

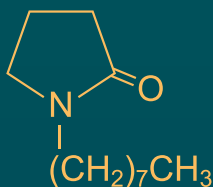
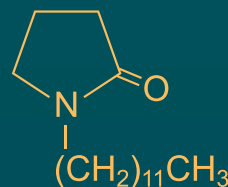
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Surfadone[®] LP

Specialty Surfactants

Product Profile

Surfadone[®] LP specialty surfactants are linear, N-alkyl-2-pyrrolidones with the following chemical structures:

**Surfadone[®] LP-100****Surfadone[®] LP-300**

Surfadone[®] LP specialty surfactants combine the hydrophilic, dipolar pyrrolidone ring with a hydrophobic alkyl group and exhibit a unique combination of solvency and surface activity. They are multifunctional and provide a variety of performance benefits in a range of applications.

Applications

- Dishwasher rinse aids
- Hard surface cleaning
- Laundry prespotters
- Specialty cleaning
- Fountain solutions
- Pigment dispersions
- Waterborne coatings adhesives
- Emulsifiable concentrates

Performance Features and Benefits

- High surface activity at low concentrations
- Rapid wetting
- Low foam
- Synergism with anionic surfactants
- Excellent solvency
- Good compatibility
- Low flammability
- Exempt under California Air Resource Board VOC guideline definitions
- Biodegradable
- Favorable toxicological profiles

Applications

Hard Surface Cleaners: Surfadone® LP-100 and LP-300 are biodegradable, performance-enhancing co-surfactants and coupling solvents. They are utilized¹⁻⁷ in institutional/household kitchen, bathroom, glass, and all-purpose cleaners. The dynamic surface activity of LP-100 promotes rapid wetting, penetration and softening of oily/greasy soils, soap scum and mineral scale, to facilitate removal from a variety of substrates. LP-100 also minimizes streaking on glass, and LP-300 is a particularly effective coupling solvent for fragrances. Use levels typically range from 0.01-2.0%.

Dishwasher rinse aids: Rinse aids perform several functions, and although the most visible benefit is the reduction of spots and film on glassware/flatware, they also reduce drying time and act as protein soil defoamers. Since high foam levels interfere with the mechanical operation of the dishwasher and reduce the effectiveness of the rinse cycle, nonionic surfactants are frequently used. Formulations incorporating 2-4% Surfadone® LP-100, which provides rapid/effective wetting and low foam, exhibit minimal filming and spotting.

Laundry prespotters: In aqueous formulations. Surfadone® LP-100 at 0.5-2.0%, provides rapid/effective wetting and facilitates the removal⁸ of oily soil and grease stains from cotton, polyester and cotton-polyester fabrics.

Specialty cleaning: In addition to providing high surface activity and wetting, Surfadone® LP-100 and LP-300 combine a broad spectrum solvent capability with favorable safety features. Consequently, they are frequently safer alternatives to hazardous solvents and provide solvency for a wide range of organic materials and resins. In aqueous metal cleaners, 1-2% LP-100 facilitates cleaning performance^{9,10} and interacts with alkoxyated thiol surfactants¹¹ to minimize odor.

Lithographic dampening (fountain) solutions: Surfadone® LP-100 is currently the preferred surfactant technology for alcohol-free, continuous dampening systems¹² for web offset printing. Performance in such a dynamic process is determined by the speed with which the bulk surfactant influences the interface. The high dynamic surface activity of LP-100 provides rapid wetting of the non-image area of the printing plate to ensure high print quality. LP-100 also provides low foam, low VOC, high flash points, and by minimization of ink build up, allows longer runs between clean up. Fountain solution concentrates typically incorporate 2-5% LP- 100.

Pigment dispersions: To provide stable mill bases with high tinctorial strength, Surfadone® LP-100 functions to enhance the wettability of organic pigments. At low use levels, LP-100 permits high pigment loading with low viscosity and is particularly effective with phthalocyanine pigments.

