

# **COMPARING THE CURRENT CHEMICAL CLEANING REGIME AND CHEMICAL-FREE CLEANING AT THE UNIVERSITY OF CANTERBURY:**

**A Report and Practical Microbiological Experiment  
for the Sustainability Office, University of Canterbury**

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*I hate housework. You make the beds, you wash the dishes and six months later you have to start all over again. Joan Rivers.*

## **ABSTRACT**

The primary objective of this project was to do microbiological sampling in a real setting, to see if there was any difference in bacterial and fungal loadings, after two daily cleaning regimes. The two cleaning regimes were, firstly the University of Canterbury's current regime which uses standard cleaning products containing chemical cleaning agents and disinfectants and secondly, a regime which used only fibre-based cleaning cloths (generically called microfibre cloths). The samples were taken on two floors of the English Building at the University of Canterbury. I found that there was no significant difference in bacterial or fungal loadings between the two cleaning regimes.

A secondary objective of this project was to do a literature review. From this, it would appear that the consensus of opinion in the literature is broadly that for ordinary domestic or commercial cleaning, a cleaning regime using fibre-based cleaning cloths and thorough drying, or a cleaning regime using soap, rinsing and thorough drying, can give results equal to a cleaning regime which uses conventional chemical-based cleaning and disinfecting products. Furthermore, the consensus from the literature is broadly that routine use of disinfectants is not necessary, except in hospitals, in commercial kitchens or in homes where there is a resident who is very young, very old, immunocompromized or very infectious.

There is an increasing body of evidence which highlights how the routine use of harsh cleaning products and disinfectants is having serious adverse affects on the environment, on biota and on people. The adverse effects on people include DNA damage, brain and immune system impairment, asthma and allergic reactions to products. Because routine use of harsh cleaning and disinfecting chemicals is not necessary and because they have serious adverse effects, we should be questioning our use of them.

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## **PART ONE - LITERATURE REVIEW**

### **1.1 Why we clean**

Cleaning, by dusting, sweeping or with soap and water, removes dust, dirt and grease and reduces the number of germs to a less than infectious dose (ID) for most pathogens. Disinfecting can kill a high percentage and range of germs, but surface disinfection only works after thorough cleaning. We need to ask: what level of cleanliness do we need to stay healthy and what methods are best at removing dirt? Do homes require much less cleaning than public buildings or hospitals? What are germs and what conditions promote or kill them? And should we listen to the TV advertising, warning that germs are everywhere and need to be killed. Should we use the toxic chemicals commonly available today or are green alternatives good enough? This literature review aims to give the reader a broad overview of the issues around chemical cleaning and a taste of the extensive literature available.

Germs are comprised of bacteria, viruses and fungi/moulds which are pathogenic to us. Germs are a tiny minority of the vast numbers of bacteria, viruses and fungi/moulds, collectively called microbes, most of which are not pathogenic to us. The majority of microbes do us no harm and many are directly or indirectly essential to our well-being and survival. Since the numbers of microbes which science has so far cultured in laboratories is tiny in comparison to the number of microbes we cannot yet culture and hence study, science has only recently begun to appreciate our complete dependence on microbes (Ingraham 2010) and the necessity to not kill everything microbial in our environment.

The ideal conditions for growing microbes, as for other organisms, include the presence of nutrients (ie dirt), moisture, warmth and the right pH. If conditions are inhospitable, then microbes die. Pickling is a successful way of preserving food because pathogenic microbes, even the feared *Clostridium botulinum*, cannot grow or survive in either vinegar or lemon juice ( pH 2.4-3.4). Dehydration is another good method of food preservation. Thorough cleaning will reduce the numbers of microbes on a surface, as they and their food source are removed. Moisture increases the incidence of all pathogenic microbes and their toxins.

Good hygiene can prevent gastro-intestinal, respiratory, skin and parasitic infections and neonatal mortality (Rhee et al 2008 in Curtis et al 2011). Promotion of hygiene is important, and is arguably the single most cost-effective way of reducing the global burden of infectious disease, and without the clever use of new or expensive technologies (Jamieson et al 2006). Ryan et al (2002) noted that the causes of infectious intestinal disease (IID) were inadequate cooking 11%, food storage 50%, poor surface hygiene 11% and poor hand hygiene 28%.

### **1.2 Pathogen sources and reservoirs**

Many outbreaks of infection are related to poor temperature control of raw and cooked foods (Roberts 1990), in which case disinfection will not necessarily prevent these. An infective dose depends on the health of the person and the number and virulence of pathogens (McCullough & Eisele 1951 in Bloomfield and Scott 1996).

Illnesses caused by ingestion of pathogens by hand/mouth transfer, include those caused by rhinoviruses and rotavirus and the bacteria *Shigella*, *S aureus*, *E coli*, *Salmonella spp*, *Klebsiella spp* and *Pseudomonads*. Ingested food borne pathogens include: *E coli*, *Salmonella*, *Klebsiella* and *Pseudomonads*. All these pathogens can survive on surfaces for varying degrees of time depending on soiling and moisture levels. Whilst raw food is probably the main source of kitchen contamination, wet sites such as kitchen sinks, U-bends and wet cleaning cloths/sponges are reservoirs for these pathogens (Bloomfield & Scott 1996). In the bathroom, whilst the toilet is probably the origin of enteric bacteria, wet items including baths, basins, toilets, and cleaning cloths/sponges are potent reservoirs of pathogens (Scott 1990; Scott & Bloomfield 1990a,b in Bloomfield & Scott 1996). Aerosols generated by toilet flushing deposit significant numbers of pathogens on surfaces (Gerba et al 1975 and Scott & Bloomfield 1985 in Bloomfield & Scott 1996), where they can rapidly multiply in soiled, moist and warm conditions. Normally dry places of hand/food contact such as chopping boards, sink taps, toilet handles, toilet seats, show less pathogen loadings. Floors and walls had the least pathogen loadings, due to absence of cross-contamination by hands (Bloomfield & Scott 1996).

