4. Aqueous Scouring and Detergents

Errol Wood

Learning objectives

On completion of this topic you should be able to:

- Explain how grease may be removed from wool
- Describe the conditions under which liquids may, or may not, mix, and the role of the interface
- Explain how surface active agents behave
- Differentiate between anionic, cationic, non-ionic and amphoteric surfactants
- Outline the key stages in the removal of grease from wool in a scouring bowl
- Describe, by means of a sketch, the types of detergent mostly used today for wool scouring
- Explain how entanglement and felting occurs with wool
- Explain the role of the squeeze press and the factors that affect its performance

Key terms and concepts

Suint, woolgrease, vegetable matter, detergent, relative density, interface tension, emulsification, surfactant, non-ionic detergent, oxidised and non-oxidised woolgrease, entanglement, felting, differential friction effect, squeezing, roller lapping, regain

Introduction to the topic

This topic outlines the principles of aqueous wool scouring, in particular the role of the detergent in grease removal by the formation of an emulsion.

While solvent scouring has certain advantages and has been tried, with limited success, in various parts of the world, aqueous scouring is virtually the only commercial technique operating today. While water is readily able to remove suint, a soluble salt, from the wool, more effort in the form of agitation and squeezing is required to remove the grease and particles of dirt attached to the fibre.

For these insoluble contaminants a suitable detergent (or soap in bygone years) is the necessary agent. Using its surfactant action, a detergent lifts droplets of grease, which contain dirt particles, from the fibre and the droplets of grease thus form an emulsion with the water. To understand the surfactant action it is necessary to know something about the structure of detergent molecules and to appreciate that one end of the molecule is water seeking (i.e. hydrophilic) and the other end is grease-seeking (i.e. hydrophobic). Consequently, one end of the molecule is buried in water and the other end is buried in the grease. This ensures that a droplet of grease once removed becomes part of a stable emulsion and is not re-deposited on the wool.

Mechanical action, in the form of the motion of the rakes and the squeeze rollers is also vital to effective aqueous wool scouring. The rakes gently move the wool across the bowl without introducing entanglement while the squeeze rollers ensure that a large proportion of scour liquor is removed and is not carried to the next, cleaner bowl.

4.1 Removal of wool contaminants in scouring

Raw wool has natural, applied, and acquired contaminants. These vary in their nature and amount from fleece to fleece and between wool types. Sheep management practices and the environments under which the wool is grown also have effect on the nature and amount of contamination.

In woolscouring, it is necessary to remove the following impurities:

- Suint, which is mainly dried sweat and contains mainly potassium salts. Suint is water soluble
- Woolgrease, which is a complex mixture of compounds called *esters*. Esters are formed by a reaction between acids and alcohols, with the elimination of water. Esters formed from fatty acids are called *fats*. Fatty acids occur naturally, and they react with alcohols to form fats
- Surface soiling, which includes dust, dirt, sand, faeces, and vegetable matter, such as burrs picked up when the sheep is grazing. Traces of dipping compounds (for fly strike) and branding chemicals may also be found.

Most wool scoured in New Zealand contains comparatively little vegetable matter (VM), while in Australia a significant portion of the clip has high levels of VM. Furthermore, certain types of VM are more troublesome than other types. Carbonising may be carried out on these wools, which precludes them being used for worsted processing.

When all the three impurities listed above have been removed by scouring, the natural colour of wool, that is, creamy white, remains. Wool can be made whiter by bleaching if needed, and this is carried out in the last bowl of the scouring line.

Removing suint

The salts in suint are water soluble and hence are easily removed.

Removing woolgrease

To understand the removal of woolgrease, it is important to note that oils, greases and fats:

- Are insoluble in water
- Form emulsions when shaken in water containing soap or detergent. An emulsion is the dispersion of one liquid in another. For example, milk is an emulsion
- Dissolve in organic solvents, such as white spirits.

Thus an oil, grease or fat can be removed by one of the following methods:

- Converting the oil, grease or fat into a soap by using an alkali. This is called *saponification*. The fatty matter in the oil or grease is converted to a soap by the action of the alkali, but too much alkali can damage wool
- Emulsification with soap or some other surface-active agent, such as a detergent. Emulsification means that the grease is dispersed as tiny droplets in another liquid. In scouring, the other liquid is water
- Dissolving the oil, grease or fat with an organic solvent (solvent scouring).

Of the three methods of scouring, emulsion scouring is the most widely used.

