Chapter 15

Laundries

15.1 Introduction

Commercial, institutional and industrial laundries are designed to handle a wide range of fabrics in large quantities. These facilities can use large quantities of water to clean hotel and healthcare linen, all manner of uniforms, mops, industrial mats and carpets.

Water is the universal solvent for the removal of soil and odour. However water quality can impact on cleaning efficacy. Calcium and magnesium hardiness affects the soaping ability of the water. Similarly the presence of iron and manganese can spot linen. Therefore water quality and water consumption is of importance to this industry. Water quality aspects are discussed in Chapter 2.

In commercial laundries labour accounts for close to 50% of a laundry's operating costs. After labour the next highest costs are for energy, water, chemicals, linen replacement and maintenance. Given the high proportion of labour related costs, gaining a marginal increase in productivity increases the launderer's bottom line significantly. Productivity improvements have been achieved through automation of the whole laundry process including collection, sorting, washing and drying, ironing and folding, packing and delivery of the finished goods whilst maintaining hygiene and cleanliness standards.

In a typical laundry, water related costs could be one third the utility costs. A commercial laundry can use as much as 400–500 m^3/day (105 680–132 100 US gallons/day) and over 85% of this water is used in the washing process. The other uses are for steam generation, cooling and amenities. Close to 70 – 90% of this water is then discharged to the public sewer. Commercial laundries not only discharge significant proportion of the incoming water, the effluent also may contain toxic and flammable chemicals that a public utility is incapable of removing before they are discharged to the environment. For this reason, environmental protection authorities and water utilities are also applying pressure on them to improve their effluent quality.

Given the important role of chemicals in the washing process, chemical suppliers have also responded by developing more environmentally friendly wash formulations such as low temperature and low pH wash formulations, the use of peroxide bleach formulations instead of chlorine bleach and minimizing the use of surfactants such as alkyl phenol ethoxylates (APE). These product changes have produced water and energy savings as well as environmental and occupational health and safety benefits.

15.2 Industry Structure

The laundry market consist of

- large commercial laundries and textile leasing companies
- hospital laundries
- large On-Premise Laundries (Large OPLs)
- small On-Premise Laundries (Small OPLs).

15.2.1 Large Commercial Laundries

The large commercial laundries and textile leasing companies are geared to provide the linen and cater to the heavy work wear from food-processing and automotive industries; hospital and food catering and restaurant industry linen and industrial wipers, carpets and mats. A characteristic is the presence of solvents, oil and grease and heavy metals in the soiled linen. Solvents such as creosote are occupational health hazards.

These laundries have capacities to process 3–50 tons of dry linen per day [1]. The main washing equipment consists of large washer extractors and continuous batch washers (CBWs). The laundries own the linen.

15.2.2 Large Hospital Laundries

Hospital laundries process bed linen (the vast majority), theatre clothing, patient clothing and theatre packing. Equipment and facilities are similar to large commercial laundries. One particular aspect of this linen is the presence of blood, pus, faeces, urine, pathogenic bacteria, food and medicine in the soiled garments.

Equipment capacities are around 3–30 tons of dry linen [1]. Laundry equipment consists of CBWs and washer extractors and laundries own the linen.

15.2.3 Large and Small On-premise Laundries

Large on-premise laundries (OPLs) are found in food-processing plants, hotels and hospitals. Daily processing capacities are 0.5–3 tons of dry linen [2]. Small OPLs are found in nursing homes, motels and retirement villages. Coin-operated laundries also can be included in the small OPL sector. These have loads of less than 500 kg/day. Equipment in both cases are washer-extractors.

15.3 Types of Laundry Equipment

The objectives of any washing process are

- to achieve maximum dirt and stain removal
- to minimise detrimental effects on the fabrics (mechanical and chemical damage)
- ensure hygiene standards are met (microbial contamination)
- the look and feel is enhanced (whiteness, softness and fresh and clean smell).

The washing process consist of the following stages:

1. Pre-wash (break wash) – removes loose soil and blood.
2. Wash – disinfection is carried out in this step. Alkaline pH of 11 and above is maintained.
3. Bleach – removes stains, enhances whiteness and provides chemical disinfection.
4. Rinse – removes suspended solids and any chemicals remaining.
5. Sour – reduces the pH of the water to neutral by the addition of acid to minimise further damage to textiles and reduce skin irritations.
6. Finishing – reduces moisture by extracting water from the textiles through centrifugal action.