### **1.3 Cleaning reservoirs of pathogens - do we need to disinfect?**

For reservoirs of pathogens such as toilets and U-bends where the risk of pathogen transfer is low, disinfection under normal use is not necessary, whereas for wet cleaning cloths where the probability of contamination and transfer is high, disinfection is necessary (Bloomfield & Scott 1997).

For hard surfaces, washing only with soap and water can increase cross-contamination (Scott et al 1984 in Bloomfield & Scott 1996 and Cogan et al 2002), whereas washing with soap and water and rinsing can significantly reduce bacterial loadings (Cogan et al 2002). Washing, rinsing and thorough drying are enough to eliminate most pathogens (Bloomfield & Scott 1996). However Scott & Bloomfield (1990) also noted that "drying produced substantial reductions in numbers of recoverable organisms and achieved satisfactory decontamination of clean laminate surfaces, but although drying plays an important part in maintenance of hygiene in the kitchen and other environments, drying *per se* cannot be relied upon to prevent transfer of infection from laminate and cloth surfaces involved in potentially hazardous situations. The investigation emphasizes the importance of good hand hygiene and adequate decontamination procedures applied to cloths, laminate surfaces, utensils and other food contact surfaces during handling and/or preparation of food and in other critical environments." Scott & Bloomfield (1990) further noted that the effects of disinfectants were seen to be short-lived with most surfaces substantially re-contaminated after 1.5-3hrs by microbial re-growth, due to very heavy initial contamination, reuse, or where surfaces or cloths were wet and warm. "Post-disinfection overnight storage at ambient temperatures produced re-growth of residual survivors to levels up to  $5 \times 10^5$  colony forming units (cfu)/cm<sup>2</sup>, even though some cloths were apparently sterile following disinfection. For consistent effective decontamination, detergent washing followed by drying at 80°C for 2 hours was required" "Therefore, for sites where chemical disinfection is required, eg for food preparation, surfaces should be disinfected immediately before use" and "application of disinfectants as part of weekly routine household cleaning achieves relatively little" (Bloomfield & Scott 1996).

Griffith et al (2007) compared two cleaning regimes at a hospital in Wales and found the existing regime which used non-ionic detergent, was greatly improved when rinsing and drying were incorporated. Replacing the non-ionic detergent with a quarternary ammonium compound sanitizer produced only a slight reduction in bacterial levels.

Larson et al (2004) found that not only did antibacterial surface cleaning products provide no advantage over those without antibacterial agents, but that disease symptoms of persons with poor health or chronic disease, were actually worse for people who used antibacterial products than for people who did not.

Several investigators found that incorporating rinsing (Barker et al 2003, Department for Health 2004) and drying (Dillon et al 1999, Barker et al 2003, Bloomfield et al 1997, Scott & Bloomfield 1990) significantly removed organisms and reduced transfer rates. "Surfaces assessed as dry reduced the potential for microbial growth and survival" and hence transfer (Griffith et al 2007).

According to Daschner et al (2004), the Robert Koch Institute recommends disinfection in hospitals, only for surfaces in frequent contact with hands and skin of patients and personnel, as repeated disinfection of other areas is unnecessary and leads to allergic symptoms in health care workers.

In their research into chemical exposure of cleaning personnel in hospitals, Bello et al (2009), Exner et al (2004 in Bello et al 2009), Larson et al (2004) and Dharan et al (1999) all queried the high frequency of disinfectant use, where disinfectants are mixed in with cleaning products. Disinfection is done to kill microbes and cleaning is done to mechanically remove surface soil. For disinfection to be effective, surface soil must first be removed and disinfection should follow surface cleaning. The disinfectant must reside on the surface for a period of time after application, ie: 10-15 minutes depending on the disinfectant used, its concentration and the species of microbe to be eliminated.

#### **1.4 Fibre-based cleaning**

Water is called the universal solvent and fibre-based cleaning technology exploits this by using water as the only cleaning agent. There are a wide range of such products on the market all of apparently differing qualities. Many of these are called 'microfibre products', although in many instances they do not meet the technical definition of a microfibre. A microfibre is a synthetic fibre measuring less than 1 dtex (a dtex, or decitex, being the mass in 1 gram per 10,000 metres). In this report, the term 'microfibre' is used to describe fibre-based cleaning systems generally. However, it should be noted that the brand tested in this report, ENJO, uses microfibres in only approximately 30% of its products. The remainder of the products are properly described as 'fibre products'.