Removing surface soiling

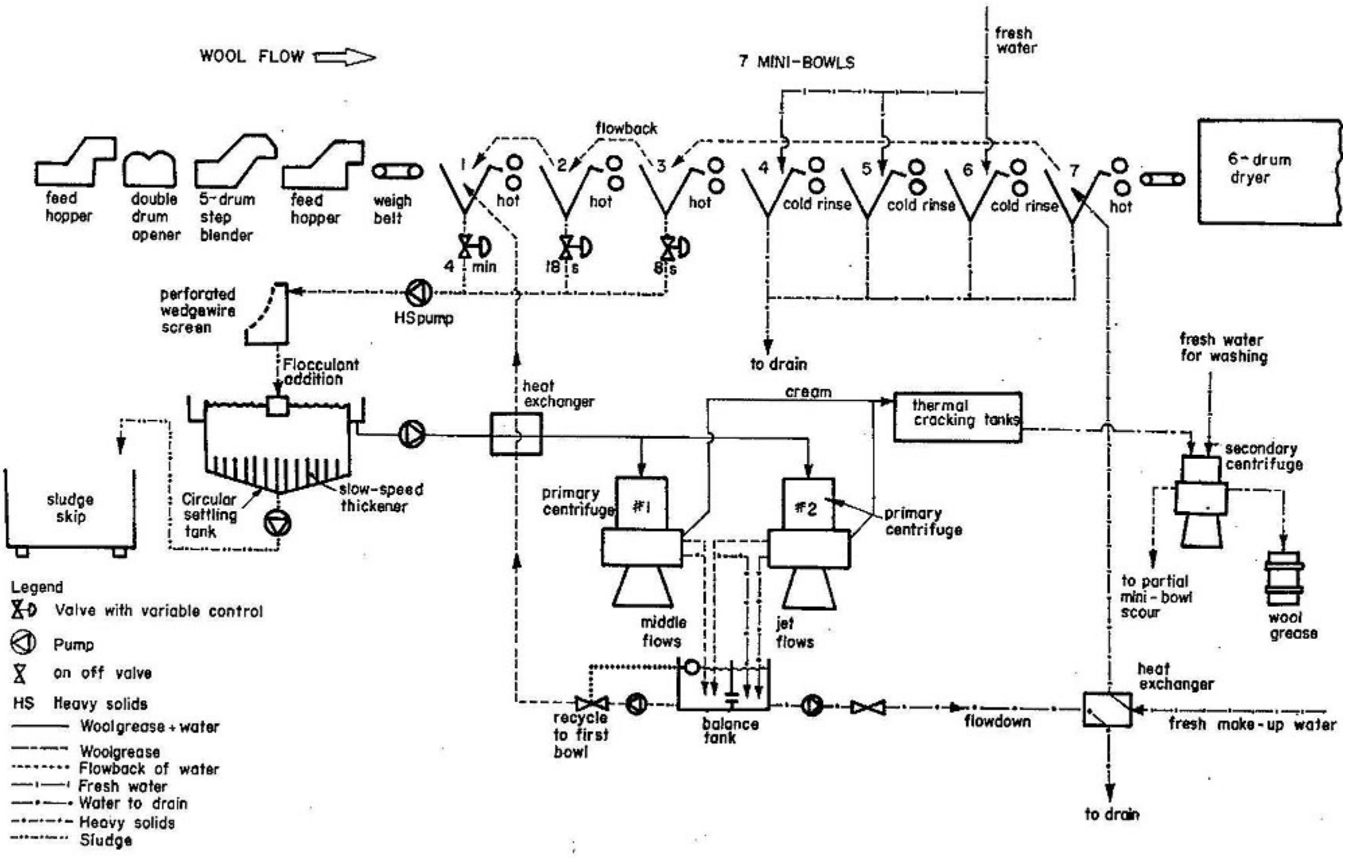
Surface soiling is removed by:

- Agitating the wool in the liquor with the harrow rakes, and
- Squeezing the wool with the squeeze rollers.

Wool scouring is carried out by a ‘counterflow’ method. While the wool moves forward from the start of the first bowl to the end of the final rinse bowl, the liquor flows back from the final rinse bowl through the third and second scour bowls to the first scour bowl. This flowback compensates for the liquor carried forward with the wool. Equally important - the flowback of liquor keeps the level of contamination in each bowl to a minimum while keeping the efficiency of the detergent at a maximum.

Most of the grease, dirt, and suint are removed in the first bowl. Figure 4.1 shows the layout of a typical woolscour. The temperatures of the scour bowls are 60 - 70°C and the final rinsing temperature is about 60 - 65°C.

Figure 4.1 Typical scouring plant layout. Source: Wood, 2006.



4.2 Emulsion scouring

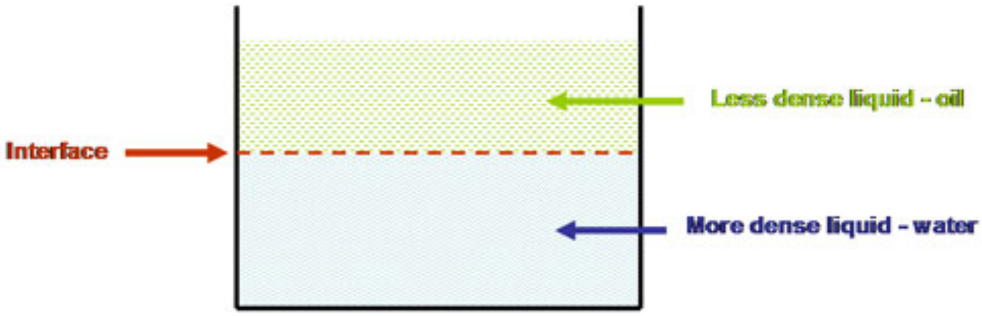
This section explains how surface-active agents, such as detergents, facilitate wool scouring (Selinger 1988).

If two liquids that do not mix at all (i.e. are immiscible), such as oil and water, are shaken together, some of the oil will disperse in the water. This dispersion is an emulsion until the two liquids separate. However, the dispersion of oil in water is unstable and if the two liquids are left to stand, they will separate. This concept can be tested by boiling sausages in a saucepan and then leaving them to cool. The grease or fat from the sausages rises to the top of the water to form a separate layer.

The reason why the oil, grease, or fat rises to the surface is that one liquid is less dense than the other. In the case of the boiling the sausages, the grease or fat is less dense than the water. Every substance has a density relative to another substance. The density of a substance is usually compared with the density of water. If the substance floats in water, it is less dense than water as has a relative density less than 1. If the substance sinks in water, it must be denser than water and thus has a relative density greater than 1.

Strictly speaking, the relative density of a substance (solid, liquid or gas) is defined as the ratio between the mass of a certain volume of the substance and the weight of the same volume of water at 4 °C. Oil has a lower relative density than water and so the oil floats to the surface of the water after it has separated from the water. Figure 4.2 shows how this separation occurs.

