		Source of information
Phenol, 4-nonyl-, branched CAS: 84852-15-3, EC : 284-325-5 and Nonylphenol CAS: 25154-52-3, EC : 246-672-0		
SAFETY HAZARDS		
Explosivity	Not expected to be explosive based on its structure	ECHA Risk Assessment, 2002 [8]
Flammability	conclusive but not sufficient for classification Indicative flash-point 141-155°C	ECHA registred substances, data dossier, 2012 [4] ECHA Risk Assessment, 2002 [8]
Oxidizing	Not expected to be oxidiser, based on its structure	ECHA Risk Assessment, 2002 [8]
Other properties of reactivity	-	
HUMAN HEALTH HAZARDS		
Acute toxicity		
Highly toxic	No Acute Tox 4 – Harmful if swallowed - H302	CLP, List of harmonised classification and labelling of hazardous substances
Skin or eye corrosion / irritation	Yes Skin Corr. 1B causes severe skin burns and eye damage- H314	CLP, List of harmonised classification and labelling of hazardous substances
Chronic toxicity		
Carcinogenicity	…'it is considered unlikely that that nonylphenol is mutagenic, so concerns for cancer caused by a genotoxic mechanism are low'.	ECHA Risk Assessment, 2002 [8]
Mutagenicity	See above	ECHA Risk Assessment, 2002 [8]
Reproductive toxicity (including developmental toxicity)	Yes Repr.2 - Suspected of damaging fertility or the unborn child –H361fd	CLP, List of harmonised classification and labelling of hazardous substances

Properties		Source of information
Endocrine disruption	Yes Estrogenic effects	ECHA Risk Assessment, 2002 [8], ECHA registred substances, data dossier, 2012 [4]
Respiratory or skin sensitization	Lacking data Low skin sensitization potential	ECHA registred substances, data dossier, 2012[4] US EPA 2010[6]
Neurotoxicity	Lacking data	-
Immune system toxicity	Lacking data	-
Toxic metabolites	Lacking data	-
ENVIRONMENTAL HAZARDS		
Acute/chronic aquatic toxicity	Yes Acute Cat 1, Very toxic to aquatic life-H400 Cronic Cat 1, Very toxic to aquatic life-H410	CLP, List of harmonised classification and labelling of hazardous substances
Bioaccumulation	Calculated bioacc.factor- BCF:1,280, significant but not classifiable as bioaccumulative Moderately bioaccumulative	ECHA Risk Assessment, 2002 [8] US EPA 2010
Persistence	Not readily biodegradable; persistence increases with branching	ECHA registred substances, data dossier, 2012 [4]
Greenhouse gas formation potential	Not applicable	-
Ozone-depletion potential	Unlikely	ECHA Risk Assessment, 2002 [8]
Monitoring – has the substance been found in human or environmental samples?		

Table 4. Hazard characteristics of nonylphenol ethoxylates

Properties		Source of information
4- Nonylphenol, branched, ethoxylated, CAS: 127087-87-0, EC: 500-315-8		
SAFETY HAZARDS		
Explosivity	Not expected to be explosive based on its structure	ECHA Risk Assessment, 2002 [8]
Flammability	Lack of data for classification Unlikelly to be flammable Indicative flash-point 150°C	C&L Inventory Danish EPA , 2009[10]
Oxidizing	Lack of data for classification	C&L Inventory
Other properties of reactivity	Unlikelly Autoignition point: 425 °C for NPE9 (NPE with 9 ethoxy gr.)	Danish EPA , 2009[10]
HUMAN HEALTH HAZARDS		
Acute toxicity		
Highly toxic	No Sligtly toxic, LD50: 1680-5000 mg/kg	US EPA, 2006 [11]

Properties		Source of information
Skin or eye corrosion / irritation	Eye damage Corrosive to skin (shorter ethoxylated chain NPEs)	ECHA C&L Inventory
Chronic toxicity		
Carcinogenicity	Lacking data	-
Mutagenicity	Lacking data	-
Reproductive toxicity (including developmental toxicity)	Insufficient data Self classified Repr.2 - Suspected of damaging fertility or the unborn child –H361fd	C&L Inventory self classification
Endocrine disruption	Yes	US EPA , 2012 [1] SUBSPORT –SIN List
Respiratory or skin sensitization	Lacking data	-
Neurotoxicity	Lacking data	-
Immune system toxicity	Lacking data	-
Toxic metabolites	Lacking data	-
ENVIRONMENTAL HAZARDS		
Acute/chronic aquatic toxicity	Yes Acute toxicity: -LC50: 1.0-14 ppm (fish), for NPE9 (NPE with 9 ethoxy gr.) -EC50: 2.9-14ppm, daphnia, for NPE9 -EC50: 12ppm, green algae, for NPE9	US EPA , 2012 [1]
Bioaccumulation		
Persistence	Moderate : not readily biodegradable (cf.OECD 30days test)	US EPA, 2012 [1]
Greenhouse gas formation potential	Not applicable	-
Ozone-depletion potential	Unlikely	ECHA Risk Assessment, 2002 [8]
Monitoring – has the substance been found in human or environmental samples?	Yes	US EPA , 2010 [6] WWF [12] Soares at al, 2008 [13]

1.3 Specific regulations

The concern about the hazards of nonylphenol and NPE generated legal restrictions and action plans in Europe and world wide.

In 1992 the Paris Commission (PARCOM) recommended studies on the concentration of NPE and similar substances in sewage and surface water, the phase out of NPE in domestic and cleaning agents, identify and exchange information on substitutes.
The 1995 Ministerial Declaration on the Protection of the North Sea at Esbjerg requested OSPAR Commissions and the European Commission to “adopt necessary measures” by year 2000.