Mirofibres are becoming increasingly widely used and are the most often-used material for cleaning cloths in professional home cleaning in Finland (Reisbacka et al 2008 in Toiviainen-Laine et al 2010). Microfibre cloths were shown to be more effective at removing microbial deposits from surfaces than cotton or non-woven cloths (Nielsen et al 2002; Rutala et al 2007; Toiviainen-Laine et al 2009), but the quantities of removal of different bacteria varied greatly between different microfibre cloths (Bergen et al 2008). Toiviainen-Laine et al (2009) found that microfibre cloths give greater cleaning efficiency than disposable non-woven cleaning cloths and Bergen et al (2008) found that whilst bacteria loadings were

reduced on contaminated surfaces, the bacteria were spread via the microfibre cloth from contaminated surfaces to sterile surfaces during cleaning. Moore & Griffith (2006) tested six brands of microfibre cloths, both wet and dry. They found that dry microfibre cloths were ineffective at removing dry organic debris and micro-organisms, regardless of type. Wet microfibre cloths did reduce bacterial populations by approximately 90%, but in most cases, this was not significantly better than using paper towels or a conventional cloth. Moore & Griffith (2006) concluded that whilst "different microfibre cloths have different characteristics, the name microfibre should not imply superior cleaning efficacy". Smith et al (2011) in their evaluation of ten different microfibre cloths, found that whilst cloth performance improved with repeated laundering, there was no difference between any of the cloths as to microbial removal and that "price was not an indicator of performance". Rutala et al (2007) studied mop use in a surgical ward and found that in comparison to cotton string mops, microfibre mops significantly reduced bacterial levels when used with a detergent, but that using disinfectant did not further reduce the pathogen loading of microfibre mops.

### **1.5 Washing and disinfecting cleaning cloths, sponges and microfibre cloths**

Cloths and sponges can provide excellent growth media for and cross-contamination with microbes (Scott and Bloomfield 1990). The International Scientific Forum on Home Hygiene (IFH) advises that all non-disposable cleaning cloths be rendered hygienic with a hygiene procedure, which involves cleaning and microbial kill, using either heat or a disinfectant. The IFH also advises that cleaning cloths be dried immediately after decontamination and stored dry, to prevent the re-growth of any residual pathogens. Washing machines should be run once weekly using a high temperature wash or disinfectant to prevent biofilm build-up within the machine and hence contamination of laundry (IFH 2002).

Rutala et al (2007) concluded that since microfibre cloths entrap but do not inactivate pathogens, effective laundering is necessary to reduce their contamination. Sattar et al (2008) noted that as microfibre cloths can be washed and reused up to 500 times or more, it is important that laundering achieve hygienic results. Smith et al (2011) noted that tumble-drying affects the microfibre structure, so that air drying is possibly the only option for laundering microfibre cloths. This could be a drawback in commercial and hospital settings with high volumes of use.

Cogan et al (2002) found that storing cloths in damp conditions overnight, caused microbial cells to become more strongly attached than for cloths which were cleaned immediately after use, which reduced the efficiency of detergent-based washing. Toiviainen-Laine et al (2010) found that the numbers of *Staphylococcus aureus* increased in microfibre cloths in some cases during a normal working day (8 hours storage) and more clearly after 16 or 48 hours of storage, with the increase being greater than that seen in disposable fibre cloths. They also found that washing microfibre cloths at 60°C reduced the numbers of bacteria on the cloths but a small to moderate number of microbes remained entrapped within the microfibre cloth. Toiviainen-Laine (2010) recommended washing any cleaning cloth as soon as possible after use, at the end of the working day at the latest and that cleaning cloths for professional use should be selected to allow for washing at hot temperatures. They concluded that type of soiling, detergent used, storage time before cleaning, humidity and temperature and damp storage after cleaning were all factors that affected microbial re-growth of washed cloths. Dharan et al

(1999) noted that as housekeeping staff were convinced that disinfectants killed all bacteria, they could never understand why when using disinfectants, care had to be taken to store mops clean and dry.

Gerba & Kennedy (2007) found that detergent alone was not effective in removing or inactivating enteric viruses on cotton cloths. The virus survived a wash cycle, a rinse cycle and a 28 minute permanent press drying cycle. With current laundering practices aiming to decrease the volume of water used, this will lead to higher concentrations of microbes in wash waters which could allow pathogens to remain in laundered items after standard washing and rinsing (Block et al 2001). Furthermore, studies by Larson & Duarte (2001) and Gerba & Kennedy (2007) demonstrated that microbes can transfer between contaminated and uncontaminated items of clothing during laundering. Microbes can also be transferred from cleaned, damp laundry which if it is left for a period of time, can allow microbes to re-grow, thus acting as a pathogen reservoir (IFH, 2002).

Ikawa & Rossen (1999) tested sponge cleaning and assessed effective treatment resulting in a reduction of bacteria greater than 99.9%. They found that for consumer-used sponges, which are generally accepted in the literature as having higher bacterial loadings than laboratory-inoculated sponges, and hence to give more realistic evaluations of contamination, bleach or a quarternary ammonium compound were the only chemicals that were effective. For laundry pathogen reduction, washing with detergent, rinsing and drying at 80°C for 2 hours was effective, as was laundering with detergent and bleach or a quarternary ammonium compound wash load. Soaking consumer sponges in bleach or a quarternary ammonium compound for 5 minutes was effective, but hydrogen peroxide, isopropyl alcohol, ammonia and vinegar were not effective. Boiling for five minutes reduced bacteria by 99.9% as did heating in a microwave.

