Generic Scenario: Surfactants in Industrial/Commercial Laundries
August 16, 1996
Prepared for the Chemical Engineering Branch by SAIC

Introduction

The purpose of this generic scenario was to search available sources of information to obtain data on production, exposure, and releases for CEB to use in the assessment of PMNs. This generic scenario is applicable for any surfactant used in powder or liquid detergents at commercial or industrial laundry facilities. It covers most (but not all) of the detergent formulation processes and the use of a surfactant/detergent at both industrial and commercial laundry facilities. Most of the traditional surfactants, and the surfactants for which PMNs have been submitted for in the past, have been nonvolatile (e.g., having a vapor pressure of less than 0.001 torr at 25 °C). This generic scenario will not address the manufacture of the surfactant or other components used in detergent formulations. Caution should be used when using this scenario in evaluating other components of the formulation. Use submitter-supplied data and CEB's *Manual for the Preparation of Engineering Assessments* for these scenarios.

Surfactants are used in detergent for soil removing properties through the reduction of surface tension. Their structure is composed of water attracting (hydrophilic) groups on one end of the molecule and water-repelling (hydrophobic) groups on the other end. Surfactants can be divided into four main types: anionic, cationic, nonionic, and amphoteric. The largest group consists of anionics, which are usually the sodium salts of an organic sulfate or sulfonate. Commercial detergents products are formulated balancing the desired properties of maximum cleaning power, cost, and biodegradability. Typically, this is accomplished through a combination of anionic and nonionic surfactants (Austin, 1984; USEPA, 1983).

Market

A detailed market analysis of the surfactant industry is complicated by other factors: (1) the number of surfactants and their end-use applications is enormous, (2) there are many suppliers, (3) the surfactant industry is stratified, with producers that vary in size selling not only to end users but also to each other, and (4) end users in a given industry segment are frequently unable to provide accurate market information because the products they buy are often complex formulations and many do not know the true composition of such formulations (SRI, 1995).

Approximately twelve US producers have a significant position in both surfactant raw materials and downstream surfactants. Most of these companies can be subdivided into those using petrochemical-derived raw materials and those using largely olechemical-derived (ie, from fats and vegetable oils) raw materials. Most of the large surfactant producers using petrochemical raw materials sell surfactants and their raw materials directly to large-volume customers, and most sell a large percentage of their sales of surfactants to the household detergent industry. They also sell surfactants and their raw materials to intermediate-size producers and smaller producer/formulators, both of which may be their potential competitors in some end-use markets. Those using largely olechemical-based raw materials are much broader participants in the downstream surfactant business, in terms of the wide variety of surfactant products they make and the end-use markets into which they sell them (SRI, 1995).

Formulation - Laundry Detergent Manufacture

Most of the marketing data for this processing scenario is based on the 1992 Census of Manufactures, whose statistics encompass 710 establishments classified under SIC 2841, Soap and other detergents, and 205 establishments classified under 2843, Surface active agents. Data are presented for both powder and liquid detergent formulation, although in absence of information, the assumptions for powder detergent manufacture should be used due to their greater prevalence.

Process Description

Detergents are manufactured in both solid (dry granular) and liquid forms, with heavy-duty granular detergents being the most widely used form. Heavy-duty liquid detergents account for 40% of the laundry detergents sold in the U.S. (USEPA, 1993). Surfactant concentrations range from 5-30 percent by dry weight of the detergent for heavy-duty formulations (USEPA; 1983; Austin, 1984).

Powdered Detergents: The manufacture of spray-dried detergent has three main processing steps: (1) slurry preparation, (2) spray drying, and (3) granule handling (USEPA, 1993). The surfactant slurry, a corrosion inhibitor, a builder (typically a phosphate), other miscellaneous additives and water are introduced into a crutcher (large mixing tank). Any remaining water is removed and the paste is thickened by a phosphate hydration reaction. The mixture is heated and pumped to the top of a spray tower, where it is sprayed under high pressure through a ring of spray nozzles into the spray tower, counter to hot air from a furnace. Water is flashed off leaving dry granules of product. Dried granules of accepted shape, size and suitable density are formed then cooled. The stabilized granules are separated in a cyclone, screened, perfumed and packaged (USEPA, 1983; Austin, 1984). Figure 1 illustrates the manufacture of spray-dried detergents (USEPA, 1992).

Emissions from the tower are treated typically in some sort of environmental control equipment, such as cyclone collectors, scrubbers, and/or electrostatic precipitators, leaving only hot water to escape from the stack (USEPA, 1983).