EU Water Framework Directive 2000/60/EC: Framework for action Community in the field of water policy and identifying the priority pollutants classified nonylphenols as priority hazardous chemicals

EU Regulation 166/2006 for the creation of a European Pollutant Release and Transfer Register (PRTR) sets thresholds for mandatory notification of the release of nonylphenol and nonylphenol ethoxylates in water or soil: 1 kg / year.

Directive 2003/53/EC amending Directive 76/769/EEC relating to restrictions on the marketing and use of certain dangerous substances and preparations provides that nonylphenol and nonylphenol ethoxylate may not be placed on the market or used as a substance or constituent of preparations in concentrations equal or higher than 0,1 % by mass for the following purposes:

1) industrial and institutional cleaning except:
   - controlled closed dry cleaning systems where the washing liquid is recycled or incinerated,
   - cleaning systems with special treatment where the washing liquid is recycled or incinerated;
2) domestic cleaning;
3) textiles and leather processing except:
   - processing with no release into waste water,
   - systems with special treatment where the process water is pretreated to remove the organic fraction completely prior to biological waste water treatment (degreasing of sheepskin);
4) emulsifier in agricultural teat dips;
5) metal working except uses in controlled closed systems where the washing liquid is recycled or incinerated;
6) manufacturing of pulp and paper;
7) cosmetic products;
8) other personal care products except spermicides;
9) co-formulants in pesticides and biocides.

From January 2005 Directive 2003/53/EC came into force. Even before this, voluntary phase–out occurred in companies or sectors or were regulated at national level[12].

In 2004 'Environment Canada' published the Risk Management Strategy for Nonylphenol and its Ethoxylates Under the Canadian Environmental Protection Act, 1999 (CEPA) [14]. Nonylphenol and NPEs are listed as toxic substances and measures to reduce environemnetal risks were proposed.

In 2010 the USA initiated an Action plan to reduce the risks from nonylphenols and NPEs. The Plan initiated rulemaking, encouraged on-going voluntary phase-out of NPEs and evaluated (in 2012) alternatives to NPEs through the Design for the Environment programme.

Nonylphenols and Nonylphenol ethoxylates are not allowed as ingredients in cleaners by ecolabels EU flower and the Swan.

2. Identifying functions and uses

2.1 Nonylphenols and nonylphenol ethoxylates uses

Nonylphenols are used to fabricate nonylphenol ethoxylates but have also other uses, mostly as intermediates or catalysts, as presented in table 4.

Nonylphenol ethoxylates (NPE) are chemicals that have surface – active properties that make them useful as surfactants, wetting agents, emulsifiers and dispersants.
Nonylphenolethoxylates with less than 10 ethoxyl groups (EO) are used as detergents, i.e. they dissolve a small amount of dirt/grease in a great deal of water. Nonylphenolethoxylates with

between 10 and 30 EO are used as emulsifiers, i.e. they help to form stable systems of more fat in less water. Nonylphenolethoxylates with up to 80 EO can be used as dispersants.

Main uses of NPE are also presented in table 5.

Table 5. Nonylphenols and nonylphenol ethoxylates uses - overview

Sector	Function	Product, article	Source of information
Nonylphenol			
20. Manufacture of chemicals and chemical products	Intermediate	Nonylphenol ethoxylate -surfactant	Min. Env. Netherlands, 2001[2]
24.16 : Manufacture of plastics in primary forms	Intermediate (monomer)	Phenol/formaldehyde resins	Min. Env. Netherlands, 2001[2]
24.16 : Manufacture of plastics in primary forms	Intermediate	Tri (4-nonylphenyl) phosphite (TNPP)- antioxidant	idem
24.16 : Manufacture of plastics in primary forms	Curing catalyst	Epoxy resins	idem
27 : Manufacture of basic metals		Phenolic oximes - extraction reagent	idem
24.16 : Manufacture of plastics in primary forms	Heat stabiiser (as barium, calcium salts)	PVC	US EPA, 2010 [6]
Nonylphenol ethoxylates			
24.5 : Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations	Surfactant	Detergents, cleaners	US EPA , 2012 [1] Fraunhofer Oekopol 2006 [3]
24 : Manufacture of chemicals and chemical products	Emulsifier	polymers (coatings, paints, adhesives)	idem
26.6 : Manufacture of articles of concrete, plaster and cement	Release agent	mold release agents	idem
1.1 : Extraction of crude petroleum and natural gas	Coolant	lubricants, drilling oils	idem
DL : Manufacture of electrical and optical equipment		flux for electronics printed circuit boards- PCB	idem
21 : Manufacture of pulp, paper and paper products	De-inking agent	recycled paper	Idem
DB : Manufacture of textiles and textile products	Scouring agent	textiles	Idem

Sector	Function	Product, article	Source of information
21 : Manufacture of pulp, paper and paper products 37.2 : Recycling of non-metal waste and scrap	Wetting agent	pulp & paper	Idem
DC : Manufacture of leather and leather products	Degreaser	leather and hides	Idem
24.2 : Manufacture of pesticides and other agro-chemical products	Wetting agent	pesticides	Idem
24.2	Surfactants	vet medicinal products	Idem
24.2	Wetting agent	photographic film	idem

Recent data on quantities for NP and NPE produced, processed or commercialised are hard to find at EU or international level. Many of the information dates back before the EU restrictions were introduced.
According to REACH registration data for branched, 4- nonylphenol (CAS 85852-135-3) the total production and import is in the range 10,000-100,000 t/year.
Nonylphenol ethoxylates (under CAS 8412-54-1)4 are registered in the range of 2,000-20,000 t/year.