Figure 4.2 Separation of oil and water. Source: Wood, 2006.



The boundary layer where the liquids are in contact is called the *interface*. At the interface, a tension exists so that the two liquids will either mix well, or not at all.

An interfacial tension:

- Exists between layers of liquids
- Exists around droplets of liquids, and
- Is high or low, depending on how well one liquid mixes with the other.

The interfacial tension between oil and water is high, so they are immiscible. In other words, they separate easily under the influence of gravity into two discrete layers.

In wool scouring, the task is to remove the grease from the fibre, and dirt is attached to the grease. Thus, if the grease is removed, the dirt is also removed. The necessary steps are as follows:

- Wet the surface of the fibre with the scour liquor. This is the aqueous phase of scouring
- Detach the grease and dirt from the fibre
- Stabilise the two liquids to form an emulsion so that the grease is not redeposited on the fibre.

A soap or detergent is used to wet the fibre, detach the grease, and create interfacial tension so as to stabilise the dispersion of the grease in the water.

4.3 Detergents

Detergents are cleansing agents and they contain *surfactants*.

The term *surfactant* is the abbreviated form of *surf*ace *act*ive *agent*. A surfactant is a substance that has the effect of reducing the interfacial tension between water and other liquids. Surfactants are used in textile processing in many forms, including wetting agents, emulsifiers, and detergents.

In wool scouring, water alone is not enough to remove the lubricant and dirt because water molecules cannot penetrate the greasy layer to detach it from the fibre surface. To remove the fibre impurities, such as the film of grease with dirt attached, it is necessary to transfer the greasy film from the fibre into the liquor. To do this, the liquor must first wet the fibres. The presence of a surfactant in a detergent enables water to coat (i.e. wet) a non-wettable surface.

The wetting reduces the interfacial tension between the grease and the water, so that the grease droplet detaches and floats away from the fibre.

A molecule is the smallest chemical unit of a substance that is capable of a stable, independent existence. It is a group of atoms held together by chemical bonds. Molecules are attracted to one another. For example, each individual molecule of water is attracted to others and they coalesce to form a liquid. However, where the water molecules meet another substance such as grease, a lower attractive force is present between the water and that substance. This lower attraction means that the water molecules pull away from the contact surface of the other substance, and so the water will not penetrate a greasy film.

For effective grease and dirt removal the aim is to spread the water over the complete surface of the fibres, loosen and remove the grease and dirt, and then suspend the molecules of lubricant and dirt in the liquor so that they can be rinsed away. The detergent, with the required surfactant properties, does this.

Types of surfactants

The surfactant molecules are often described as being ‘tadpole-like’ with a long ‘tail’ that is *hydrophobic* (i.e. has an affinity for oil and grease and repels water), and a more compact ‘head’ that is hydrophilic (i.e. has an affinity for water and is repelled by oil and grease). There are four general types of surfactant (see Figure 4.3):

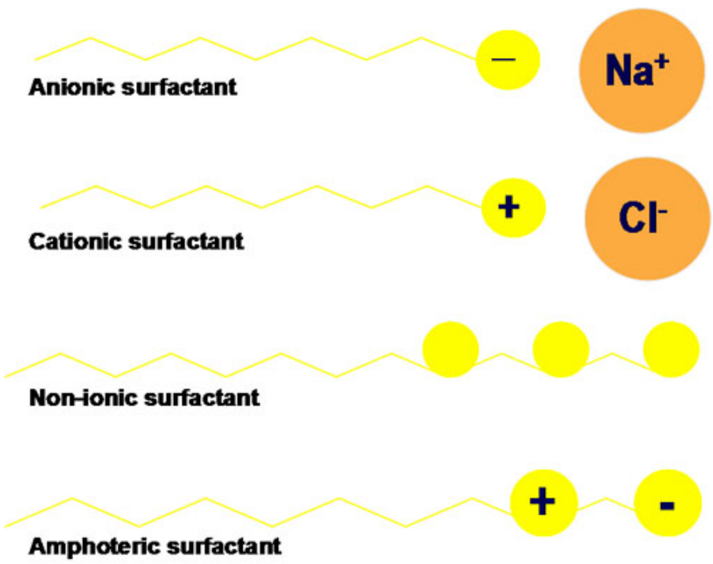
1. **Anionic**: The surfactant is an anion (it carries a negative charge) and the charge is concentrated in the hydrophilic head

2. **Cationic**: These are the opposite of anionic surfactants – the head carries a positive charge

3. **Non-ionic**: These do not have a specific charge, but the hydrophilic portion of the molecule is usually achieved by incorporating a polyethylene oxide group into the molecule. Because it is less polar than an ion, the hydrophilic portion of these molecules is usually larger than in the case of the ionic surfactants

4. **Amphoteric**: Some specialised products carry a positive and negative charge in the same molecule. Hence they behave as either an anion or a cation depending on the pH of the solution in which they are being used.

Figure 4.3 Types of surfactant molecules. Source: Wood, 2006.



A surfactant molecule can also be likened to a matchstick, i.e. it has a compact head and a long tail with very different affinities for water and grease. The head of the molecule, which because it is charged is termed *polar*, is water seeking. The tail of the molecule, which is completely non-polar, is oil or grease seeking.