Photoresist strippers: In non-aqueous formulations, 10-20% Surfadone® LP-100 is used as a co-solvent, usually in conjunction with M-Pyrol® (N-methyl-2-pyrrolidone) and BLO® (γ -butyrolactone), to enhance performance by broadening the solvency range.

Printed circuit board cleaners: In aqueous formulations, 1-2% Surfadone® LP-100 enhances wetting of aluminum and Teflon® substrates, and facilitates removal of polymerized rosin residues.^{13,14}

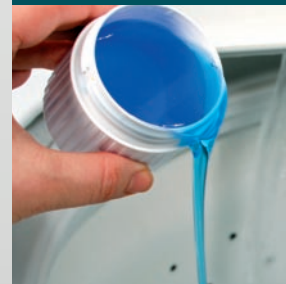
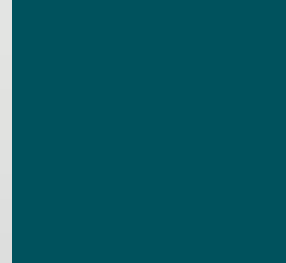
Waterborne coatings and adhesives: Achieving acceptable adhesion as well as good flow and leveling in water-based systems requires the use of high-performance wetting agents. The low dynamic surface tensions possible through the use of Surfadone® surfactants (specifically Surfadone® LP-100), together with their low VOC, support their use as high-performance, low-foaming wetting agents in these applications. The low hydrophilic-lipophilic balance (HLB) values of Surfadone® surfactants indicate that they will not add to the water sensitivity of the finished product. For example, Surfadone® LP-300 has been shown to optimize the spray pattern and improve adhesion of a chloroprene latex adhesive.¹⁵

Emulsifiable concentrates: Emulsifiable concentrates comprise a concentrated solution of agrochemical actives in solvent/surfactant mixtures, which, when added to water, afford stable macro/micro emulsions. Surfadone® LP-100 and LP-300 are excellent solvents for many crystalline pesticides,^{16, 17} and as a consequence of their low solubility in water, eliminate the problem of active crystallization, which can occur when the concentrate is added to water. Biodegradability, low volatility, high flash point, emulsion stability, low foam, rapid wetting, and compatibility with aromatic/aliphatic hydrocarbons are also vital features of Surfadone® LP specialty surfactants. Use levels range from 1-40%.

Table 1: Surfadone® LP properties

Properties ^{7, 18-29}	Surfadone® LP-100	Surfadone® LP-300
Physical Form (25°C)	Liquid	Liquid
Purity (Area % GC)	98 min.	98 min.
Color (APHA)	100 max.	180 max.
Moisture (%)	0.1 max.	0.1 max.
Boiling Point (°C)	100 @ 0.3 mm Hg	145 @ 0.2 mm Hg
Flash Point (°C) Closed Cup	113	116
Freezing Point (°C)	-25	10
Vapor Pressure (mm Hg @ 20°C)	<0.001 est.	<0.001 est.
Density (g/cm ³ @ 20°C)	0.922	0.903
Viscosity (m Pas @ 20°C)	9	18
Refractive Index @ 25°C	1.471	1.466
Dipole Moment (Debye)	3.83	3.82
Hansen Solubility Parameters (J/cm ³) ^{1/2}	$\delta_T = 18.9$ $\delta_D = 16.9$ $\delta_P = 6.2$ $\delta_H = 5.8$	$\delta_T = 18.2$ $\delta_D = 16.9$ $\delta_P = 4.4$ $\delta_H = 5.0$
HLB	6	3
Solubility in water (g/L @ 25°C)	0.124	0.02
Biodegradable	Yes	Yes
CAS Registry Number	2687-94-7	2687-96-9
Molecular Weight	197	253
Registration status	TSCA, EINECS, MITI	TSCA, EINECS, MITI

Note: Above data are typical of current production. Product specifications may be obtained from ISP.



Solubility

Surfadone® LP specialty surfactants are readily soluble in most organic solvents and exhibit unique solubility characteristics in water.