At national level, data is available in more detail for the past years.
A report published by Danish EPA in 2012 [15] estimated the total consumption using data from the Danish Product Register for different alkylphenols and their ethoxylates. Data regarding NP and NPEs are presented in table 6.

Table 6. NP and NPE placed on the market in different mixtures in Denmark, in 2011

CAS	Name	Number of mixtures	Registered tonnage, t/year		
			Production and import	Export	Consumption
Nonylphenol					
25154-52-3	nonylphenol	84	32.513	3.651	28.862
84852-15-3	phenol, 4-nonyl, branched	7	0.091	0.000	0.091
104-40-5	4-nonylphenol	Confid.	-	-	-
	TOTAL (excluding confidentials)		32.604	3.051	28.953
Nonylphenol ethoxylates					
9016-45-9	nonylphenol ethoxylated	186	119.711	11.109	108.602
26027-38-3	4, nonylphenol ethoxylate	13	0.014	0.004	0.010
37025-87-1	poly(oxy-1,2-ethanediyl)α(isononylphenyl)-ωhydroxy	41	5.041	0.283	4.758
68412-54-4	2-{2-[4-(2,4,5-trimethylhexan-3yl)phenoxy]polyethoxy}ethanol	103	44.064	17.558	26.506
127087-87-0	4-nonylphenol branched, ethoxylated	8	0.467	0.192	0.275
	TOTAL		169.298	29.146	140.152

Source: adapted from Danish EPA , 2012 [15]

In Germany, a significant drop in production, export and use of nonylphenol was registered in 2005, the year when 2003/53 Directive entered into force (on January first), compared to year 2000, for example, as presented in table 7.

Table 7. Production, comercialisation and use of para nonylphenol in Germany, in 2000 and 2005

Year	Production t/year	Import t/year	Export t/year	Used for production of other chemicals, t/year				Total use t/year
				NPE	Phenolic resins/paints	Tnpp	Epoxy resins	
2005	19,000	2,000	12,000	6,000	2,400	400	200	9,000
2000	37,000	4,000	19,800	17,000	3,500	600	100	21,000

Source : Fraunhofer&Oekopol, 2006 [7]

The Swedish Cemical Agency - KEMI has published the mass flow of nonylphenol ethoxylates (CAS 127087-87-0, 26027-38-3, 37205-87-1, 68412-54-4, 9016-45-9), based on the national Products Register. Data on the most recent years are presented in table 8 (KEMI, 2012).

Table 8. NPE produced or imported as raw material in Sweden, 2007-2010

Year	2007	2008	2009	2010
Production (t/year)	22	60	58	68
Import (t/year)	6	55	No data	12

Source KEMI, 2012 [16]

As it can be seen from the examples above, production and use of NP and NPE was considerably reduced, but continued after EU restrictions, even in countries such as those mentioned, that are among the most active in compulsory and voluntary restrictions.

2.2 Exposure to nonylphenol and nonylphenol ethoxylates

Occupational exposure

The US National Occupational Exposure Survey (1981 - 1983) listed 108 detailed occupations for which exposure to nonylphenol (CAS 25154-53-3) occurred at that time [17]. Among the occupations with the highest number of exposed persons were those presented in table 9.

Table 9. Examples of occupations exposed to nonylphenol. National USA survey 1981-1883

Occupations exposed to nonylphenol	
Mechanics (heavy equipment, airplanes, automobile etc)	Cutters
Maids and housmen	Repairers
Janitors and cleaners	Medical professionals
Printing operators	Sales workers
Textile workers	Carpenters
Waving opperators	Painting, paint spraying
Printing operators	Sheet metal workers
Construction workers	Production inspectors
Machinists	Furniture and woode finishers
Assemblers	

Source: NIOSH, 1983 [17]

More recent sources [1,18] consider that nonyplhenol is mostly used in closed systems, therefore, limiting occupational exposure. Such exposure may however, occur via dermal contact or inhalation when charging mixing vessels and while manufacturing and using speciality paints.
The report of the Scientific Committee on Occupational Exposure Limits (SCOEL) declared that available data are not sufficient to propose occupational exposure limits (OELS) for nonylphenol[18].

Environenmtal exposure
NP and NPEs have been found in environmental samples taken from freshwater, saltwater, groundwater, sediment, soil and aquatic biota [6].
Water is the environmental compartment most affected by nonylphenol and NPE pollution, because of the considerable quantities discharged in industrial municipal and agriculture waste water. Soil may also be polluted, directly or through contaminated water and atmospheric deposition. Air seems to be affected to lesser extent, as the pollutants considered are not very volatile and aerosols are not very stable and tend to decompose.
Aquatic and terrestrial ecosystems are mostly at risks, and some studies consider the risk level unacceptable [19].

Table 10. Estimated EU-wide emissions nonylphenols (NP) and nonylphenol ethoxylates (NPE) in water

Use	NP [kg/day] Surface Water	NPE [kg/day] Waste Water
Nonylphenol (NP)		
NP Production	0,1	-
NPEO Production (NP release)	137,7 0,38	-
Phenol/formaldehyde resins	0,2	-
TNPP Production	0	-
Epoxy resins	0,12	-
Production other plastic stabilizers	0,43	-
Phenolic oximes	0	-
Sub Total	**139**	-