A combination of factors are controlled to achieve the objectives in each washing process and these are

- Optimal Water usage
- Mechanical energy
- Heat
- Optimal chemical usage
- Time
- Number of washing operations.

A deficiency in one of the factors needs to be compensated by the other factors. Adjustments are made to the type of fabric and soiling. For example, in hospital laundries, blood can get fixated if the washing temperature is above 35° C.

The degree of mechanical action is managed by specifying the machine load for the particular machine. In washer extractors a typical ratio is 10 L for every kg of load. Overloading leads to reduced soil removal. Underloading leads to utilities being wasted.

Heat is required to make the oils and fats soluble in the water, for disinfection and for activation of bleaching chemicals. Higher the temperature the more efficient the soil removal process is; however, high temperatures also increases the cost of energy production. Regulatory or national standards such as the Australian and New Zealand Standard AS/NZS 4146:2000 : *Laundry Practice* specify a minimum temperature of 65° C for 10 minutes or 71° C for 3 minutes to kill pathogenic microrganisms [2]. In countries such as Germany, Austria and Belgium the thermal disinfection temperatures could be as high as 90° C and maintained for 10 minutes.

Chemicals are essential for washing and are added at every stage of the washing process and range from:

- alkalies (e.g. caustic, metasilicate) – increases pH to facilitate breakdown in proteins, soil removal and increases the efficacy of bleaching chemicals.
- surfactants (like linear alkyl ethoxylates) – these range from nonionic, anionic and cationic surfactants. The nonionic and anionic surfactants increase the soil removal capabilities and cationic surfactants are applied as fabric softeners.
- builders such as phosphate and chelating agents inactivate hardness minerals and thereby increase the cleaning efficiency of the surfactants. Phosphates (are being phased out due to environmental impacts on the receiving waters).
- bleaching chemicals such as hypochlorite, peroxides, perborates and percarbonates. Hypochlorite usage is decreasing since the byproducts are not biodegradable and have carcinogenic properties.
- Acids such as phosphoric and citric are used to neutralise the alkaline pH.

Timing can vary from 2 minutes for a rinse to 10 minutes for the wash cycle. The number of washing operations performed depends on the type of soil and fabric to be washed. To achieve these objectives two types of laundry equipment are used in laundries. These are

- Washer extractors
- Continuous batch washers (Tunnel Washers).

They both accomplish the same goal. Successive baths are used to wash, rinse and finish the goods.

15.3.1 Washer-Extractor

A washer-extractor does all of the washing in one cylinder similar to the domestic variant. The load stays in place, and baths are changed by draining and refilling the single cylinder. An extraction cycle spins water out of the goods and prepares them for drying. Washer-extractors range in sizes from 16 to 363 kg (35 to 800 lbs). They can be either top loading or more commonly of the front loading or side loading types. Front loading machines use much less water and energy than the top loading models. Washer extractors conserve water in two ways. Intermediate extracts reduces the number of rinse water cycles. Some designs reduce water usage by injecting the water from below and tumbling the linen. These are reportedly more efficient that spray rinses. Other water conservation opportunities in these machines include proper scheduling, collection of rinse water in external tanks and other measures which are described below. Around 30% of water can be saved by reusing the final rinse water [3]. Modern washing extractors have programmable logic control and card systems to optimise water and chemical usage. Extraction speeds can be varied according to the linen washed thus saving on energy costs.

15.3.2 Continuous Batch Washers or Tunnel Washers

CBW systems are the work horses of the large industrial laundries or more commonly called *tunnel washers*. They were first invented by the German engineer Erich Sulzmann. The linen is moved by an internal 'auger' through a number of internal compartments. Each compartment requires a certain washing temperature. This is achieved by direct injection of steam to heat the water within the machine. Modern CBWs come with internal recycling options. Fresh water enters from the opposite direction i.e. the chamber with the cleanest linen. The water then cascades to the other chambers and then discharged. The use of counter current washing reduces the water and steam usage by 60–70% compared to the washer extractors. It also saves on detergents and chemicals used. At the end of the tunnel the linen is removed automatically and sent to dryers.

Figure 15.1 A photo of a typical CBW System

Courtesy of Sdyney Water.

Case Study: Parramatta Linen Service installs 3 new CBWs and halves its water usage.