- In aqueous solution at ambient temperature, single-phase systems are obtained with LP-100 concentrations <0.124% and LP-300 concentrations < 0.002%.
- As the concentration of Surfadone® LP is increased, two phases separate until at 65% LP-100 and 80% LP-300, a single phase is obtained.
- As the temperature of two-phase systems is decreased, the solubility of both Surfadone® LP-100 and LP-300 increases. Before the lower critical solution temperature (LCST) or cloud point can be reached, ice crystals form.

Surfadone® LP-100 and LP-300 interact with anionic surfactants and are solubilized in aqueous solution to afford mixed micelles. Low-viscosity solutions of up to 8% LP-100 and up to 4% LP-300 may be obtained with 1-2% sodium dodecyl sulfate (SDS). Viscous solutions and gels are obtained with LP-300 concentrations > 4%.

Surfadone® LP specialty surfactants are also solubilized in water, although less efficiently, by water-miscible organic solvents – e.g., 30% propylene glycol is required to dissolve 3% LP-100.

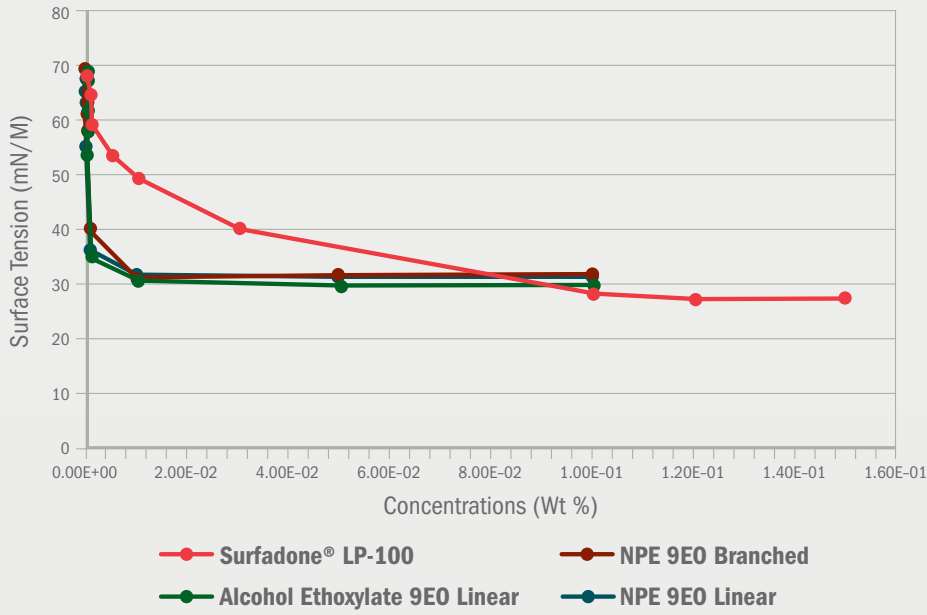
Surface Tension Reduction, Wetting and Foaming

Both Surfadone® LP-100 and LP-300 exhibit comparable effectiveness in reducing the static (equilibrium) surface tension of water and do not reach a critical micelle concentration (CMC). Surfadone® LP-300 exhibits greater efficiency in static surface tension reduction than LP-100.