Use	NP [kg/day] Surface Water	NPE [kg/day] Waste Water
Nonylphenolethoxylates (NPE)		
NPE Production (NPE release)	152	526
Formulation	13,3	533
Agricultural use	30,8	1.233
Captive use by chemical industry	3	120
Elect. engineering industry	0,03	1,15
Industrial and institutional cleaning	1.276	51.041
Leather processing	174	6.962
Metal extraction	35	1.402
Mineral and fuel oil	0,25	10
Photographic industry	4,58	183
Polymer industry	0,06	2,22
Pulp, paper and board industry	49,3	1.973
Textile processing	419	16.767
Paints, lacquers and varnishes: -manufacture - use	 1,23 4	 49,3 160
Civil engineering	0,57	22,9
Other applications (incl. Import)	677	27.074
Sub Total	**2.840**	**108.060**
Total	**2.979**	**108.060**

Source: ECHA 2002 [8]

In table 10 the sectors generating the highest emissions of NP and NPE in water, before the Directive 2003 /53 came into force, were :
-for NP: NPE production, by far the most important source, followed by plastic stablisers and phenol/formaldehyde resisns production (both with much lower emissions).
-for NPE: industrial and institutional cleaning, textile processing, leather processing and pulp&paper&board.

General population exposure
Nonylphenol has been detected in human breast milk, blood, and urine and is most probably caused by exposure to decomposition products of nonyplhenol ethoxylates [6].
Population may be exposed to nonylphenol and nonylphenol ethoxylates in nonionic surfactants in cleaners, pesticides and some personal care products.

2.3 Prioritizing uses

Consumption levels are important factors in determining the uses that sould be addressed as priority when searching for substitution. This information may provide some idea on the exposure to humans and environment. It is reasonable to assume that uses with high consumption level of a certain chemical have the potentiall to impact more on health and environment. This is indeed one of the indicators considered in practice, because it is often more readily available than other data, which are also important: number of wokers exposed and the level of occupational exposure, existence of voulnerable groups (like children), level of environmental emissions and fate.

For example, in the table 11 , the highest quantity of NPE used in Germany in 2000 was for emulsion polymerisation. However, the emissions in sewage for this use, were much lower than for other sectors, like industrial cleaners, leather & textiles or construction.

Table 11. Overview of NPE quantities used or emitted, in various applications in Germany, in 2000 and 2005. In italics are applications that fall under EU Directive 2003/53/EC

Sector /application	Quantity used (t) 2000	Emissions in sewage (t) 2000	Quantity used (t) 2005
Emulsion polymerization	1.400	7	800
Leather / textile auxiliaries	***320***	***37***	***150***
Construction Chemicals	825	83	200
Industrial cleaners	**70**	**63**	**0**
Coolants	210	6	30
Flocculants	30	30	0
Colors and coatings	200	1	70
Offshore applications	No data	No data	No data
Photographic Industry	25	No data	No data
Medical (veterinary) products	***10***	*No data*	*No data*
Raw / finished textiles import	No data	500	No data
Agro-chemistry	***250***	***25 t (water emission)***	***100***

Source Fraunhofer&Oekopol, 2006 [7]

Emissions in water are important, since water ecosystems are, as mentioned, the most likely to be affected. Uses for consumers goods are also very important, for example in the case of textiles, leather, cosmetics, that may be in direct contact with the skin.

2.4 Conclusion

The exposure to NP and NPE is a big issue in sectors with a high consumption as well as in sectors were there is a high level of pollution, especially to water.

Because of the nature of the processes in which is involved, direct exposure to NP is considered [1, 18] to occur at lower levels than NPE , which can decompose in the environment into NP. NPE exposure for the cleaning, textile&leather and pulp&paer sectors are of high concern because of the level of use and emissions.

Reports are already published for NPE alternatives in detergents and cleaners, in USA , 2012 [1] and in the textile industry by the Danish Environemnt Ministry , 2013 [20] or as EU document for best available techniques BREF [21].

Therefore, this report will identify and prescreen alternatives for the main (five) uses of NP and NPE and will proceed with further characterisation and comparison of alternatives to NPE in the leather sector. The leather sector has one of the highest rates of emissions into water, manufactures consumer goods and preliminary operations are often carried out in less developed areas, with limited awareness of health and environmental effects. The EU BREF document [22] for tanning hidedes and skins lacks information regarding NPE substitutes to guide enterprises that have to prove integrated pollution control measures.

3. Preliminary identification of alternatives

Tables 12, 13 present alternatives to nonylphenol and nonylphenol ethoxylates. They are listed without priority, and do not represent recommendation of commercial product by SUBSPORT. A prescreening of the listed alternatives can be found in chapter 4 for the main uses and in chapter 5 for leather degreasing use.

3.1 Alternatives for nonylphenol

Table 12. Examples of alternatives to nonylphenol and derivatives

Use	Alternative	Note
NPE	-	-
TNPP	-	TNPP itself can be substituted by (2,4-di-tert-butylphenyl) phosphite [23]
Phenolic resins	Phenol	Resin use: coatings, adhesives, circuit boards [24]
	Cresol	Resin use: Coatings, epoxy hardeners [24]
	p-t Butylphenol	Resin use: Coatings, adhesives [24]
	p-Octylphenol	Resin use: Carbonless paper, coatings [24]
	pPhenyl phenol	Resin use: Carbonless paper [24]
	BisphenolA	Low coatings molding compounds, coatings [24]
	Resorcinol	Resin use: Adhesives [24]
	Cashewnut shell liquid	Friction particles [24]
Rubber	Dixylene disulphide	[25 26],
	Diallyl disulphide	[27]
	Bitumen	[28]
PVC	Alpha-tocopherol	[29, 30]
Epoxy resins	Diethylene triamine	[31, 32]
	Tetraethylene-pentamine	
	N –aminoethyl piperazine	
	4,4, diaminodiphenyl methane	

3.2 Alternatives for nonylphenol ethoxylates

Alternatives have been found and implemented for most uses of nonylphenol ethoxylates. An overview is presented in table 14 and examples of alternatives are given in table 15 .