Parramatta Linen Service (PLS) a NSW government owned laundry is the largest laundry in Australia. It processes 250 tons of linen a week and supplies 70% of the NSW Health's requirements for hospital linen, ward and sterile theatre linen and surgical garments.

PLS was consuming 12 L of water/kg of dry linen. It recently replaced the 3 CBWs with new CBWs and reduced its water usage to 6.4 L/kg of dry linen. Thus saving 250 m^3 of water per day and $78,000 per year.

Source: Media release, NSW Government, 26 February 07 and personal communications.

15.4 Benchmarking

In the US, a study conducted by the US Laundry environmental stewardship program of 500 laundries established that the overall water usage is 19 litres per kg of dry linen (2.28 US gal/lb) whilst dedicated linen plants use around 9.2–10 L/kg (1.1 - 1.2 US gal /lb) [4]. Average energy usage for the 500 respondents is estimated at 7.4 MJ/kg (3200 Btu/lb).

European values for tunnel washers are in the range of 8–12 L/kg (0.96–1.44 US gallons/lb) [1]. For washer extractors, Sydney Water has estimated the best practice water usage values and these are shown in Table 15.1 [3].

Besides heating of wash water, steam is used for heating of air in tumble dryers and ironers. For tunnel washers steam consumption is in the range of 0.4–0.5 kg/kg [1]. For washer extractors, steam consumption is in the order of 0.6–0.8 kg/kg of linen (0.27–0.36 lb of steam/lb of dry linen) [3].

In the UK, according to a survey carried out by the Energy Efficiency Office in 1993 established that the mean energy consumption was 2.66 kWh/kg [5]. The survey also established a good practice target of 1.96 kWh/kg.

Table 15.1 Best practice water usage for washer-extractors

Rating	Water usage without reuse		Water usage with reuse	
	Litres/kg Linen	US gal./lb linen	Litres/kg Linen	US gal./lb linen
Good	17–22	2.0–2.6	12–15	1.4–1.8
Fair	22–26	2.6–3.1	15–18	1.8–4.8
Poor	>26	>3.1	>18	>4.8

Courtesy of Sydney Water. Water Conservation Best Practice Guidelines for Hotels. Sydney. December 2001.

15.5 Water Conservation

Water conservation opportunities for laundries can be classified as follows:

- Get senior manager commitment. Refer to Chapter 3 on how to plan for water conservation.
- Install sub-meters and track daily water- and energy-usage to identify abnormal behaviour in machines or when processing a particular type of linen.
- Improve maintenance practices such as fixing leaks in water systems. Generally a 3% reduction in water usage is realizable [6]
- Improve scheduling of washing equipment and modify wash programs to suit the linen.
- Do not under load washers. A 10% under load results in 10% wastage of water and energy [6].
- Reduce rewash rates to a minimum.
- Change chemical ingredients to low pH and low temperature formulations.
- Purchase water efficient washer – extractors and CBWs with internal recycling.
- Install water efficient fixtures in amenities blocks.
- Replace defective steam traps and recover steam condensate.
- Repair live steam and condensate leaks.
- Ensure that the heat reclaimers are operating properly. Install temperature gauges to ensure that the unit is working properly to recover heat.
- Improve dryness of steam to processing areas.
- Recover vented flash steam. Refer to Chapter 7.
- Lag steam and condensate lines. Poorly insulated lines are a safety hazard and gives out heat through radiation.
- Ensure that the boiler blowdown practices are in accordance with national standards. High dissolved solids lead to scaling of boiler tubes.
- Practice on-site water reuse.
- Do not wash above the recommended temperature settings.

Water-reuse options are discussed in greater detail below.

15.5.1 Water and Energy Reuse

Laundry washing consists of discharging a very high proportion of the water it uses to the sewer. Moreover the water is hot and frequently needs to be cooled to below 38° C before discharging to the sewer. By recovering the waste heat using a heat exchanger as much as 60% of the heat can be recovered. The wastewater quality is frequently at a high pH. If the alkalinity can be recovered then the chemical costs can be reduced. Table 15.2 shows the wastewater quality from an industrial and two hospital laundries.