Parnes (1997) tested sodium hypochlorite bleach, ammonia, vinegar, baking soda, borax and liquid detergent for disinfecting surfaces and found that after a 10 minute contact time, undiluted ammonia or vinegar killed *E. coli* and *Salmonella typhi* but not *S. aureus*, whereas after a five minute contact time, bleach killed all three. Bloomfield & Scott (1996) found that bleach was better than phenolic compounds for disinfection and that boiling was very effective at reducing pathogens on cloths. Parnes (1997) remarked that microorganisms have been shown to persist on surfaces from hours to weeks and that gastrointestinal organisms from flushed toilets can be aerosolized and settle on surfaces in bathrooms. Parnes (1997) also noted that many organisms, including pathogenic ones, are found in areas that are dry (floors, clothing) and wet (sinks, baths, damp cloths, dishcloths, toilets, etc). These areas can act as reservoirs for illnesses such as food poisoning, which is also known to be transmitted between hands, food, surfaces, utensils and dishcloths. Parnes (1997), suggested that baking soda, borax and liquid detergent be used for cleaning only. Parnes (1997) also suggested that household surfaces as well as hospital surfaces should be disinfected with sodium hypochlorite bleach (in 1997 Parnes was senior microbiologist for The Clorox Company which manufactures Clorox bleach). However, Allerberger et al (2002) in a letter signed by 38 experts in the field, from 16 countries stated that there was insufficient scientific data to support the routine disinfection of environmental surfaces in health care facilities.

Dharan et al (1999) investigated daily disinfection of surfaces in a large hospital in Geneva where they compared QAC with an active oxygen based compound (AOB). They concluded that AOB worked better than QAC for disinfecting and that disinfection of floors was only necessary on alternate days. Dharan et al (1999) would also have liked to introduce less-than-daily disinfection of patients' furniture, however due to poor hand washing compliance by healthcare personnel, this was not possible.

## 1.6 Hand washing and hand sanitizing

Whilst *Enterobacteriaceae* such as *Klebsiella pneumoniae*, *Enterobacter cloacae*, *Citrobacter*, *Proteus* and *E. coli* are not normally pathogenic to a healthy adult, they are indicators of poor hygiene (Bloomfield & Scott 1996) ie: not washing hands before eating or after blowing your nose. Todd et al (2010) said that in the UK, one in five persons experience intestinal infection annually. Hand washing can reduce food-borne illness and respiratory disease in households, eg: diarrheal infections reduced by 41% and 36% respectively. Bloomfield et al (2007) concurred that hand washing significantly reduces gastrointestinal infections as well as respiratory tract and skin infections. Diarrhoea was reduced by 43-47% when soap was used, respiratory infections by 16% and lower respiratory tract infections by 50% (Curtis et al 2011, and Ejemot et al 2008 in Curtis et al 2011)

Requirements for effective hand washing were potable water for rinsing, soap to loosen microbes, vigorous rubbing to generate friction and thorough drying with a clean, single-use cloth or paper towel which removes pathogens by friction and wicks away moisture (Todd et al 2010). Antimicrobial soaps were only marginally more effective than plain soaps and could result in a buildup of antimicrobial compound on the skin (Todd et al 2010).

Soaps act as emulsifiers suspending oil and dirt and allowing them to be washed off. Soap also decreases water surface tension and binds to dirt, oil and bacteria. In slum settings, hand washing even with contaminated water and soap, measurably improved women's hand cleanliness (Luby et al 2001 in Todd et al 2010).

Whilst Fuls et al (2008 in Todd et al 2010) found that antimicrobial soaps were more effective than plain soaps at removing enteric bacteria, Gillespy and Thorpe (1962 in Todd et al 2010) found that germicidal soaps were not much more effective than ordinary soap for reducing numbers of bacteria transferable from skin to handled objects; and Miller (1994) confirmed this.

Miller (1994) also found that "instant hand sanitizers increased residual flora on hands", so that "their use in food service establishments could be counterproductive."

Adequate exposure time is necessary for antimicrobial compounds to be effective, and this is not always feasible in industrial settings where hands need to be washed repeatedly (Todd et al 2010). The benefit of chlorhexidine gluconate (CHG) is purported to be in its long-term residual effects on hands, but Kampf (2008) reviewed eight studies of CHG and found them all to have flawed designs. Kampf (2008) said that since no advantage could be shown from using CHG in hand hygiene, its use should be stopped as CHG carries risks of skin irritation, allergic reaction, including anaphylactic shock, and acquired bacterial resistance.

Soaps with triclosan in common concentrations of 0.1 - 0.45% wt/vol may not be any more effective than plain soap for preventing infections and reducing bacterial loadings (Aiello, Larson & Levey in Todd et al 2010). As regards triclosan-containing cutting boards, Moretro et al (2011) found no difference in bacterial counts on cutting boards with or without triclosan after one hour. After 72 hours at a relative humidity (RH) of 100%, the triclosan-containing cutting boards showed no antibacterial effect at all, except against *Listeria monocytogenes*, but at 70% RH there was less bacteria on the triclosan-containing boards. They concluded that using triclosan in cutting boards was possibly only effective for low RH, long exposure time and clean conditions, and not against all genera of bacteria.

Aiello et al (2007 in Todd et al 2010) concluded that time spent hand washing, and soap volume were the important factors, with increased soap volumes having a decidedly positive impact. The New Zealand Food Safety Authority (2008) uses the 20\*20 rule: wash hands for 20 seconds with soap and dry for 20 seconds with a clean dry towel.

In some instances, such as health care settings, alcohol based hand rubs (ABHRs) are more efficient than antimicrobial soaps for hand sanitization. Alcohol has been used as an antiseptic since ancient times; the drying action of alcohol can be ameliorated with glycerol as an emollient (Todd et al 2010a).