Table 14 Overview of the type of alternatives to various applications of NPE

Use	Alternative
Detergents and cleaners	- alcohol ethoxylates - fatty acids and derivatives - fatty amines - unsaturated hydrocarbons
Paint	- fatty alcohol ethoxylates - esterified linseed oil - nonionic tensides - phosphate esters - potassium polycarboxylates
Adhesives	- fatty alcohol ethoxylates
Textiles	- alcoholethoxylates
Leather	- fatty alcohol ethoxylates - mixtures of alcohol ethoxylates - anionic surfactants

Source: OSPAR , 2009 [33]

Different formulations are needed to match various application detailed requirements.
Some general observation hade been made on the relation between structure and properties, for example on alcohol ethoxylates, a large group of chemicals, highly used as alternatives.

In the guidance published by a producer the following indications are given[28]:

- influence of alkyl chain length: longer chain reduce wetting properties but increase emulsifying properties,while foame is maximum at middle chain length
- influence of chain structure: higher branching increases wetting, decreases foaming and is slowing biodegradability
- influence of polyoxyethylene chain length: medium ethoxylation degrees give the best surface active and wetting properties; highly ethoxylated alcohols have very good dispersing properties.

In table 15 examples of alternatives are presented.

Table 15. Example of alternatives to nonylphenol ethoxylates

	Alternative	Note
Detergents and cleaners	C9-11 Alcohol, ethoxylated (6EO)	[1]
	C12-15 Alcohol, ethoxylated (9EO)	
	Oxirane, methyl-polymer with oxirane, mono(2 ethylhexyl ether)	
	Oxirane, methyl-polymer with oxirane, mono(2 ethylhexyl ether)	
	D-Glucopyranose, oligomeric, decyl octyl glycosides (Alkyl polyglucose –APG)	
	Benzensulfonic acid, C10-13 alkyl derives.sodium salt (Linear alkylbenzene sulfonates LAS)	
	Sodium lauryl sulfate (Alkyl sulfate esters-AS)	
	Polyoxy (1,2 ethandiyl) alpha-sulpho-omega-dodecyloxy-, sodium salt (Alkyl ether sulfates –AES)	
	Sorbitan monostearate(Sorbitan esthers)	
	Octylphenol ethoxylate	
Paint. Emulsion polymeri-sation	Alkyl polyethylene glycol ether (5EO)	http://www.paints-coatings.clariant.com/C12576720021BF8F/vwWebPagesByID/63E52272050ECA40C125770A002E795C [34]
	Alkyl polyethylene glycol ether (7EO)	
	Alcohols, C12-14-secondary, ethoxylate CAS 84133-50-6	http://www.green-chemical.com/down/MSDS-e/15-S-40.pdfv [35]
Paint&ink Pigment dispersant	Sodium salt of castor oil polyoxyethylene sulphosuccinic acid ester	http://www.specialchem4coatings.com/tds/selector/additives/10589/index.aspx?did=0&lr=google&gclid=CJGe9dSZv7cCFcVa3godqyEA2w [36] http://www.clariant.com/C12576720021BF8F/vwWebPagesByID/D577CCA4193BF41FC125770A00309BF0 [37]
	Alcohols, C8-22, ethoxylated CAS 69013-19-0	https://apdirect.airproducts.com/msds/DisplayPDF.aspx?docid=63503 [38]
	Inulin, carboxymethyl ether, sodium salt CAS 430439-54-6	http://www.saael.com/en/saa/?type=detail&id=5367 [39]
Textiles	Sodium laurylsulfate	http://www.thesmarttime.com/faq/apeo-free-surfactants.htm [40]
	Polyoxy (1,2 ethandiyl) alpha-sulpho-omega-dodecyloxy-, sodium salt (Alkyl ether sulfates –AES)	
Leather	Lipase	http://www.tfl.com/web/files/Competence-Articve-Borron.pdf [41]
	Oxirane, 2-methyl-, polymer with oxirane, mono(2-propylheptyl) Ether CAS 166736-08-9	http://www.prismadye.com/Files/MSDS/EN/MSDS%20EUSAPON%20OE%20%20(E).pdf [42]
	Water (hot)	http://www.leathermag.com/features/featurehot-water-treatment-for-degreasing-sheepskins [43]
	Fatty alcohol ethoxylates (FAEs)	
	Dodecan-1-ol, ethoxylated CAS 9057-32-3	BREF, 2003 http://www.arpc.ir/Portals/0/Pdf/Products/Chemical/lae.pdf [44]

4. Screening out regrettable substitutes

The purpose of this chapter is to eliminate any alternatives that would pose a high risk to the environment or human health. SUBSPORT developed a database containing substances that are not acceptable as alternatives due to their hazards. The alternatives are all screened against this database. It can be found on the SUBSPORT database by following this link: http://www.subsport.eu/case-stories-database. If a substance meets any of the SUBSPORT screening criteria, it is removed from further consideration as an appropriate alternative, unless the author (SUBSPORT) regards the alternative safer than the original substance.