While this simple picture is realistic for anionic detergents such as sodium lauryl sulphate, it is a less realistic representation for non-ionic surfactants where the water-seeking end is a long poly(ethylene oxide) chain. In an anionic surfactant the 'head' is relatively long and doesn't have a full charge, but has many localised little charges (δ-) along its length, i.e.

$$\overset{\delta-}{—CH_2CH_2O}\;\overset{\delta-}{—CH_2CH_2O}\;\overset{\delta-}{—CH_2CH_2O}\;\overset{\delta-}{—CH_2CH_2O}$$

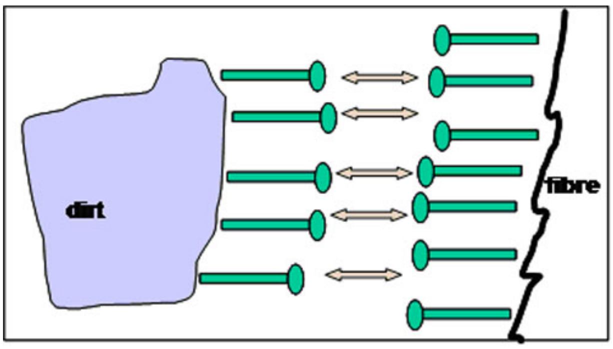
The net effect is that the head is slightly polar and thus has an attraction for water. This type of surfactant (which is the type mostly used in wool scouring) is described more fully later.

Detergency

If a detergent is added to water, it becomes evenly distributed throughout the water. Where there is an interface present between the grease and the water, the surfactant molecules preferentially orient themselves at the interface, due to the different polarities of the head and tail. The surfactant is said to be *adsorbed* at the interface, i.e. aligned, but distinct. The effect of adsorption is that the interface is expanded and the interfacial tension is lowered by the presence of the surfactant molecules. One outcome of lower interfacial tensions is that surfaces are easier to wet. Surfaces must be wet for detergency to occur, and wetting certainly helps wool which has a hydrophobic surface.

The heads of an ionic surfactant molecule will repel each other, because they have the same charge. This means that two surfaces coated with preferentially oriented surfactants, will repel each other (Figure 4.4).

Figure 4.4 The negatively charged heads in an anionic detergent repel each other, to assist separation of dirt from the fibre. Source: Auer (1999).

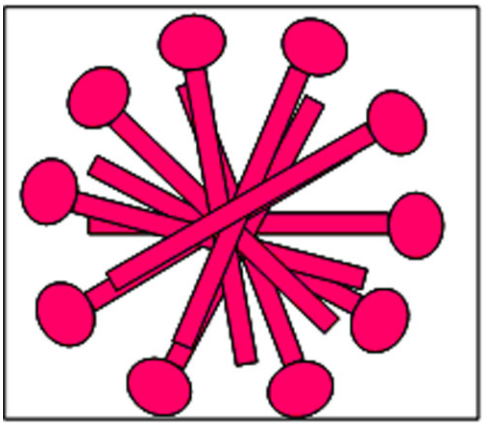


This repulsive effect is greater for anionic surfactants due to their full negative charge, but also occurs with non-ionic surfactants to a lesser extent. This repulsion means that it is easier to separate the surfaces and thereby remove the contaminants.

Furthermore, the materials removed will be easier to keep separated or *suspended* with a surrounding absorbed layer. For anionic detergents the suspension is maintained through electrical repulsion, while for non-ionic detergents the particles are kept separated by the coatings of surfactant. It must be noted that some form of agitation is necessary to dislodge the particles.

Another effect that occurs above a certain concentration of surfactant is the formation of clusters of molecules. The surfaces are crammed with surfactant but the surfactant is still in solution. These clusters of surfactant, called micelles, can be visualised as a drop of liquid hydrocarbon, the tails of the surfactants forming the centre of a sphere covered with charged heads (Figure 4.5).

Figure 4.5 A micelle formed by surfactant molecules. Source: Auer (1999).



For the emulsification of woolgrease, non-polar materials can be trapped inside the centre of the micelles. They are stable structures which effectively remove the grease from the fibre.

Relating the action of a surfactant to woolscouring, when a fibre, with a coating of grease, is immersed in the water containing the detergent, the fibre becomes wetted. The detergent spreads along the surface of the fibre to completely surround it, with the oil-seeking part of the surfactant molecule mixing with the grease on the fibre. Hence, the surfactant molecules cross the grease-water interface and get under the lubricant film and dirt, which is attached to the fibre. The tails of the surfactant molecules in the detergent then completely surround the film and lift it off the fibre as shown in the sequence of photographs in Figure 4.6.

Figure 4.6 Mechanism of grease removal by detergent action. Image supplied by E. Wood, courtesy of Canesis Network Ltd.