Todd et al (2010b) note that "fortunately even hands carrying considerable fecal contamination, eg., after diapering a child, taking care of an incontinent patient, or working in a slaughterhouse, are rarely contaminated with pathogens or pathogens are present in such low numbers that their transfer to ready-to-eat food is not sufficient to cause illness. Many people, workers included, therefore feel that their hygiene routines are sufficient because no adverse consequences have been experienced over many years of performing the same procedures". Therefore, thorough hand washing is always advised in order to avoid infectious illnesses.

## **1.7 Gloves**

The use of gloves in food preparation was shown to lead to a false sense of security and therefore complacency, leading to high-risk behaviours. Occluded skin inside gloves creates a moist, warm environment, which greatly increases pathogen numbers (Todd et al 2010). Marples (1976 in Bloomfield & Scott 1996) found that the infective dose for *S. aureus* was much less when the skin was occluded. Pinhole leaks which compromised glove integrity also led to cross-contamination of food with pathogens

## **1.8 Residual cleaning effects**

No chemical cleaner has been shown to have beneficial antimicrobial residual effects, except CHG which is used for skin sanitization and this has been cast into doubt (see above). However, studies have shown that all cloths and sponges, and in particular microfibre cloths, can have deleterious residual effects of microbial recontamination to a greater or lesser extent, if not laundered effectively. Since there appears to be an absence of beneficial residual effects from any cleaning chemicals, it would appear that the benefits of cleaning can be rapidly negated by one person with contaminated hands due to poor hand washing then touching surfaces. The author's own observations during the course of the practical part of this study, was that areas such as the coffee table, kitchen worktop and fridge door, often had a higher loading of bacteria than the toilet seat.

## 1.9 Cleaning products used at Canterbury University - information taken from product packaging

\*Chemicals in bold are discussed below as they are known to be hazardous in varying degrees and with different effects.

**Tempo HD - floor cleaner** \*Contains: **Ethoxylated nonylphenol** < 10 %w/w; Sodium tripolyphosphate <10 %w/w; **quarternary ammonium compound** <10 %w/w.

**Oasis Compac Neutral Cleaner - all purpose cleaner - spray bottle for surfaces** \*Contains: **Sodium xylene sulphonate** <10 %w/w.

**Oasis Compac Glass** \*No information available.

**Easy/ Pacer Easy - creme cleanser** \*Mild abrasive, builder, anionic surfactant, pH modifier, preservative, humectant, perfume, non-ionic surfactant, alkaline builder, water.

**Nature's Scrub - cleans toilets, urinals and basins** \*Non-acid, biodegradable surfactants, converts organic and urine build ups to odourless water and carbon dioxide. \***Polyethylene mono (nonylphenyl ethyl glycol)** pH 8.0-9.0

**Oasis Compac 70 Marble Safe Cleaner** \*N-Propoxypropanol 10-30 %w/w; potassium hydroxide <5%w/w; lauryl dimethylamine oxide<5%w/w.

**Arelle Instant Foam Hand Sanitiser** \*Cocamidopropyl betaine, Peg 7 Glyceryl Cocoate, Sodium diethlenetriamine pentamethylene phosphonate, **benzalkonium chloride**, purified water.

## 1.10 Explanations of functions of some chemicals used in cleaning products

### Surfactants

Surfactants are a diverse group of chemicals consisting of a polar, water-soluble head group and a nonpolar hydrocarbon tail group which is not soluble in water. In 2006 the worldwide production of surfactants was 12.5 million tonnes (Edser 2006 in Ivankovic and Hrenovic 2009). After use, residual surfactants are discharged into sewage systems, surface waters or wastewater treatment plants. A proportion of surfactants end up in surface waters, soil or sediment. Surfactants can sorb to soil and sediment and to dead cells in flocs and inorganic matter in wastewater treatment plants, reducing their toxicity and biodegradability. (Ying 2006 and Traina et al 1996 in Ivankovic & Hrenovic 2009).

Currently there is concern about their accumulation in sewage sludge (Holt et al 1995 and Ivankovic & Hrenovic 2009), where high concentrations inhibit sewage sludge microorganisms and compromise wastewater treatment. Quarternary ammonium compounds (QACs) in particular kill the nitrifying bacteria which are necessary for successful wastewater treatment (Wagner et al 1991 in Ivankovic and Hrenovic 2009). There is also concern about the surfactants in pesticides, fertilizers and agrochemicals generally. The toxicity of surfactants to many species of bacteria, algae, crustaceans, gastropods, fish, amphibians and mammals has been extensively documented. Cationic surfactants are the greatest

hazard followed by amphoteric surfactants, however the toxicity of a single surfactant is highly specific for the type and class of surfactant and for the organism tested, therefore generalizations can only be speculative. Ivankovic and Hrenovic (2010) concluded that more information is needed for alkylphenol ethoxylate (APE) surfactants because their biodegradation products of octylphenols and nonylphenols act as xenoestrogens in fish and accumulate in aquatic organisms.

*\*Anionic surfactants.* These include detergents and common soaps, and comprise linear alkylbenzene sulphonic acid (LAS), sodium dodecyl sulphate (SDS), alkyl sulphate (AS), sodium lauryl sulphate (SLS) and alkyl ethoxysulphate (AES). The hydrophobic part of the molecule can be an alkyl chain of various lengths, an alkylphenyl ether or an alkylbenzene. The hydrophilic part can be a carboxy, sulphate, sulphonate or phosphate. The biological activity of anionic surfactants includes binding to enzymes, DNA, proteins and peptides. Binding to proteins and peptides can change the shape of the polypeptide chain and its surface charge, and hence alter biological function, (Cserhati et al 2002 in Ivankovic and Hrenovic 2009) with serious ramifications for an organism.