Production rate of powdered detergents (kg/site-yr):

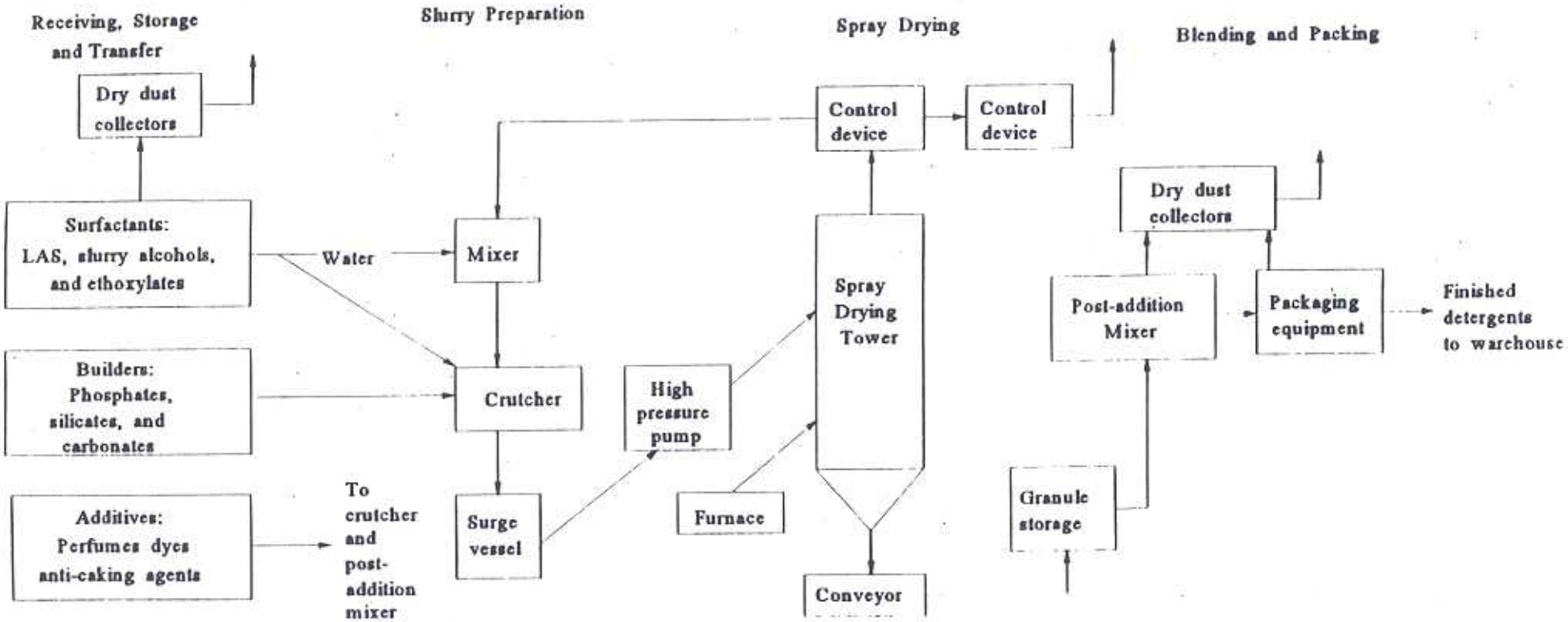
Assume 6,400,000 kg/site-yr
(basis: In 1992, 87 companies produced 1.23 billion pounds of dry detergents for commercial, industrial, institutional and household use (BOC, 1995))
[Note: a model of a spray-dried detergent manufacturing plant reports a production capacity of 4,500,000 kg/yr for small plants and 270,000,000 kg/yr for large plants taken from the "Economic Analysis of Proposed Effluent Guidelines for the Soap and Detergent Industry, August, 1973 (USEPA, 1983).]

Number of formulating sites:

NS = PV / ((6,400,000) x (% PMN in detergent))
Assume 7% concentration of surfactant PMN in detergent as default
(basis: average concentration level in powder detergents in recent study performed by SRI International (CW, 1987))

Number of operating days/yr:

Assume 250 days/yr (basis: CEB default)



LAS = linear alkyl sulfonate

AV-3

Figure 1 Manufacture of spray-dried detergents.

Liquid Detergents: The product (surfactants, builders, corrosion inhibitor, water, and other additives) is mixed in large batch units then piped to the conveyor lines for filling. Because of frequent product change, the tanks and lines are washed clean and most of the resulting wastewater is run to the sewer. There may be some pretreatment followed by discharge to a municipal treatment plant. In larger, more integrated plants, the washwater may be blended back into the product (USEPA, 1983). This is a potential pollution prevention opportunity for detergent formulators.