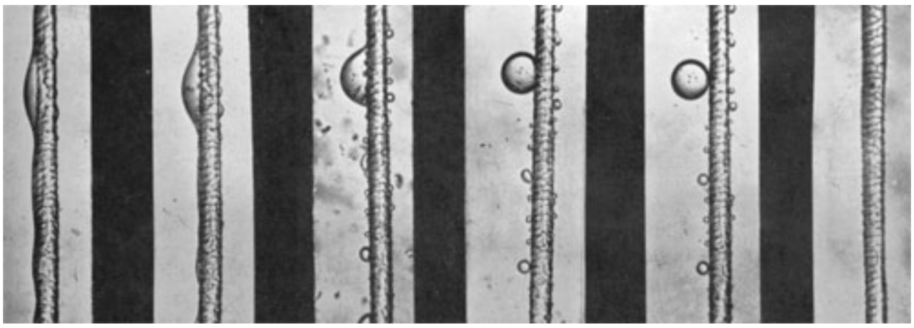
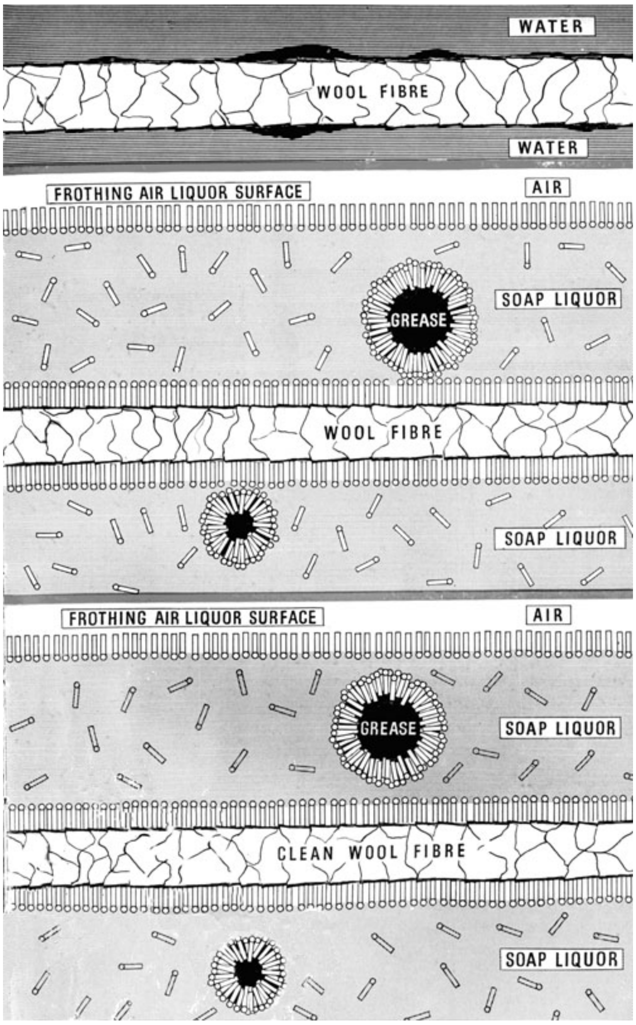


Figure 4.6 shows how the grease gradually forms into a droplet and then lifts off the fibre. When the droplet has been removed from the fibre, the water-seeking parts of the molecules attach themselves to the droplet. The water-seeking parts of the surfactant molecules are pointing outwards into the water. With the water-seeking parts directed outwards, the grease is less inclined to separate from the water. In other words, a stable emulsion has been formed with the droplets of grease dispersed in the water.

A grease droplet surrounded by surfactant molecules will not redeposit itself on the fibre because the water-seeking parts of the surfactant molecules repel each other. The surfactant molecules on the surface of the fibre repel those on the grease droplet (Figure 4.7).

Figure 4.7 Grease droplet separated from a wool fibre. Source: Wood, 2006.



4.5 Removing grease from the wool

The stages of grease removal in the scouring bowl are:

1. Water is heated to above the melting point of woolgrease, which is about 40°C. The heated woolgrease forms a stable film over the surface of the fibre. The woolgrease is more attracted to the fibre than to itself, and this is why it forms a film over the fibre

2. The scouring liquor wets the fibre

3. Surfactant molecules from the detergent cover the film of grease. The grease-seeking tails are attracted to the grease, with the heads in the liquor

4. Surfactant molecules on the wetted fibre reduce the attraction of the grease to the fibre. The grease rolls up into droplets

5. The water-seeking heads of the surfactant molecules on the fibre and on the grease droplet attract water to themselves. The water attracted to these molecules pushes between the fibre and the grease droplet. This helps to detach the grease droplet

6. Agitation by the harrows and the high-speed liquor flow at the squeeze rollers float the grease droplets away from the fibre

7. Particles of dirt are removed from the fibre by:

   - Agitation of the liquor
   - Being washed away with the grease droplets, and
   - Mutual repulsion between fibre and dirt.

Emulsion stability is maintained when enough detergent is in the liquor to completely disperse in the water and surround the surfaces of all the fibres and grease droplets.

If the amount of detergent in the liquor falls below the required minimum level:

- There is a quick drop in the amount of woolgrease removed from the fibre
- Droplets of emulsified grease may redeposit on the fibre because fewer surfactant molecules surround the droplet
- Droplets of emulsified woolgrease may combine to form larger masses. This will, in turn, break down the emulsion and form a layer of grease on the surface of the liquor. Again, the reason is that fewer surfactant molecules surround each droplet of grease.

Detergents for wool scouring (Rankin 2004)

Before the 1950s, the main detergent used to scour wool was soap, which was used with an alkaline builder such as soda ash (sodium carbonate). The role of the builder was to stabilise the emulsion formed by the woolgrease and water and prevent re-deposition back onto the wool. The propensity of soaps to form insoluble salts with calcium and magnesium ions in hard water areas prompted the development of synthetic detergents. It was necessary for soft water to be used because of the insolubility of calcium and magnesium soaps. In fact, the wool textile industry developed in the Yorkshire area of the United Kingdom because of its abundance of soft water.