*\*Cationic surfactants.* Cationic surfactants are used in detergents, fabric softeners, hair conditioners, mouthwashes and disinfectants and comprise benzalkonium chloride (BAC), cetylpyridinium bromide (CPB), cetylpyridinium chloride (CPC), hexadecyltrimethylammonium bromide (HDTMA) and QACs. The molecules contain at least one hydrophobic hydrocarbon chain linked to a positively charged nitrogen atom, or alkyl groups such as methyl or benzyl groups.

QACs have antimicrobial activity against gram-negative and gram-positive bacteria as well as some pathogenic species of fungi and protozoa (Petrocci 1983 in Ivankovic and Hrenovic 2009). As QACs are toxic to mammalian cells they are only recommended for topical not systemic use (Thorsteinsson et al 2003 in Ivankovic and Hrenovic 2009), however alternative soft analogues of long chain QACs are considered less dangerous as they readily biodegrade to non-toxic, biologically inactive products in vivo and in the environment. Cationic surfactants bind to the cytoplasmic membrane of bacteria and disorganize them (McDonnell & Russel 1999 in Ivankovic and Hrenovic 2009). Cocamidopropyl betaine (CAPB), is derived from coconut oil and dimethylaminopropylamine (Wikipedia ref accessed 02.05.11). It is used in shampoos, hand soaps, cosmetics and cleaning products as an emulsifying agent and thickener and to reduce irritation caused by ionic surfactants. It is also used in hair conditioners as an antistatic (Wikipedia accessed 02.05.11). QACs are deactivated by soaps, other anionic detergents, and cotton fibers (Wikipedia accessed 02.05.11). They are not recommended for use in hard water. MSDA information notes that QACs generally, cause skin and respiratory irritation ranging from mild to severe caustic burns on skin and gastro-intestinal lining, depending on concentration (Bellow et al 2009) gastro-intestinal symptoms (e.g., nausea and vomiting), coma, convulsions, hypotension and death (International Programme on Chemical Safety accessed 23.05.11). CAPB was voted 2004 Allergen of the Year (American Contact Dermatitis Society, accessed 22.05.11).

*\*Amphoteric surfactants.* Amphoteric surfactants are used as dishwashing foam boosters, as anti-static agents for textiles, and as antibacterials in deodorants. Amphoteric surfactants include lauryldimethylamine oxide, also known as dodecyldimethylamine oxide (DDAO), which is the most frequently used surfactant of this type (Wikipedia accessed 02.05.11). Amphoteric surfactants change their charge

from net cationic to anionic with low or high pH, with zwitterionic behaviour at intermediate pH (Singh et al 1006 in Ivankovic and Hrenovic 2009). The most common amphoteric are amine oxides (AOs). AOs have low to moderate toxicity and are easily removed by sewage treatment, with a low potential for bioaccumulation in terrestrial organisms (Garcia et al 1007 in Ivankovic and Hrenovic 2009).

*\*Non-ionic surfactants.* These are widely used as emulsifiers, wetting agents, for foam stabilization, to facilitate solubilisation and increase drug carrier stability (Cserhati 1995 in Ivankovic and Hrenovic 2009), and to enhance pesticide performance. Nonylphenol ethoxylates (NPEs) are found in many cleaning products. The hydrophobic part of a nonionic surfactant is an alkylated phenol derivative, fatty acid or long-chain linear alcohol. The hydrophilic part can be an ethylene oxide chain of various lengths. NPEs contain nonylphenol, a hydrophobe that is attracted to oily materials, and ethylene oxide, a water-loving appendage that keeps the molecule in solution (Going Green 2007).

Alkylphenol ethoxylates (APEs) are included in this group. As nonionic surfactants lack charge, they are compatible with cationic and anionic surfactants. Nonionic surfactants demonstrate antimicrobial activity by binding to proteins and phospholipid membranes, thus increasing the permeability of membranes and vesicles, causing leakage resulting in cell damage or death (Cserhati 1995 in Ivankovic and Hrenovic 2009). A Sierra Club report (2005), said that unlike other cleaning agents, NPEs and APEs break down into more toxic, less biodegradable metabolites, which have estrogenic properties, such as nonylphenol itself. NPEs have been banned in Europe since the 1990s, for all down-the-drain applications (Going Green 2007).

### **Solubilizers**

Solubilizers are hydrotropes. Hydrotropes solubilize hydrophobic compounds in aqueous solutions.

*Polyethylene mono (nonylphenyl ethyl glycol) - Synonyms:* IGEPAL CO-630; Nonidet P40; Protachem 630; Polyethylene Mono(nonylphenyl)ether Glycols; Polyethylene Glycol 450 Nonylphenyl Ether; Polyoxyethylene (9) Nonylphenyl Ether. Polyethylene glycol (PEG) is a polyether compound. PEG is used in a number of toothpastes as a dispersant, where it binds water and helps keep Xanthan gum uniformly distributed throughout the toothpaste (Wikipedia, 2011 accessed 02.05.11).