Table 15.2 Wastewater quality from industrial and hospital laundries

Parameters	Industrial laundry	Hospital laundry	Hospital laundry 2	License discharge limits to sewer
pH	8.26	11.4	11.6	7–10
Conductivity, μS/cm	640	808	1000–2000	NA
Total dissolved solids, mg/L	420	456	800	10,000
Total suspended solids, mg/L	69	71	66	600
Total hardness as mg/L $CaCO_3$	44	68	53	NA
Total alkalinity, mg/L $CaCO_3$	128	302	375	NA
Total oil and grease, mg/L	24	26	25	110
Phosphate, mg/L	3.43	10.8	167	50
BOD, mg/L	262	50	44	230

A consideration for installing water-reuse plants are that they are space limited and therefore the equipment needs to have a small footprint.

As Table 15.2 shows the major contaminants are high pH, suspended solids, oil and grease and BOD. Industrial laundries would have a higher concentration of oil and grease since they wash industrial carpets and mats, work clothes from a variety of industries such as from the automotive sector. Petroleum hydrocarbons could be an issue in some cases. Besides this laundry wastewater contains lint, hair and heavy metals.

The common wastewater external reuse strategies are

- Partial reuse of water
- Total reuse of water
- Ozone technology.

15.5.2 Reuse for Wash Water Quality

Partial reuse of water systems are designed to reuse of water as wash water rather than as rinse water. These systems typically do not reduce total dissolved solids and as such cannot be used in the rinse cycles.

Retrofit conventional washers with a holding tank to capture final rinse water and reusing in the wash cycle has been a common practice. It is estimated that this option has 30% water saving [4]. Since only the rinse water is captured, these systems typically have high initial costs and long payback periods [8].

Another option is to treat the total effluent and use it only in the wash water cycle. The effluent from the collection pit is first sent to an equalization tank and from there to a static screen or lint shaker. The lint shaker screen removes particulates. From here the water is pumped to a clarifier or dissolved air flotation unit (DAF) with coagulants and polymers injected online. The chemicals breakdown oil and grease and trap remaining suspended solids. However no dissolved solids are removed. From the tank the water is sent to a reclaimed water storage tank. The water is used for hot water applications only. The rinse and bleach cycles use fresh water. The total dissolved solids levels are monitored and controlled within allowable limits by diluting with freshwater. Another system marketed by Wastewater Resources Inc known as the Aquatex 360 uses backwashable pressure filters to remove 90–95% of the suspended solids [9]. Manufacturers claim to save 50–65% of the water and energy [8]. Chemical savings are achieved because the reclaimed water is at a pH of 9.5–10.5 compared to towns water pH of 6.5–7.5. Thus a reduced amount of caustic is required to boost the pH to 11.5.

Another manufacturer of such systems is Ecolab Inc. The case study below gives a description of their system.

Case Study: Illawarra Linen Service, Wollongong, Australia

Illawarra Linen Service is a NSW government-owned hospital linen service in Australia. It has a daily washing load of 15 tons per day and used to consume over 260 m^3/day of water.

It installed and Aquamiser unit from Ecolab Australia that allowed it to reduce its water consumption by 47 m^3/day. The Aquamiser removes sand, dirt and lint down to 25 μm. The reclaimed water is used in the washing cycles. The Energy Optimiser allows it to recover heat reducing the amount of natural gas required to fire the thermal oil heaters.

Adapted from: Sydney Water. The Conserver. Issue 9. December 2005.

15.5.3 Reuse for Rinse Water Quality

In total reuse of water suspended solids as well as dissolved solids are reduced. To reduce total dissolved solids most systems use nanofiltration or reverse osmosis membranes. However, due to the high suspended solids and oil and grease loadings nanofiltration and reverse osmosis systems cannot be used without pre-treatment that frequently includes microfiltration or ultrafiltration. The need for extensive pre-treatment makes the use of membrane systems cost prohibitive. Chapter 8 gives an explanation of membrane systems.

The effluent known as permeate can then be used as wash water or as rinse water. Generally 80–85% of the water can be recovered. The reject water is sent to the sewer.