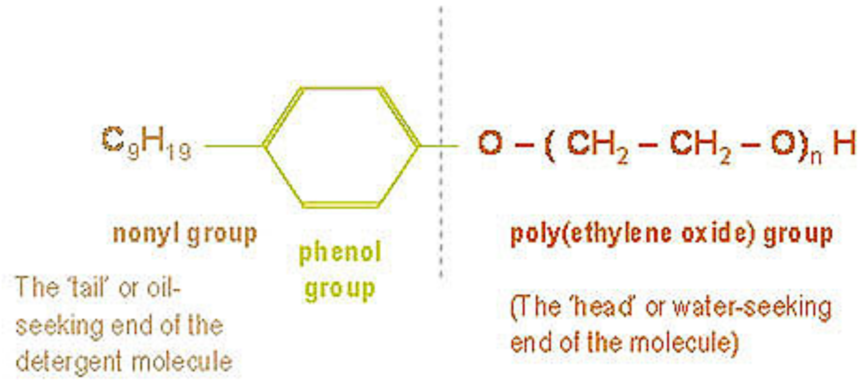
Suint has soap-like detergent properties when either natural alkalinity is present in the fleece, or alkali is added to the washing liquors. Greasy crossbred wools contain more suint than fine wools, and are naturally alkaline and contain less woolgrease. This explains why crossbred wools are usually scoured with a hot first bowl without any addition of soda ash. In contrast, soda ash may be added to the early bowls of fine wool scours.

Although most detergents used today are synthetic, both soap and synthetic detergents work in a similar way. The synthetic detergents widely used in wool scouring today are non-ionic detergents, usually of the alkylphenol/ethylene oxide type. To make the non-ionic detergent, phenols and ethylene oxide, which are products of the oil industry, are combined.

A number of ethylene oxide units make up the water-seeking head group of a surfactant molecule (see Figure 4.8). The size and shape of the hydrocarbon components in the tail determines how well it seeks oil. Usually, eight to ten ethylene oxide units in the poly (ethylene oxide) group, and a 'tail' containing a highly branched nonyl group attached to a phenol group make a good scouring detergent. It is also a good general-purpose detergent with various uses other than in wool scouring so it is manufactured in large amounts. It is the most cost-effective detergent for wool scouring so far developed.

The most widely used detergent used in wool scouring is Lissapol TN450, which is a condensate of nonyl phenol with 8.5 moles of ethylene oxide. This means that the head has on average 8.5 molecules of (CH_2CH_2O). The presence of oxygen causes localisation of electrons along the head.

Figure 4.8 Nonylphenol poly (ethylene oxide) detergent molecule. Source: Wood, 2006.



Although this type of detergent is widely used in Australian and New Zealand, it is no longer permitted for wool scouring in Europe. This ban has arisen from environment concerns about phenol derivatives that are produced during biodegradation. In Europe, fatty alcohol ethoxylate detergents, which are similar in molecular structure to the type depicted in Figure 4.8 (but without a phenol group), are used instead for wool scouring.

The amount of detergent needed to maintain an emulsion and give a good scour varies with the type of wool being scoured. For example, clean wools need less detergent than dirty wools such dag wool blends.

To keep the correct amount of detergent in the liquor, it is necessary to check that:

- Detergent is added to the bowls regularly
- The detergent tank does not empty
- Stopcocks on the pump are open
- The pump mechanism is unblocked, and
- The pump motor is in good working order.

A large amount of detergent does not necessarily give better scouring. Also, it costs more to use too much detergent, and detergent is deposited on the wool fibres, to give potential problems downstream.
Woolgrease is of two kinds, unoxidised and oxidised. During wool growth, the grease near the tip of the fibres slowly becomes chemically degraded. The oxygen in the air causes this chemical change, and the woolgrease becomes oxidised. At the base of the fibre, the more freshly deposited grease is unoxidised.

Compared with unoxidised grease, oxidised grease is:

- Harder to remove during scouring than the unoxidised grease, and
- Removed more after the first bowl.

Residual grease left on the fibres of scoured wool has a higher proportion of oxidised grease.

Removing dirt

Dirt is harder to remove than woolgrease. Sufficient mechanical action by the harrows is essential for good dirt removal. The squeeze rollers play a key part too.

Pressure on the squeeze rollers is important to ensure that:

- As much dirt and grease as possible is removed from the wool, and
- As little dirty liquor as possible is carried to the next bowl so that less dirt is redeposited on the wool.

It is important to remove as much dirt as possible during scouring to avoid problems in later processing. For example, dirt in yarn can cause variable light fastness and inferior colours in dyeing. Most dirt and impurities are removed in the first bowl, with the rest being removed in subsequent bowls. After the last (rinse) bowl, almost all impurities have been removed, except for about 0.1 - 0.4% of woolgrease (in New Zealand), or 0.3 – 0.8% in Australia.

Research has shown that all the contaminants, not only the grease, can be divided into two fractions – an easy-to-remove fraction and a hard-to-remove fraction (Christoe and Bateup 1987). The former fraction comprises the unoxidised grease, most of the oxidised grease, readily soluble suint and loosely held mineral organic and proteinaceous dirt (i.e. wool fragments). The latter fraction comprises a small fraction of the oxidised grease, slowly-soluble suint, submicron mineral dirt and flakes of proteinaceous contaminants adhering to the fibre surface

The current picture of contaminant removal from raw wool is as follows:

- Penetration of the grease by water and surfactant, followed by rapid swelling of both grease and proteinaceous contaminants
- Formation of grease globules (unoxidised grease in particular) within the swollen matrix of the contaminants
- Mechanical action causes most of this matrix to be displaced from the wool into the surrounding liquor
- The remaining contaminants, which still adhere to the fibre, are removed more slowly to give a clean fibre.

These findings have had important implications in the design of modern scouring lines. The result is that optimal systems for scouring Australian merino wools are quite different to the standard scouring lines designed for handling New Zealand crossbred wools. The major differences in the properties of these wools that are relevant to scouring mean that rather more sophisticated scouring lines are required for the gentler, thorough scouring required for Merino wools (see the comparison of these properties in Table 4.1).

Table 4.1 Properties of New Zealand and Australian wools relevant to scouring performance. Source: Wood, 2006.