*N-Propoxypropanol - Synonyms:* PnP; 1-Propoxy-2-propanol; Propylene glycol monopropyl ether; propylene glycol mono-n-propyl ether; propyl propasol ([http://www.osha.gov/dts/chemicalsampling/data/CH\\_264291.html](http://www.osha.gov/dts/chemicalsampling/data/CH_264291.html)). The MSDA information says potential symptoms in animals include eye and skin irritation (blepharospasm, lacrimation, conjunctival hyperemia and narcosis, ataxia, loss of righting reflex. Affected organs are the eyes, skin and CNS.

*Sodium xylene sulfonate* This is often added to shampoos as a thickening agent to help suspend other ingredients, thus clearing out the cloudy look of a formula (Wikipedia 2011 accessed 02.05.11). The MSDS information on sodium xylene sulfonate says that it is extremely hazardous as a lung irritant and has some effects as a skin irritant.

***Builders/water softening agents/chelating agents - ie: phosphate builders***

In detergents, phosphates demonstrate hard-water neutralization, re-deposition prevention, and buffering. Sodium tripolyphosphate (STPP) is mostly used as a component of commercial detergents, as a builder or water softener. In hard water, ie water which contains high concentrations of  $Mg^{2+}$  and  $Ca^{2+}$ , detergents such as QACs are deactivated. Being a highly charged chelating agent,  $TPP^{5-}$  binds to dications and prevents them from interfering with the sulfonate detergent (Wikipedia ref 5 accessed 02.05.11). Other examples of water softeners include pentamethylene phosphonate, a phosphonate or phosphonic acid, and chelating agent, which also binds to di- and trivalent metal ions. When the metal ions are bound, they are prevented from forming insoluble precipitates, or scale, which would otherwise form as unattractive soap scum. The introduction of an amine group improves the metal chelating activity of the phosphonate. Some examples include EDTMP and DTPMP. These common phosphonates are structural analogues to the aminopolycarboxylates NTA, EDTA and DTPA. Bacteria degrade phosphonates to orthophosphate which is assimilated by microorganisms.

Aminophosphonates can also be used as sole nitrogen source by some bacteria. The polyphosphonates used in industry differ from natural phosphonates such as 2-aminoethylphosphonic acid, because they are larger, carry a high negative charge and are complexed with metals. Biodegradation tests with sludge from municipal sewage treatment plants with HEDP and NTMP showed no indication for any degradation (Wikipedia ref accessed 02.05.11).

### **1.11 Deleterious health effects of cleaning chemicals**

Each year, cleaning agents are either the second or third most common cause of exposure among adults who are reported to the American Association of Poison Control Centers Toxic Exposure Surveillance System (70,000-80,000 reports/year, 9-10% of all reports/year) Lai et al (2006 in Rosenman 2007). A quick review of the literature will yield many studies of the harmful effects of cleaning chemicals. A few examples include the study by Elliott et al (2006 in Rosenman 2007) of the reduction in FEV and maximum mid-expiratory flow rate, that was statistically associated with blood levels of 1,4-dichlorobenzene, a chemical found in air fresheners, toilet bowl deodorants and mothballs. Also, increased, persistent wheezing in young children up to the age of 3.5 years has been reported in association with increased domestic household chemical use, predominantly due to cleaning agents that were used during pregnancy Sherriff et al (2005 in Rosenman 2007).

Allerberger et al (2002) cite several studies ( Deschamps et al 1994; Purohit et al 2000; Preller et al 1996 and Schnuch et al 1998 in Allerberger et al 2002), which say that QACs and hypochlorites can cause skin irritation and asthma. In fact benzalkonium chloride is known to be one of the leading allergens and of 15,751 health care workers, 1.6% were sensitized to benzalkonium (Allerberger et al (2002).

Part of the problem of unacknowledged deleterious health effects of cleaning chemicals is that they have historically been measured/analyzed as single chemicals and not as mixtures, as mixtures may show an obvious and immediate toxic effect. The research criteria for health effects have also generally been non-comprehensive and non-uniform, highlighting a need for systematic evaluation. For instance, a volatile organic compound (VOC), which is defined as a compound with a boiling point between 0-400°C (Wolkoff et al 1998 in Bellow et al 2009), is of concern in respiratory irritation.

Furthermore, whilst MSDSs of chemicals identify ingredients for the concentrated and ready to use (RTU) form, this can be misleading, as the RTU lists of chemicals do not report those of less than 1% by weight in a mixture, and sensitization can occur even at trace concentrations (Bello et al 2009). Of further concern is the synergism of a mix of chemicals and the frequency of occurrence of a chemical in a range of commonly used cleaning products. Bello et al (2009) set out criteria for the systematic evaluation of exposure to cleaning chemicals. They prioritized exposure according to 1) how frequently it occurred in multiple cleaning products, 2) how likely it was to cause respiratory or skin irritation and sensitization, 3) whether it occurred at higher concentrations compared to other ingredients in a product, and 4) a chemical's potential to become airborne compared to other ingredients in a mixture. They used this information to create a frequency analysis. Bello et al (2009) searched Toxnet's Hazardous Substances Data Bank (HSDB), ChemID-plus (National Library of Medicine, Hazardous Substances Data Bank and ChemIDPlus, in Bellow et al 2009), the ACGIH 2008 TLVs and BEIs booklet (American Conference of Governmental Industrial Hygienist (ACGIH) 2008 in Bello et al 2009) and the NIOSH guide to chemical hazards (National Institute for Occupational Safety and Health (NIOSH): Pocket guide to chemical hazards 2005, in Bello et al 2002).