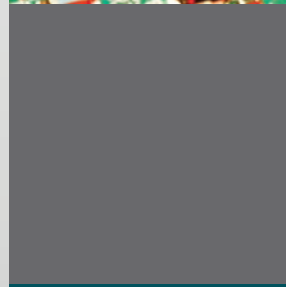
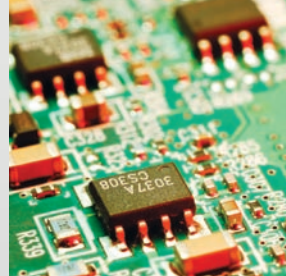
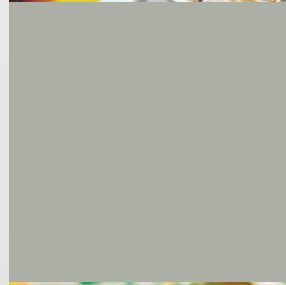
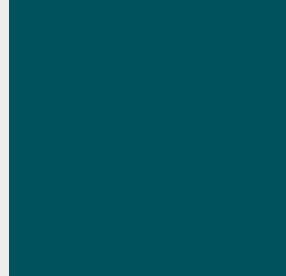
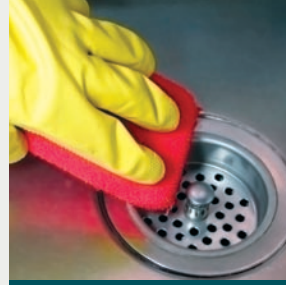
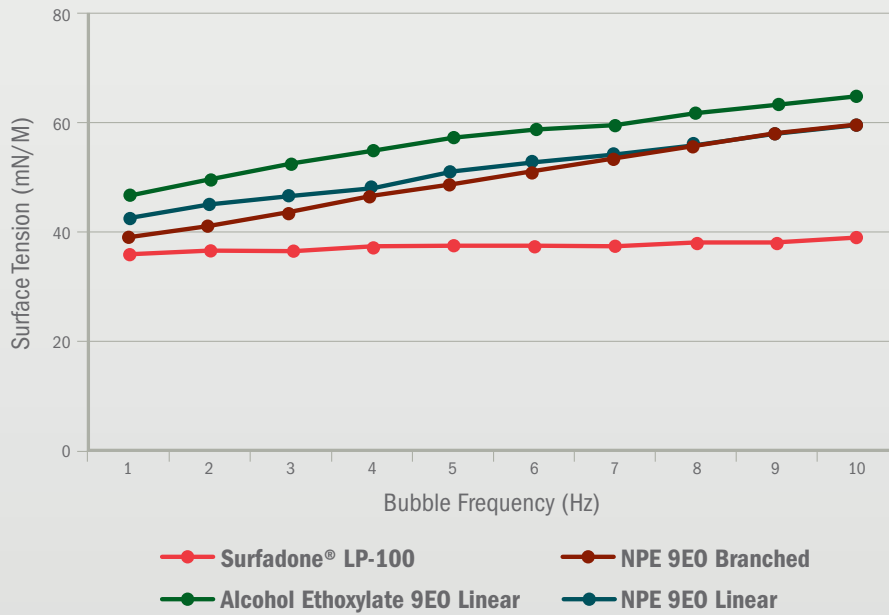
Dynamic surface tension is a measure of the kinetics of surfactant adsorption/orientation at the interface and may be correlated with wetting speed. Surfadone® LP-100 is a more effective dynamic surface tension reducer/wetting agent than LP-300, which may be attributed to the greater solubility/mobility of LP-100 in an aqueous environment. Anionic surfactants, such as SDS and linear alkyl benzene sulfonate (LAS) interact with Surfadone® LP-100 and LP-300 to provide synergistic surface tension reduction and wetting enhancement. Surfadone® LP-100 and LP-300 are low foaming, as determined by the Ross-Miles method. Mixtures of LP-100 with SDS, at total surfactant concentrations of 0.1%, exhibit minor synergistic increases in foam height, although no synergism was observed with LP-300.

Surfadone® LP specialty surfactants are compatible with cationic, nonionic and amphoteric surfactants, although no synergistic interactions have been reported. Surface tension (Graphs 1-3), Ross-Miles (Table 4) and Draves data (Graph 4 and Table 2) for Surfadone® LP-100 and LP-300 are summarized.