4.1 Screening of alternatives to nonylphenol

Table 16. Prescreening alternatives to nonylphenol against SUBSPORT SDSC database of substances known to be very hazardous

Alternative	Prescreening against SDSC	Recommendation
Use: phenolic resins intermediate		
Phenol CAS 108-95-2	Not listed	Further evaluation should proceed
Cresol CAS 106-44-5	Listed as EC endocrine disruptor cat 2	Avoid use
p-tert Butylphenol CAS 98-54-4	Listed as EC endocrine disruptor cat 2	Avoid use
p-Octylphenol CAS 140-66-9	Listed as EC endocrine disruptor cat 1	Avoid use
p Phenylphenol CAS 92-69-3	Listed as EC endocrine disruptor cat 2	Avoid use
BisphenolA CAS 80-05-7	Listed as EC endocrine disruptor cat 1	Avoid use
Resorcinol CAS 108-46-3	Listed as EC endocrine disruptor cat 1 and endocrine disruptor in SIN list	Avoid use
Cashewnut shell liquid CAS 8007-24-7	Not listed	Further evaluation should proceed
Use: Rubber reclaiming agent		
Dixylene disulphide CAS 27080-90-6	Not listed	Further evaluation should proceed
Diallyl disulphide CAS 2179-57-9	Not listed	Further evaluation should proceed
Bitumen CAS 8052-42-4	Listed as IARC carcinogen group 2	Avoid use
Use: PVC stabiliser		
Alpha-tocopherol CAS 10191-41-0	Not listed	Further evaluation should proceed
Use: Epoxy resins curing agent		
Diethylene triamine, CAS 111-40-0	Listed as CLP sensitizer	Avoid use
Tetraethylenepentamine	Listed as CLP sensitiser	Avoid use
N –aminoethyl piperazine CAS 140-31-8	Listed as CLP sensitiser	Avoid use
4,4, diaminodiphenil methane	Listed as CLP sensitiser and CMR	Avoid use
TNPP alternative antioxidant		
(2,4-di-tert-butylphenyl) phosphate, CAS 31570-04-4	Not listed	Further evaluation should proceed

4.2 Screening of alternatives for nonylphenol ethoxylates

Table 17. Prescreening alternatives to nonylphenol against SUBSPORT SDSC database of substances known to be very hazardous

Alternative	Prescreening against SDSC	Recommendation
Use: Detergents and cleaners surfactants		
C9-11 Alcohol, ethoxylated (6EO) CAS 68439-46-3	Not listed	Further evaluation should proceed
C12-15 Alcohol, ethoxylated (9EO) CAS 68131-39-5	Not listed	Further evaluation should proceed
Oxirane, methyl-polymer with oxirane, mono(2 ethylhexyl ether) CAS 64366-70-7	Not listed	Further evaluation should proceed
D-Glucopyranose, oligomeric, decyl octyl glycosides CAS 68515-73-1	Not listed	Further evaluation should proceed
Benzensulfonic acid, C10-13 alkyl derivs., sodium salt CAS 68411-30-3	Not listed	Further evaluation should proceed
Sodium lauryl sulfate (Alkyl sulfate esters-AS) CAS 151-21-3	Not listed	Further evaluation should proceed
Polyoxy (1,2 ethandiyl) alpha-sulpho-omega-dodecyloxy-, sodium salt CAS 9004-82-4	Not listed	Further evaluation should proceed
Sorbitan monostearate CAS 1338-41-6	Not listed	Further evaluation should proceed
Octylphenol ethoxylate CAS 9002-93-1	Listed as endocrine disruptor (SIN List)	Avoid use
Use: Paint, ink , paper dispersants		
Sodium salt of castor oil polyoxyethylene sulphosuccinic acid ester	Not listed	Further evaluation should proceed
Alcohols, C8-22, ethoxylated CAS 69013-19-0	Not listed	Further evaluation should proceed
Inulin, carboxymethyl ether, sodium salt CAS 430439-54-6	Not listed	Further evaluation should proceed
Use: Textiles surfactants		
Sodium laurylsulfate CAS 151-21-3	Not listed	Further evaluation should proceed
Polyoxy (1,2 ethandiyl) alpha-sulpho-omega-dodecyloxy-,sodium salt CAS 9004-82-4	Not listed	Further evaluation should proceed
Polyoxyethylene alkyl ether, CAS 9002-92-0	Not listed	Further evaluation should proceed
Polyoxy tridecyl ether CAS 24938-91-8	Not listed	Further evaluation should proceed
Alcohols C 10-16, ethoxylated	Not listed	Further evaluation should proceed

Alternative	Prescreening against SDSC	Recommendation
Use: Paint.Emulsion polymerisation		
Alkyl polyethylene glycol ether (5EO)		
Alkyl polyethylene glycol ether (7EO) CAS		
Alcohols, C12-14-secondary, ethoxylate CAS 84133-50-6	Not listed	Further evaluation should proceed
Use: Leather degreasers		
Lipase CAS 9001-62-1	Not listed	Further evaluation should proceed
Oxirane, 2-methyl-, polymer with oxirane, mono(2-propylheptyl) ether , CAS 166736-08-9	Not listed	Further evaluation should proceed
Water (hot) CAS 7732-18-5	Not listed	Further evaluation should proceed
Fatty alcohol ethoxylates (FAEs), CAS 37335-03-8	Not listed	Further evaluation should proceed
Alcohols, C10-13, ethoxylated, CAS 9057-32-3	Not listed	Further evaluation should proceed

5. Characterizing alternatives

5.1. Hazard characterization of alternatives for leather degreasing

In the case of alternatives for leather degreasing that passed the prescreening phase, further investigations regarding their hazards are presented bellow. Because of its acknowledged lack of toxicity, water was not evaluated, though is one of the alternatives.