Production rate of liquid detergents (kg/site-yr):

Assume 11,800,000 kg/site-yr
(basis: In 1992, 171 companies produced 2.01 billion gallons of liquid detergents for commercial, industrial, institutional, and household use (BOC, 1995))
[Note: a model of a liquid detergent manufacturing plant reports a production capacity of 11,000,000 kg/yr for small plants and 23,000,000 for large plants taken from the "Economic Analysis of Proposed Effluent Guidelines for the Soap and Detergent Industry, August, 1973 (USEPA, 1983)

Number of formulating sites:

NS = PV / ((11,800,000) x (% PMN in detergent))
Assume 10% concentration of surfactant PMN in detergent as default
(basis: average concentration level in powder detergents in recent study performed by SRI International (CW, 1987))

Number of operating days/yr:

Assume 250 days/yr (basis: CEB default)

Environmental Releases

Water:

Spray Dried Detergents: The principal sources of releases to water are wash down of the tower, scrubber water, and leaks and spills. There is a large variation in the operation of spray towers with regard to use and reuse of water. Some plants employ total recycle of cleanup water, whereas other plants discharge all waste waters to the municipal sewer (USEPA, 1983).

For total releases from spray tower operations including equipment and packaging container washouts, assuming no recycling of waste waters,

Releases, kg/site-day = (0.15% x PV) / ((# of sites) x (250 days)), over 250 days
(basis: The highest surfactant raw waste loading out of three types of operations of spray towers was reported to be 1.5 kg per 1000 kg of dry detergent produced (USEPA, 1985))

Liquid Detergents: The principal sources of releases to water are from filling lines, leaks, spills, overflows, and purging lines for both blending and filling operations between products. Also, filled detergent bottles are sometimes washed (USEPA, 1983).

For total releases from equipment washing, leaks, spills, and package washing,
Releases, kg/site-day = (0.11% x PV) / ((# of sites) x (250 days)), over 250 days
(basis: The range of surfactant raw waste loadings was reported to be 0.4 - 1.1 kg per 1000 kg of liquid detergent produced (USEPA, 1983))

Air:

For powder detergent manufacture, there are several sources of release to air. The exhaust to air from detergent spray drying towers contains detergent particles and organics vaporized in the higher temperatures zones of the tower. Some type of collection equipment, primarily cyclones, are considered integral to a spray drying system to capture the detergent dust in the spray dryer exhaust for return to processing (USEPA, 1993).

In addition, dust emissions are generated at scale hoppers, mixers, and crutchers during the batching and mixing of fine dry ingredients to form slurry. Conveying, mixing, and packaging of detergent granules can also cause dust emissions. Pneumatic conveying of fine materials causes dust emissions when conveying air is separated from bulk solids. For this process, fabric filters are generally used, not only to reduce or to eliminate dust emissions, but also to recover raw materials. The dust emissions principally consist of detergent compounds, although some of the particles are uncombined phosphates, sulfates, and other mineral compounds (USEPA, 1993).

For powder detergents,
Releases, kg/site-day =(0.7% x PV) / ((# of sites) x (250)), over 250 days
from: detergent spray drying, assuming average cyclone efficiency of 85%
(basis: AP-42 particulate emission factors for detergent spray drying (USEPA, 1993))

Incineration or Landfill:

No releases to incineration or landfill are expected. Releases due to equipment cleaning and container residue are accounted for in the emission factors for releases to water.

Occupational Exposure

Number of workers/site:

Assume 50 workers/site
(basis: In 1992, there were 14.2 thousand production workers for 255 establishments producing commercial, industrial, and institutional soaps and detergents, and household detergents (BOC, 1995).

Worker activities:
- Receiving/transfers - 12 workers
- Slurry preparation - 8 workers
- Spray tower operation - 8 workers
- Sampling - 2 workers
- Blending - 8 workers
- Packaging - 12 workers

(basis: engineering estimate based on NIOSH HHEs)

Inhalation Exposure:

Surfactants are typically produced in liquid form and inhalation exposure occurs only after its processing into granular detergents (USEPA, 1983). Assume 30 workers with inhalation exposure from spray tower operations, sampling, blending, and packaging.