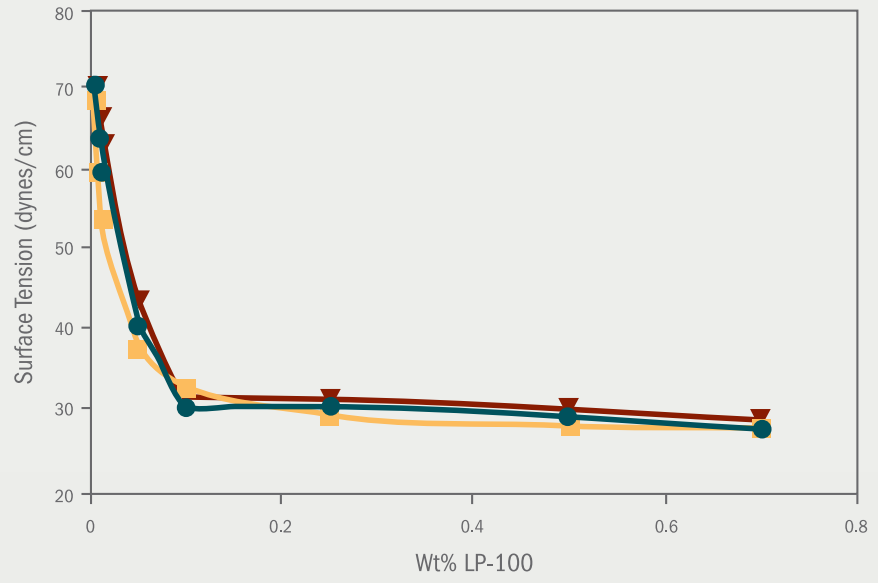
Graph 1: Static Surface Tension on Various Surfactants



Graph 2: Dynamic Surface Tension on Various Surfactants at 0.1% Concentration



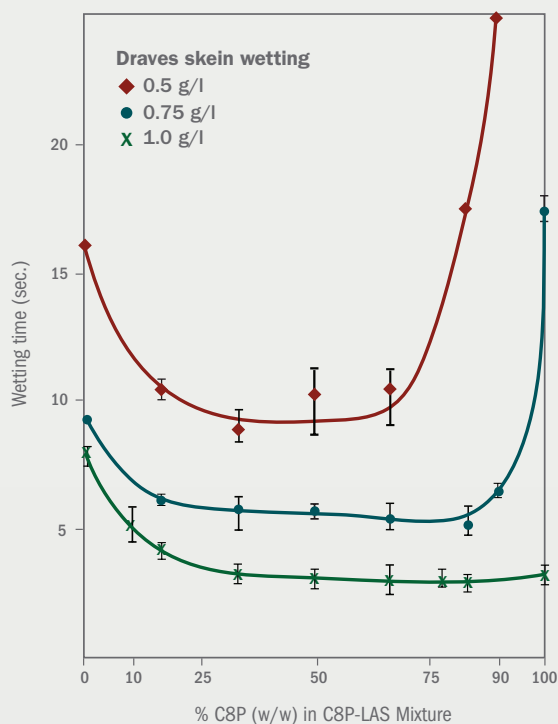
Graph 3: Dynamic Surface Tension of Surfadone® LP-100 with Sodium Dodecyl Sulfate*



%LP-100 (+0.025% SDS)	Surface Tension (dynes/cm) Bubbles/sec.		
	1 ■	5 ●	10 ▼
0.000	69	70	71
0.005	60	65	67
0.010	54	60	64
0.050	38	41	44
0.100	33	31	32
0.250	30	31	32
0.500	29	30	31
0.700	29	29	30

* American Ink Maker, October 1994

Graph 4: Draves Wetting Surfadone® LP-100 and Sodium Dodecyl Sulfate

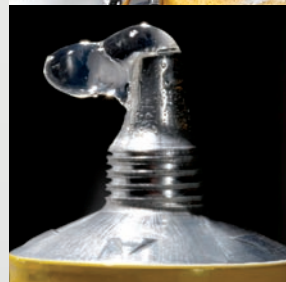
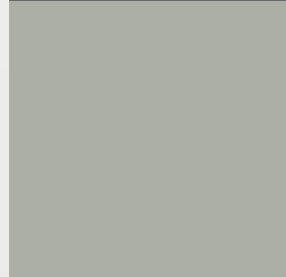
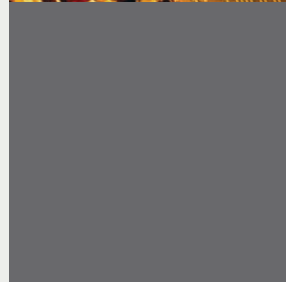