Table 18. Hazard characteristics of lipase

Hazards	Evaluation	Source of information
Lipase CAS 9001-62-1, EC : 232-61-9 This substance (from organisms or vegetal origine) is not classified in the Annex I of Directive 67/548/EEC		
Physical Hazards		
Explosivity	No data	C&L Inventory [45] MSDS [46]
	May occur for fine airborne powder	P&G Env, Sci. Data [47]
Flammability	No data	C&L Inventory [45] MSDS [46]
	Low, because of extremely low vapour pressure	P&G Env, Sci. Data [47]
Oxidizing	No data	C&L Inventory [45] MSDS [46]
Other properties of reactivity	No data	C&L Inventory [45] MSDS [46]
Human Health Hazards		
Acute toxicity		
Highly toxic	No data	C&L Inventory [45] MSDS [46]
	Effects for subchronic oral exposure not observed . NOAEL 1000 mg/kg bwt/day	Coenen et al. 1997 [48]

Hazards	Evaluation	Source of information
	Effects not observed in 13 weeks, oral, on rats, dose 0.6-2500mg/kgbwt/day	Flood&Kondo [49]
Skin or eye corrosion / irritation	Selfclasified as eye irritant and skin sensitizer by some notifiers	C&L Inventory [45]
Chronic toxicity		
Carcinogenicity	Not listed in IARC, CLP and ESIS,	CLP, List of harmonized classification and labbeleing of hazardous substances [57]
Mutagenicity	No data	C&L Inventory [45], MSDS [46]
	No evidence of mutagenic potential in 90 oral essays	Coenen et al. 1997 [48]
	No effects observed in vitro, mouse lymphoma cells	Flood&Kondo [49]
Reproductive toxicity (including developmental toxicity)	No data	C&L Inventory [45], MSDS [46]
	No developmental effect is expected up to 5000mg/kgbwt/day, oral	USEPA, 2011 [26]
Endocrine disruption	No data	C&L Inventory [45], MSDS [46]
Respiratory or skin sensitization	Self classified as respiratory sensitizer, also as skin sensitizer	C&L Inventory [45]
Neurotoxicity	No data	-
Immune system toxicity	No data	-
Systemic Toxicity	No evidence of systemic effects	USEPA, 2011 [50]
Toxic metabolites	No data	-
Environmental hazards		
Acute/chronic aquatic toxicity	No data	C&L Inventory [45], MSDS [46]
	Estimated low toxicity	P&G Env, Sci. Data [47]
Bioaccumulation	No data	C&L Inventory 45], MSDS [46]
	Does not accumulate in living organisms lipid phases	P&G Env, Sci. Data [47]
Persistence	Biodegradable	P&G Env, Sci. Data [47]
Greenhouse gas formation potential	Not listed	ICCP [58]
Ozone-depletion potential	Not listed	ICCP [58]
Monitoring – has the substance been found in human or environmental samples?	No data	-

Table 19. Hazard characteristics of Oxirane, 2-methyl-, polymer with oxirane, mono(2-propylheptyl) ether

Hazards	Evaluation	Source of information
This substance (**CAS 166738-08-0**)is not classified in the Annex I of Directive 67/548/EEC		
Physical Hazards:		
Explosivity	No data	C&L Inventory [30]
Flammability	No data	C&L Inventory [30]
	Unlikely to ignite, very low volatility	MSDS [29]
Oxidizing	No data	C&L Inventory [51]
Other properties of reactivity	No data	C&L Inventory [51]
Human Health Hazards		
Acute toxicity		
Highly toxic	No,Selfclassified Acute tox 4 (low)	C&L Inventory [51]
Skin or eye corrosion / irritation	Yes, Selfclassified Eye dam. 1, skin Irritant 2	C&L Inventory [51]
Chronic toxicity		
Carcinogenicity	Not listed in IARC, CLP and ESIS,	CLP, List of harmonized classification and labbeleing of hazardous substances [57] ESIS, IARC
	No data	C&L Inventory [51]
Mutagenicity	No data	C&L Inventory [51]
	Structure does not suggest such effect	MSDS [52]
Reproductive toxicity (including developmental toxicity)	No data	C&L Inventory [51]
Endocrine disruption	No data	C&L Inventory [51]
Respiratory or skin sensitization	No data	C&L Inventory [51]
Neurotoxicity	No data	C&L Inventory [51]
Immune system toxicity	No data	C&L Inventory [51]
Systemic Toxicity	No data	C&L Inventory [51]
Toxic metabolites	No data	C&L Inventory [51]
Environmental hazards		
Acute/chronic aquatic toxicity	No data	C&L Inventory [51]
Bioaccumulation	No data	C&L Inventory [51]
Persistence	No data	C&L Inventory [51]
Greenhouse gas formation potential	Not listed	ICCP,
Ozone-depletion potential	Not listed	ICCP, Montreal protocol
Monitoring – has the substance been found in human or environmental samples?	No data	-

Table 20. Hazard characteristics of fatty alcohol ethoxylates (FAEs)

	Properties	Source of information
This substance (CAS 37335-03-8) is not classified in the Annex I of Directive 67/548/EEC		
Physical Hazards		
Explosivity	No data	C&L Inventory [53]
Flammability	No data	C&L Inventory [53]
Oxidizing	No data	C&L Inventory [53]
Other properties of reactivity	No data	C&L Inventory [53]
Human Health Hazards		
Acute toxicity		
Highly toxic	No data	C&L Inventory [53]
Skin or eye corrosion / irritation	No data	C&L Inventory [53]
	Yes, known to cause a problem	PPDB [32]
Chronic toxicity		
Carcinogenicity	Not listed in IARC, CLP and ESIS,	CLP, List of harmonized classification and labbeleing of hazardous substances [57] ESIS, SDSC
	No, known not to cause a problem	PPDB [54]
	No data	C&L Inventory [53]
Mutagenicity	No data	C&L Inventory [53]
Reproductive toxicity (including developmental toxicity)	No data	C&L Inventory [53]
	No, known not to cause a problem	PPDB [54]
Endocrine disruption	No data	C&L Inventory [53]
	No, known not to cause a problem	PPDB [54]
Respiratory or skin sensitization	No data	C&L Inventory [53]
Neurotoxicity	No data	C&L Inventory [53]
Immune system toxicity	No data	C&L Inventory [53]
Systemic Toxicity	No data	C&L Inventory [53]
Toxic metabolites	No data	C&L Inventory [53]
Environemntal hazards		
Acute/chronic aquatic toxicity	Selfclassified as Aqatiq chronic (toxic with long lasting effects)	C&L Inventory [53]
Bioaccumulation	No data	C&L Inventory [53]
Persistence	No data	C&L Inventory [53]
Greenhouse gas formation potential	Not listed	IPPC [58]
Ozone-depletion potential	Not listed	IPPC [58]
Monitoring – has the substance been found in human or environmental samples?		