For powder detergents during sampling and packaging,
Potential dose rate (mg/d) = 0.82 mg/m^3 * duration (hr) * 1.25 m^3 /hr breathing rate * PMN wt%
(basis: factory worker exposure during granular detergent formulation measured as an average of total dust at eleven Procter and Gamble facilities, 1981 (USEPA, 1983))

For a bounding estimate for powder detergents, use OSHA PEL for nuisance dust.
Potential dose rate (mg/d) = 15 mg/m^3 * 8 hr * 1.25 m^3 /hr breathing rate

For liquid detergents, inhalation exposure to vapors is negligible for VP < 0.001 torr. If vapor pressure of surfactant is >0.001 torr, use standard CEB models.

Dermal Exposure: To estimate dermal exposure to the PMN during detergent manufacture, the dermal contact model presented in the CEB manual should be used with the following assumptions for routine 2-hand contact (CEB, 1991).

D = SQC

Where: D = Dermal Exposure (mg/day)
S = Surface area of contact (cm^2) = 1300
Q = Quantity typically remaining on the skin (mg/cm^2)
= 5-14 for powder
= 1-3 for liquids
C = % PMN in formulation.

Use - Industrial/Commercial Laundries

Industrial launderers fall under the Standard Industrial Classification code 7218. An estimated 300-600 million pounds of laundry detergents are consumed in industrial, institutional, and commercial outlets (SRI, 1994). A industrial facility processes between 110,000 and 10,000,000 kg/site-yr of dry laundry and a commercial facility processes between 120,000 and 21,000,000 kg/site-year of dry laundry (USEPA, 1994). Most of the data for this use scenario is based on a survey of 64 industrial facilities and 11 commercial facilities conducted by EPA's Office of Water in support of the "Effluent Guidelines for Industrial Laundries". Data is presented for both industrial and commercial laundries, although in absence of information, the assumptions for industrial laundries should be used due to their greater prevalence.

Process Description

Detergent, water, and bleach are loaded into a commercial/industrial washer. Commercial washing machines have short cycles, about 15 minutes (SRI, 1994). After washing is completed, washwater may be pretreated and discharged to a POTW (USEPA, 1994).

For industrial laundry facilities, detergent use rate :

Assume 14,000 kg/site-year for powdered detergent (basis: mean usage rate of powdered detergent for industrial laundry facilities per site-year (USEPA, 1994)
Assume 11,000 kg/site-yr for liquid detergent (basis: mean usage rate of liquid detergent for industrial laundry facilities per site-year (USEPA, 1994)

Number of Use Sites:

For powder detergent, NS = PV / ((14,000) x (%PMN in detergent))
For liquid detergent, NS = PV / ((11,000) x (%PMN in detergent))

For commercial laundry facilities, detergent use rate:

Assume 7,000 kg/site-year for powdered detergent (basis: mean usage rate of powdered detergent for commercial laundry facilities per site year (USEPA, 1994)
Assume 1,700 kg/site-year for liquid detergent (basis: mean usage rate of liquid detergent for commercial laundry facilities per site-year (USEPA, 1994)

Number of Use Sites:

For powder detergent, NS = PV / ((7,000) x (%PMN in detergent))
For liquid detergent, NS = PV / ((17,000) x (%PMN in detergent))

Days/year Operation:

For industrial laundries, assume 250
(basis: mean based on 64 industrial facilities is 254 days/site-yr (USEPA, 1994))

For commercial laundries, assume 280
(basis: mean based on 11 commercial facilities is 282 days/site-yr, (USEPA, 1994))

Environmental Releases

Water:

Industrial and commercial laundry facilities use between 450 and 218,000 gallons of water per site-day for laundering processes only (excluding water used for equipment washdown) with a mean usage rate

of about 46,600 gallons/site-day (USEPA, 1994). While, less then half of the facilities reported some sort of wastewater pre-treatment, all of the facilities reported discharging to a POTW.

Releases, kg/site-day = PV/ ((# of sites) x (# of days/yr)) over # of days/yr
(basis: The total amount of PMN surfactant/detergent is released to water discharged to a sewer after washing is complete. The amount of residual detergent deposited on the fabric is 0.04 ug/cm^2 (USEPA, 1986))

Air: For liquid detergent manufacture, air releases are negligible if VP < 0.001 torr (CEB).
For powder detergent manufacture, air releases during unloading are negligible.

Incineration or Landfill:

For powder detergents,
Releases, kg/yr =(1% x PV)
from: container residue
(basis: CEB estimate for container residue for solids)

For liquid detergents,
Releases, kg/yr =(4% x PV)
from: container residue
(basis: CEB estimate for container residue for liquids)

Note: media of release is uncertain because containers may be rinsed.