Draves skein wetting time vs. percentage of C8P in C8P-LAS mixtures at various total surfactant concentrations. JAOCS 66(7): 998-1001, 1989

Table 2. Draves Wetting at 0.1%, seconds*

Name	Surfactant Alone	1:1 blend with Surfadone LP-100
Poloxamer 182	>300	41
Poloxamer 407	>300	48
Nonoxynol 30	>300	13
Dodecylphenol + 6EO	>300	44
Polysorbate 20	>300	33
Nonoxynol 9 Phosphate	142	20
Sodium dodecyl diphenyl oxide disulfonate	103	11
Surfynol 104	12	—
LAS	9	Instantly
Surfadone LP-100	3.5	3.5

*JAOCS 72: 759-771, 199



The wetting capability of Surfadone® LP is also demonstrated by contact angle reduction on both high and low energy surfaces. LP-100 is particularly effective on aluminum and representative data are summarized in Table 3.

Table 3. Contact Angles

	Aluminum	Silicone	Polypropylene	Teflon
Water	84	95	95	113
Surfadone® LP-100 (0.1% in water)	< 5	56	34	54
Surfadone® LP-300 (0.1% in water)	36	53	33	54

Foaming

Surfadone® LP products are low foaming in aqueous solutions. The initial foam heights in Ross-Miles tests are 25mm and 13mm for Surfadone® LP-100 and LP-300 respectively. The initial and five minute foam heights for Surfadone® LP-100 and LP-300 mixed with SDS are shown in Table 4 below.

Table 4. Surfadone® LP/SDS Ratio

	Pure	3:1	1:1	1:3
Surfadone® LP-100	25/5	159/159	164/161	58/157
Surfadone® LP-300	13/11	139/139	135/135	151/151
Sodium Dodecyl Sulfate (SDS)	156/156	—	—	—

Foam Height (mm), initial/5 min

Total concentration, 0.1%

Compatibility with Plastics and Elastomers

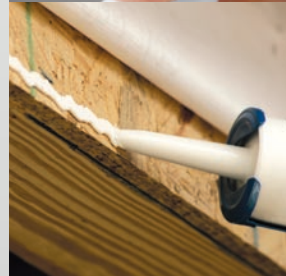
Quantitative results on weight and dimensional changes, for 15 plastics or elastomers exposed to Surfadone® LP specialty surfactants, at ambient temperature for 7 days, are shown in Tables 5 and 6. Polyethylene, polypropylene, nylon, Kynar® (polyvinylidene fluoride) and Teflon® (polycarbonate), Noryl® EN-265 (polyphenylene oxide), Viton® (polyvinylidene fluoride-hexafluoropropylene) ABS, EPDM-70 and PVC should be avoided.

Table 5: Surfadone® LP-100 at ambient temperature for 7 days % change

Coupon	Weight	Length	Width	Thickness
ABS	Coupons fragmented after 24 hours			
Butyl rubber	12.48	3.23	0.39	3.23
EPDM-70	66.7	20.06	19.73	25.66
Kynar® (Penwalt)	0.58	0.19	0.32	2.13
Lexan® (GE)	Coupons dissolved after 48 hours			
Noryl EN-265® (GE)	4.8	0.43	0.98	3.19
Nylon	-0.4	-0.1	-0.19	0.07
Polyethylene (XL)	0.15	0.03	0	0.24
Polyethylene (LD)	0.02	0.42	1.4	0
Polyethylene (HD)	0.25	0.07	-0.13	-0.88
Polypropylene	0.08	0.2	0.33	0
Polyvinyl chloride	Coupons dissolved within 48 hours			
Silicon rubber	17.6	5.16	7.4	6.7
Teflon® (DuPont)	0.01	0.07	0.26	0
Viton® (DuPont)	201.4	65.0	75.5	71.7