Property	New Zealand crossbred wool	Australian merino wool
Fineness	coarse	fine
Staple length	longer	shorter
Fleece density	open	densely packed
Crimp/bulk	low	high
Entangling propensity	lower	higher
Grease content	lower	higher
Proportion of oxidised grease	higher	lower
Dust and dirt content	lower	higher
Suint content	higher	lower

Entanglement and felting

The felting of wool, in a mild form, can be regarded as fibre entanglement. In its most severe form felting forms the basis for a number of wool products such as felts.

Considering the essential requirements for felting, it is no surprise that this is cause of concern in aqueous scouring:

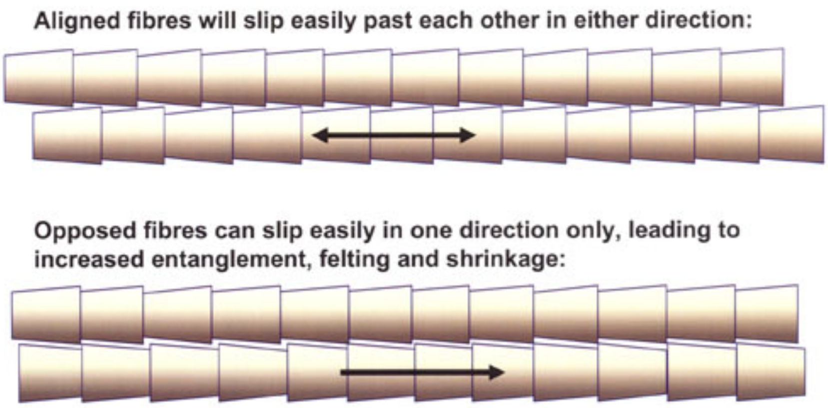
- Fibres need to have freedom to move and be in contact with other fibres. Once the staple structure has been broken down this can be achieved, and also, the fibres can achieve an opposed configuration (i.e. neighbouring fibres can point in opposite directions)
- Water acts as a lubricant, enabling the fibres to slip past each other. Wool also absorbs water, which tends to raise the scales of the fibre and increase the flexibility of the fibres
- Agitation is necessary to achieve relative movement of the fibres past each other. Even though the agitation in scouring is relatively gentle, it is still sufficient to cause some entanglement.

A feature of wool, along with other animal fibres, is a Directional Friction Effect (DFE). This means that the coefficient of friction against the scales (μ_a) is greater than the coefficient of friction with the scales (μ_w). This is expressed mathematically thus:

$$DFE = (\mu_a - \mu_w) / (\mu_a + \mu_w)$$

When the two coefficients of friction are equal, DFE = 0. The effect is shown in Figure 4.9.

Figure 4.9 The Differential Friction Effect (DFE) with wool fibres. Source: Wood, 2006.



It is much easier for fibres in contact to slide past each other when the scales point in the same direction (upper diagram). When fibres in this configuration are agitated they may move, but they can also slip back to their original positions. Entanglement will not occur in this case, where DFE = 0. This is the situation when wool is retained in a staple structure where the fibres are all oriented the same way.

When adjacent fibres are in opposite directions, slippage can occur in one direction, but the interaction of the scales obstructs slippage in the other direction. Hence DFE > 0. The result is that the agitation of a fibrous structure, where a significant proportion of adjacent fibres are opposed, will tend to move towards a more entangled state. The eventual outcome is a dense, felted mat. This can occur in scouring bowls, if the agitation is excessive or prolonged.

Cotting is an example of natural felting of a fleece while still on the sheep. It is associated with extreme tenderness, where parts of the fleece become detached from the body of the sheep. Fibres become free and are able to migrate to a sufficient extent that the conditions for felting are reached, i.e. some fibres become opposed in direction. Some moisture is likely to be present and the sheep will provide the agitation by movement and lying on the ground. The result is a fleece that is densely matted in parts, requiring a vigorous opening treatment (de-cotting) prior to scouring. A high level of fibre breakage is inevitable.

Squeeze rollers

The action of the squeeze rollers is critical to the effective removal of contaminants from the wool. As the wool mat enters the nip of the squeeze rollers, it is subjected to intense hydrodynamic forces which are particularly efficient at removing wool grease from the wool fibres, but less effective in removing dirt. Effective squeezing also minimises the carryover of contaminants entrained in the wool to the next bowl in the scouring line. When dirty liquor is carried on to the next bowl, dirt is redeposited on to the wool fibres. Squeeze roller efficiency is especially important at the end of the first scouring bowl to remove most impurities.

The efficiency of the squeeze rollers of the last bowl in the scouring line is also very important. By reducing the regain of the wool entering the dryer, the energy usage of the dryer is reduced while its wool throughput capacity is increased. The squeezing efficiency of rollers in a scouring line increases with (a) temperature and (b) the downward force applied on the top roller. Typical industrial squeeze rollers are designed for a maximum force of 5-10 tonnes per metre of scour width. Most modern squeeze rollers are pressurised by pneumatic systems, with the bottom roller commonly made of steel with stainless steel or chrome steel coating. The top rollers are also commonly made of steel, with a lapping of polyamide rope of square cross section.

Squeeze roller efficiency determines the amount of liquor left in the wool after pressing. The *regain* is the term for the moisture content of wool and it is always shown as a percentage.

The regain of wool is calculated as follows:

$$\text{Regain \%} = \frac{\text{weight of moisture in the wool}}{\text{dry weight of the wool}} \times 100$$

Squeeze roller inefficiency may result from:

- The roller lapping being in poor condition
- The squeeze pressure being too low
- The wool feed being uneven and lumpy, or
- Rollers bowing under excess pressure so that the effective squeeze force in the centre is reduced.