Occupational Exposure

Days/year Operation:

For industrial laundries assume 250
(basis: mean based on 64 industrial facilities is 254 days/site-yr (USEPA, 1994))

For commercial laundries assume 280
(basis: mean based on 11 commercial facilities is 282 days/site-yr, (USEPA, 1994))

Hours/site-day:
Assume 12 hrs/site-day
(basis: mean for industrial and commercial laundry facilities (USEPA, 1994))

Number of workers/site:
Assume 80 workers/site
(basis: mean number of workers for industrial laundry facilities is 75 and for commercial facilities is 78 (USEPA, 1994))

Worker Activities:
Flat work iron operators - 8 workers
Washer/dryer operators - 20 workers
Towel folders - 10 workers
Press assemblers - 10 workers
Dry Clean Operators - 20 workers
Clerical staff - 6 workers
Maintenance/Supply personnel - 6 workers
(basis: engineering judgement based on NIOSH HHEs)

Inhalation Exposure:

Assume 20 workers (washer/dryer operators) with inhalation exposure.
For powder detergents during washing machine loading,
Potential dose rate (mg/d) = 0.0083 mg/m^3 * duration (hr) * 1.25 m^3 /hr breathing rate * PMN wt% (basis: consumer exposure assessment data for powdered laundry detergent during use application. In-home and simulated-laboratory studies were conducted for double-pour machine laundering (USEPA, 1983))
Assume duration of 1.6 hours (basis: average duration of 2 minutes for measuring and pouring detergent (USEPA, 1983), commercial washing machine cycle of 15 minutes (SRI, 1994), 12-hour day (USEPA, 1994))

For liquid detergents, inhalation is expected to be negligible.
(Basis: traditional surfactants have a vapor pressure << 0.001 torr.)
If vapor pressure of surfactant is >0.001 torr, use standard CEB models.

Dermal Exposure: To estimate dermal exposure to the PMN during measuring and pouring of detergent into machine, the dermal contact model presented in the CEB manual should be used with the following assumptions for incidental 2-hand contact (CEB, 1991).

$$D = SQC$$

Where: D = Dermal Exposure (mg/day)
S = Surface area of contact (cm^2) = 1300
Q = Quantity typically remaining on the skin (mg/cm^2) = ~~5-14~~ 1-3
C = % PMN in formulation

Data Gaps/Uncertainties:

- There is an uncertainty in the media release of container residue in the use scenario because the containers may be rinsed on-site resulting in these releases to water instead of landfill/incineration.
- There are no release factors available for air releases from the hoppers and mixers in the processing scenario and from unloading in the use scenario.
- Production rates of detergents may be overestimated because it is based on number of companies not number of establishments (e.g., sites)
- Number of workers having inhalation exposure is uncertain due to lack of breakdown in worker activities.

References

(Austin, 1984) George Austin, Shreve's Chemical Process Industries, Chapter 29 Soaps and Detergents, McGraw-Hill Book Company, 5th Edition, 1984.

(BOC, 1995) 1992 Census of Manufactures, Industry Series, Soaps, Cleaners, and Toilet Goods, U.S. Department of Commerce, Economics and Statics Administration, Bureau of Census, 1995.

(CW, 1987) Chemical Week, "Soaps and detergents: A basketful of high-tech products, *Composition: Surfactant Concentrations Climb Higher*, January 21, 1987.

(SRI, 1995) Stanford Research Institute, Surfactants, October, 1995.

(SRI, 1994) SRI International Chemical Economics Handbook, Surfactants, Household Detergents, and their Raw Materials, Surface-Active Agents, December 1994

(USEPA, 1994) U.S. EPA, Office of Water, Industrial Laundries Detailed Questionnaire, Parts A&B, Engineering & Analysis Division, 1994.

(USEPA, 1993) U.S. Environmental Protection Agency, Office of Air, AP-42, Soap and Detergents, July, 1993.

(USEPA, 1983) U.S. EPA, Office of Pesticides and Toxic Substances, Draft Final Report Generic Premanufacture Notification Report on Surfactants, Submitted by JRB Associates to USEPA, February, 1983.

(USEPA, 1986) U.S. EPA, OPTS, ETD, Standard Exposure Scenario for Estimating Exposure to Chemical Substances During Use of Consumer Products, Vol. I, EPA Contract No. 68023968, Submitted by Versar Corporation, September, 1986.

(USEPA, 1985) U.S. EPA, Technical Support for Pre-Manufacture Review of New Chemical Substances, Data on Soap and Detergent Manufacturing and Formulation, prepared by MITRE Corporation, September, 1985.