Table 6: Surfadone® LP-300 at ambient temperature for 7 days % change

Coupon	Weight	Length	Width	Thickness
ABS	Coupons fragmented after 24 hours			
Butyl rubber	12.5	3.14	3.02	3.13
EPDM-70	66.7	6.67	19.73	24.0
Kynar® (Penwalt)	0.02	0.13	0	2.13
Lexan® (GE)	18.9	13.1	0.39	0.03
Noryl EN-265® (GE)	0.13	0.59	0.13	0.55
Nylon	0.3	0.23	0.07	0
Polyethylene (XL)	0.09	0.13	0.13	0.49
Polyethylene (LD)	0.24	0.19	0.32	3.23
Polyethylene (HD)	0.19	0.13	0.07	0.02
Polypropylene	0.10	0.03	0.26	0.53
Polyvinyl chloride	Coupons dissolved within 48 hours			
Silicon rubber	9.7	2.05	11.09	5.52
Teflon® (DuPont)	4.68	0.07	-0.2	3.12
Viton® (DuPont)	197.9	64.5	76.0	77.2



Biodegradation Studies

Surfadone® LP-100 and LP-300 were classified as ultimately biodegradable in the modified Semi-Continuous Activated Sludge (SCAS) test and readily biodegradable in the modified Sturm test.

The modified SCAS test is designed to determine the removability/biodegradability of a test compound in activated sludge. Surfadone® LP-100, at a test concentration of 20 mg carbon/L, achieved an average 99.8% removal following a 5-day acclimation period. In accordance with EPA test guidelines, 40 CFR 796.3340, these products may be classified as ultimately biodegradable.

The modified Sturm test is designed to give an indication of the extent of ultimate biodegradation of a test compound. Surfadone® LP-100 reached levels of 80.9% and 83.1% of the theoretical CO₂ production in 28 days, for the test concentrations of 10 and 20 mg/L, respectively. Surfadone® LP-300 reached levels of 87.4% and 74.2% of the theoretical CO₂ production in 28 days, for the test concentrations of 10 and 20 mg/L, respectively. In accordance with EPA guidelines, 40 CFR 796.3260, these compounds may be classified as readily (highly) biodegradable in aerobic systems, and are fully compliant with European Parliament and the Council EC No. 648/2004 regulation.

Toxicological Studies

An extensive study of Surfadone® LP-100 and LP-300 has been carried out and both compounds exhibit a favorable toxicological profile. The results are summarized in Table 7, and more detailed information, including aquatic toxicity, may be obtained from ISP's Product Stewardship Department.

Table 7: Toxicological profile

Test	Surfadone® LP-100	Surfadone® LP-300
Acute oral LD ₅₀ in rats (g/kg)	2.05	> 5
Acute dermal LD ₅₀ in rabbits (g/kg)	> 2	> 2
Primary eye irritation in rabbits (2% aqueous suspension)	Non-irritating	Non-irritating
Primary skin irritation in rabbits (as supplied)	Extremely irritating	Severely irritating
Primary skin irritation in rabbits (2% aqueous suspension)	Mildly irritating	Mildly irritating
Dermal sensitization in humans (1% aqueous suspension)	Did not induce dermal contact sensitization	Did not induce dermal contact sensitization
Mutagenicity (Ames assay)	Non-mutagenic	Non-mutagenic
Comedogenicity (2% aqueous suspension)	Not expected to be comedogenic in humans	Not expected to be comedogenic in humans

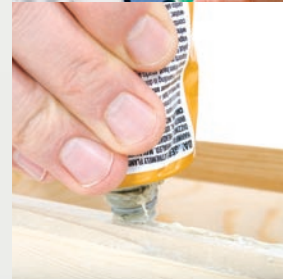
Handling and Storage

Surfadone® LP specialty surfactants are corrosive and can cause severe eye and skin burns. Normal good practices should be followed. Wear goggles and impervious gloves. In case of accidental contact with skin or eyes, wash area immediately with water. Refer to the MSDS for more detailed information.

Surfadone® LP specialty surfactants are available in tank wagon and tank car quantities, as well as various-size phenolic-lines drums. For bulk storage, unloading and handling, it is recommended that 304 stainless steel storage tanks, pumps and piping and Teflon® gaskets and seals be used. Rubber hosing is not recommended.

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