The Vibratory Shear Enhanced Process (VSEP) from New Logic Research Inc. is a membrane system that does not require extensive pre-treatment apart from a shaker screen to remove lint. It is capable of operating to produce

Table 15.3 Permeate and reject water analysis from a VSEP nanofiltration membrane

Parameter	Effluent water	Filtrate ex Nanofiltration membrane	Reject stream to sewer
pH	11.6	11.0	11.3
Conductivity, μS/cm	1000–2000	320	3,000–4,000
Total dissolved solids, mg/L	800	134	1000–2000
Total suspended solids, mg/L	66	Nil	300
Total hardness as mg/L $CaCO_3$	68	<1	
Phosphate mg/L	167	<1	470
Chloride, mg/L	61	14	75
Iron mg/L	0.32	<0.1	
Total alkalinity as $CaCO_3$ mg/L	375	68	760
Total grease mg/L	25	<1	57
BOD	44		

Courtesy of the Water Management Group Pty Ltd.

washwater quality water as well as rinse water quality water. Table 15.3 shows the results achieved from a VSEP nanofiltration membrane trial. Refer to Chapter 8 for a discussion of this system.

The nanofiltration membrane is not able to completely remove monovalent ions and for this reason the alkalinity is only partially reduced. Figure 15.2 shows a schematic of the wastewater system.

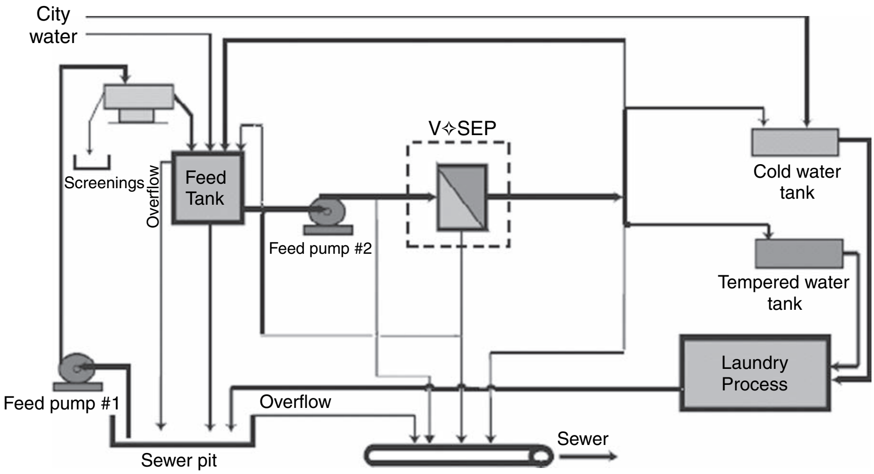

Figure 15.2 A schematic of a water-reuse system

Courtesy of New Logic Research Inc.

Case Study: Hospital Central Services Association, Seattle, USA

The Central Services Association processes the laundry of 11 hospitals amounting to 9 090 000 kg (20 000 000 lbs) of goods per year. The laundry operates for 14 hrs of the day and operates for 364 days of the year. It uses 395 m^3/day (104 US gal./day). After careful analysis the laundry installed a VSEP ultrafiltration system to recover 80% of the effluent water. At 80% recovery the operational savings are

The calculations are shown below:

Water and wastewater charges before reuse	US$218 000
Costs	
VSEP power consumption (30 kW @ US$0.38 kW)	US$ 6 600
System maintenance and cleaning	US$ 9 838
Water and wastewater charges after reuse	US$ 37 400
Additional Savings	
Heating savings (from 60° F to 100° F), 256 Therms/day @US$0.32/therm	US$ 35 438
Detergent savings	US$ 20 000

Total savings/yr = US$ 218 000 − 6 600 − 9 838 − 37 400 + 35 438 + 20 000 = US$219 600/yr

Payback = 11 months

Adapted from: Paschke P., Hill S., Lawson S. *At the Vanguard of Commercial Water Conservation. Seattle Public Utilities. Seattle Washington and* New Logic Research Inc. *Industrial Laundry Wastewater Treatment – a cost-effective and environmentally sound treatment.* January 1999.

15.5.4 Ozone Disinfection

The disinfection properties of ozone are well known. Ozone is now being applied in lightly soiled applications as a disinfectant and bleaching product instead of hypochlorite.

Ozone (O_3) is a colourless to blue gas with a pungent odour and a powerful disinfectant. It is denser than oxygen with a density of 2.14 kg/m^3 compared to 1.43 kg/m^3 at standard temperature and pressure. O_3 has an oxidation potential far greater than the hypochlorous acid (HOCl) of – 2.07V as against –1.49V. As a disinfectant, O_3 is 150% more potent and 3000 times more reactive than chlorine. It only requires as little as 1.5 mg/L of O_3 to kill bacteria and viruses. Similar to chlorine it also oxidises other soluble organic and inorganic contaminants such as tannins, iron and manganese.