Table 21. Hazard characteristics of dodecyl alcohol, ethoxylated

	Properties	Source of information
This substance (**CAS 9002-92-0**) is not classified in the Annex I of Directive 67/548/EEC		
Physical Hazards		
Explosivity	No data	C&L Inventory [55]
Flammability	No data	C&L Inventory [55]
	Flash point > 93 ^{0}C	TOXNET [56]
Oxidizing	No data	C&L Inventory [55]
Other properties of reactivity	No data	C&L Inventory [55]
Human Health Hazards		
Acute toxicity		
Highly toxic	Selfclassified Acute tox.4 (low)	C&L Inventory [55]
Skin or eye corrosion / irritation	Self clasified skin irritant 2, respiratorry irritant, and eye irritant 2/eye dammage1.	C&L Inventory [55]
Chronic toxicity		
Carcinogenicity	Not listed in IARC, CLP and ESIS,	CLP, List of harmonized classification and labbeleing of hazardous substances [57] ESIS, SDSC
	No data	C&L Inventory [55]
Mutagenicity	No data	C&L Inventory [55]
	Negative results on Salmonella	TOXNET [56]
Reproductive toxicity (including developmental toxicity)	No data	C&L Inventory [55]
Endocrine disruption	No data	C&L Inventory [55]
Respiratory or skin sensitization	No data	C&L Inventory [55]
Neurotoxicity	No data	C&L Inventory [55]
Immune system toxicity	No data	C&L Inventory [55]
Systemic Toxicity	No data	C&L Inventory [55]
Toxic metabolites	No data	C&L Inventory [55]
Environemntal hazards		
Acute/chronic aquatic toxicity	Selfclassified as Aqatiq acute 1 (very toxic) and chronic 2 (toxic with long lasting effects)	C&L Inventory [55]
Bioaccumulation	No data	C&L Inventory [55]
	Estimated BCF 81-medium	
Persistence	No data	C&L Inventory [55]
Greenhouse gas formation potential	Not listed	IPPC [58]
Ozone-depletion potential	Not listed	IPPC [58]
Monitoring – has the substance been found in human or environmental samples?	No data	

5.1.1 Technical feasibility of alternatives

All alternatives are technically feasible and replacing nonylphenol ethoxylates does not pose technological problems.
Lipase degreasing has a high efficiency, possibly due to the selective attac of lipase on triglycerides, generating species -mostly monoglycerides- that have surfactant properties of their own, therfore improving the process.
Advantages of using lipase degreasing reflect on the product as well as on some environmental indicators:
-less draw , fat wrinkles, and cleaner hides, tighter grain leather
-improves efficiency of liming and dyeiing phases
-reduces BOD and COD in watse water, compared to usual surfactants.

Degreasers based on Oxirane, 2-methyl-, polymer with oxirane, mono(2-propylheptyl) ether, have excellent wetting and emulsifying properties that are not affected by pH. The degreaser is low foaming and is miscible with water in practically all proportions. The low viscosity allows pumping.

Dodecyl alcohol, ethoxylated degreasers, generally have a higher viscosity but they have good wetting and dispersing properties.

Pickled and tanned sheepskins drummed with water at a temperature of 60°C and then washed with water with the same temperature conditions can provide quality leather, comparable to that obtained by tradinional chemical degreasing.

5.1.2 Economical feasibility of alternatives

All alternatives are economically feasible and the costs for the replacement implementation are low.
Though some years ago nonylphenol ethoxylates had a lower price, the developing production capacities for alternatives are now comparable.

6. Comparing alternatives

Table 22. Comparison of examples of alternatives to nonylphenol ethoxylates as leather degreasers.

	Lipase	Water	FAEs	Oxiyrane 2-methyl polymer.	Dodecyl alcohol, ethoxylated
Health aspects	PROS: Low acute toxicity. Negative results for carcinogenicity, mutagenicity, developmental toxicity CONS: Respiratory and skin sensitiser	PROS: not considered hazardous CONS: -	PROS: Not considered carcinogenic, mutagenic, endocrine disruptor	PROS: Low acute toxicity. Negative estimated results for mutagenicity CONS: Eye dam. 1, skin Irritant 2	PROS: Low acute toxicity. Negative results for mutagenicity CONS:skin irritant 2, eye irritant /dammaging
Environmental aspect	PROS: does not accumulate, is biodegradable Reduced COD& BOD in waste water CONS:	PROS: does not pollute CONS: -	CONS: Aquatic chronic 2		PROS: processes for reagent recovery have been developed CONS: Aquatic chronic 2 and accute 1
Performance aspects	PROS: good leather quality, improves further processing CONS: depends on alkaline conditions	PROS: Similar quality to chemical degreasing CONS: Is not suited for all leather types		PROS: Wetting and emulsifying properties do not depend on pH	
Cost aspects	PROS: Costs may be reduced by improving further processing	PROS: cheap			

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