The roller lapping is used to:

- Minimise the crushing action of the rollers
- Reduce the amount of regain in the wool, and
- Remove the maximum amount of impurities.

The following should be considered when roller lapping is selected:

- It needs to provide the most efficient means of squeezing. Different lappings and combination of lappings affect the amount of liquor squeezed out and therefore the amount of grease and dirt removed from the wool
- The length of its life is important too. Some roller lapping materials are harder wearing than others
- It must not contaminate the wool with loose fibres
- Its overall cost, which includes reducing the amount of drying needed. The more water that is removed at the final squeeze, the less energy required for evaporation in the dryer.

The following are typical of the types of roller lapping used in wool scouring:

1. ***A wool top over a base rope foundation:*** A crossbred wool top is used. This type usually lasts about a week, with the top lapping needing replacement
2. ***Nylon tow over wool top and base rope:*** The nylon tow is filaments of nylon that are untwisted but may be braided together. Nylon is more durable than wool, and so the nylon tow lasts a few weeks. However, the lapping is less resilient than desirable because it tends to pack down and become harder
3. ***Wool/nylon or nylon rope:*** Either of these ropes is used without a base rope. They will last for 1 to 2 years. However, they are very costly compared with the other lappings, but the longer life compensates for the added cost.

Squeeze rollers and lappings should be well maintained to give good squeezing efficiency and to avoid costly stoppages of the scouring train.

Computer modelling has contributed to an understanding of the scouring process and the development of improved scouring systems. For example Barry and company have recently presented a computer model of a wool scouring bowl, including the action of the squeeze rollers (Barry, Mercer and Marchant 2002).

Readings

The following readings are available on CD

1. Barry, S.I., Mercer, G.N. and Marchant, T.R. 2002, *Mathematical modelling of a wool-scour bowl*, School of Mathematics and Statistics, ADFA, UNSW.
2. Rankin, D.A. 2004, Detergents for woolscouring, Canesis Network Ltd, Christchurch, NZ.

Activities	Available on WebCT
Multi-Choice Questions	Submit answers via WebCT
Useful Web Links	Available on WebCT
Assignment Questions	Choose ONE question from ONE of the topics as your assignment. Short answer questions appear on WebCT. Submit your answer via WebCT

Summary

Summary Slides are available on CD

The principles of aqueous wool scouring were outlined in this topic. In particular, the role of detergent in grease removal by the formation of an emulsion and the optimal conditions for grease removal were examined. The molecular structure of a surfactant was outlined in order to understand the surfactants interaction with grease and water molecules.

The mechanical aspects of grease removal in wool scouring were covered. The motion of rakes and squeeze rollers are vital to achieve scouring. Water readily removes suint from wool but more effort in the form of agitation and squeezing is required to remove the grease and dirt particles from the fibres. However, excessive raking will result in entanglement and felting.

References

Auer, P. 1999, Fundamental Processes in Aqueous Scouring: Detergency and Felting, Woolwise PowerPoint Presentation, CRC for Premium Quality Wool.

Barry, S.I., Mercer, G.N., and Marchant, T.R. 2002, *Mathematical modelling of a wool-scour bowl*, School of Mathematics and Statistics, ADFA, UNSW.

Christoe J.R. and Bateup, B.O. 1987, 'Developments in Wool Scouring – An Australian Perspective,' *Wool Science Review*, vol. 64, pp. 25.

Rankin, D.A. 2004, Detergents for woolscouring, Canesis Network Ltd, Christchurch, NZ.

Selinger, B. 1988, Chemistry in the Marketplace, Harcourt Brace, Sydney, ISBN 07295 0334 8.

Glossary of terms

Builder	A chemical such as sodium carbonate (soda ash) added to a scouring bowl to stabilise the emulsified woolgrease and dirt, thereby preventing its re-deposition back onto the wool
Coefficient of friction	A measure (in the range 0 – 1) of the force required to produce slippage between two surfaces, relative to the force pressing the two surfaces together
Counterflow	The liquor flow in wool scouring is in the opposite direction to the movement of the wool
Detergent	Any agent that cleanses, including soap (today the term is mostly used for synthetic detergents)
Differential friction effect	The scale structure of the surface of the wool fibre causes different friction forces to operate in fibre slippage, depending on the fibre directions. Higher forces are required to produce slippage between fibres when the scale edges are opposed
Emulsion	A colloidal suspension of one material in another, e.g. milk
Hydrophilic	A liquid that mixes readily with water
Hydrophobic	A liquid that resists mixing with water
Liquor	The active agent in a wool scouring bowl, consisting of warm water and detergent
Micelle	A cluster of surfactant molecules, that may enclose a droplet of oil or grease
Regain	The amount of water contained in wool, expressed as a percentage of the dry weight of the wool
Relative density	The mass of a given volume of a substance, expressed as a fraction of the mass of the same volume of water (at 4^{o}C)
Roller lapping	The covering wound on to the upper squeeze roller to assist the squeezing process
Saponification	The process of soap production where an organic fatty acid (or ester) reacts with an alkali to produce a soap (the organic salt) and alcohol
Soap	The product of a fat, oil or grease reacting with caustic soda
Solvent	The part of a solution which is more abundant, for example in a salt solution the solvent is water
Suint	Dried sweat of the sheep in the fleece – mostly potassium salts
Surfactant	Surface Acting Agent – a liquid capable of altering the surface tension of a liquid; the active agent in a detergent
Tow	A thick continuous rope of synthetic fibre
Woolgrease	Technically, woolgrease is a wax, but this name is given to the greasy material once it is removed from the wool