However, O_3 is highly unstable and needs to be generated on-site. It has very low solubility and at temperatures above 43° C it is not soluble in water. Table 15.4 shows basic data on ozone. At pH levels below 7 the reactivity

Table 15.4 O_3 conversions and data

Parameters	
Density of O_3	2.14 kg/m^3 at standard temperature and pressure
O_3 concentration in water	1 mg/L = 1 ppm O_3 = 1 g O_3/m^3
O_3 concentration in air by volume	1 g O_3/m^3 of air = 467 ppm
Ozone solubility in water at 1% concentration (12.8 g O_3/m^3)	5° C–7.39 mg/L 15° C–5.60 mg/L 25° C–3.53 mg/L
Disinfection	bacteria and viruses – 1.5 mg/L
Oxidation – dissolved organic carbon	0.5–3.0 mg/L = 0.5–1.5 g/g COD
Pre-oxidation iron (Fe)	0.43 mg/L × Fe mg/L
Pre-oxidation manganese	0.88 mg/L × Mn mg/L

of O_3 is slow. However, at alkaline pH > 8, O_3 rapidly decomposes to the hydroxyl-free radicals which react very quickly with contaminants. Optimum pH for laundry applications are in the range 8–10.

O_3 is also a highly toxic gas and even at very low concentrations can be harmful to the upper respiratory tract and the lungs. Concentrations as low as 0.08 parts per million and exposed for 7 hours can bring about discomfort and an exposure of 50 ppm for half an hour can be lethal [10]. O_3 will also oxidise and corrode metals such as copper and its alloys. Only certain plastic materials and stainless steel are compatible with ozone applications. Best to consult a reputable ozone generator manufacturer. In poorly ventilated environments it is recommended to install an ozone monitor to monitor O_3 concentrations in the air.

In laundry applications, O_3 reduces water, energy and chemical costs. Water savings are achieved by reducing the number of rinses and some of the detergent chemicals. Although suppliers claim that water and sewer savings are as high as 50% general agreement is that this is more in the range of 15–20% [8]. Since O_3 works best at temperatures below 25°C (where a minimum dose of 3.0 mg/L is achievable) there are energy savings to be realised in the order of 40–60% as claimed by some manufacturers. There are claims that O_3 also reduces chemical costs by as much as 50%. However this depends on whether the washing formulations need to be changed to accommodate the low temperatures. Other benefits of O_3 are that the clothes are softer and clean smelling.

The efficacy of O_3 washing is dependent on how it is injected into the washer. The main methods of O_3 injection are

- bubbling O_3 gas directly into the washer
- direct injection
- supplying ozonated water through a supply tank.

Ozone dissolution in water follows the rules for solubility of gases and all of these methods depends on the four main factors that affect the solubility of O_3 in water are

- contact time between the gas and the water
- water pressure
- method of mixing of ozone in the water
- water temperature.

In the bubbling method, the efficacy of O_3 is dependent on how quickly the gas can dissolve during the cleaning cycle. Given the low solubility of O_3 and the short contact time of the cleaning cycle, the majority of the O_3 would be expected to flash off into the vapour phase. Moreover, it is difficult to precisely control the dosage of O_3 in the wash mix.

In the direct injection method, an eductor is used to suck the O_3 gas to the water supply line to the washer. This method too relies on having sufficient contact time to dissolve the O_3 gas. One way increasing the ozone and water contact time is to install a static mixer. Having sufficient contact time is crucial to achieve the desired O_3 concentration in the washer.

Dissolving the O_3 in a tank allows for sufficient time to achieve the desired concentration. The ozonated water can then be used in the washing process. This is preferred method if the site is not limited by space.

It is desirable to measure the ozone concentrations through a dedicated ozone monitor or an oxidation reduction potential monitor (ORP). Typical values to achieve 1.5 mg/L of O_3 ORP are in the order of 700–975 mV.

The ASTM Standard E 2406–04 [11] can be used to evaluate the laundry sanitisers and disinfectants for use in high-efficiency washing operations. Organisations such as the Australian Wool Testing Authority are able to test the claims of suppliers regarding the stain-removal capabilities of O_3.

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