### ***Cleaning chemical and respiratory illnesses***

The inhalation quotients of cleaning chemicals are a product of a) chemical volatility - chemicals with a lower boiling point generate higher VOC exposures, b) concentration, c) mixture, d) application type (eg spraying), e) cleaning task type, f) cleaning task frequency and g) cleaning task duration (Bello et al 2009).

Bello et al (2009) noted that 2-Butoxyethanol (2-BE), a glycol ether with a boiling point (BP) of 168<sup>0</sup>C, was a common ingredient of glass/window cleaners, carpet cleaners and other surface cleaners and that indoor exposure to its vapours at a concentration threshold of 2ppm (10mg/m<sup>3</sup>) and above may result in sensory irritation (Wolkoff 2008 in Bello et al 2009). Using data from 10 European countries, Zock et al (2007 in Arif et al 2008) found more than twice the odds of physician-diagnosed asthma among adults frequently using hand-operated sprayers during common household cleaning activities.

### ***Cleaning chemicals and allergic reaction, including dermatitis***

Dermal reactions to cleaning chemicals are also a product of chemical volatility, concentration, mixture, application type and cleaning task type, frequency and duration. Schneider (in Bello et al 2009) developed the Dermal Exposure Assessment Method (DREAM) model to evaluate the mechanisms by which a contaminant can contact the skin and this comprises 1) emission, 2) deposition and 3) transfer (Schneider et al 1999 in Bello et al 2009).

### ***Xenoestrogens***

Xenoestrogens include dichlorodiphenyltrichloroethane (DDT) and its metabolites, bisphenols, dichlorophenols, methoxychlor, chlordecone, polychlorinated biphenyls (PCBs) and dioxins.

Xenoestrogenic chemicals found in cleaning products include: alkylphenols (Lorand et al 2010), which include nonylphenol ethoxylates (NPEs) and other alkylphenol ethoxylates (APEs).

### ***Phytoestrogens and xenoestrogens***

Herbivorous and omnivorous vertebrates have evolved on a diet that includes phytoestrogens such as flavonoids, isoflavonoids, chalcones, coumestans, stilbenes, lignans, ginsenosides and other saponins. Xenoestrogens, are new chemicals that vertebrates have not yet adapted to. Unlike phytoestrogens, xenoestrogens tend to accumulate and persist in adipose tissue for decades and may cause long-lasting, adverse endocrine effects (Lorand et al (2010)).

### ***Xenoestrogens in breast milk***

There are more than 75,000 man-made chemicals in the Toxic Substances Control Act Inventory (USA), but only a few have been tested for endocrine disrupting effects (Nagel et al 1999). Hong et al (2002) evaluated 58,000 chemicals to predict those with estrogen receptor binding potential. They predicted that 6903 chemicals were estrogenic through estrogen receptor signaling. Using different mechanisms, environmental chemicals such as alkylphenols, nonylphenol and octylphenol, have all been reported to have estrogen-like activity. The data suggests that xenoestrogen levels in children are the result of exposure through BM and in utero. Massart et al (2005) note that "the scientific debate surrounding endocrine disruptors has grown contentious, partly because some suspected endocrine disruptors are economically important chemicals, high in production volume".

Contamination of human breast milk (BM) is widespread. Women in remote areas, such as the Canadian Inuit, who eat a diet rich in seal, whale and other species high on the marine food chain, also have high levels of persistent organic pollutants (Dewailly et al 1993). Lipid-soluble pollutants such as polyhalogenated chemicals, which are slow to degrade, bio-accumulate and bio-concentrate in the food chain and have long half-lives in humans. Environmental chemicals have several mechanisms of disrupting the human nervous, endocrine and reproductive systems with oestrogen and antiandrogen effects (Safe 1995). Massart et al (2005) note that xenoestrogens have previously been considered safe because of their low acute toxicity at environmental concentrations. *However, xenoestrogens can show hormone activity at concentrations many order of magnitude below the concentration at which acute toxicity occurs and within the range of current human and wildlife exposure and hence show "no-observed-adverse-effect level" (NOAEL) which according to the traditional paradigm of toxicology, means that exposure should therefore not result in any significant malignant response.* Furthermore, recent reports have suggested nonmonotonic dose-response relationships for natural and synthetic estrogens, where in utero exposure to relatively low concentrations produced measurable effects in adult mice (vom Saal et al 2000). It is also worth noting that environmental pollution is probably not caused by a single compound, but rather by a mixture of chemicals and their related metabolites.

Environmental chemicals can be absorbed into the bloodstream by ingestion, inhalation and skin contact. Chemical pollutants circulate in the bloodstream free or bound to proteins such as albumin or lipoproteins. Ingested chemicals generally deposit into adipose tissue, from where they partition into richly perfused tissue, a single compartment comprising the brain, kidney, intestines, liver and spleen, or instantaneously into muscle. The chemicals are later redistributed; those with high lipid solubility

concentrate in tissues with a high fat content, eg: adipose tissue in the brain, liver, kidney or mammary glands of lactating women (Massart et al 2005).

The polarity of a compound determines its transfer to milk. Nonpolar compounds are easily transported across lipid membranes (Needham et al 2002), usually by passive transport, of lipophilic components of molecular weight <800Da. The lipophilic nature of a chemical is affected by its structure and its degree of ionization. Halogens increase the lipophilic nature of xenoestrogens.

Some cleaning chemicals detected in BM include: alkylphenols, eg: octylphenol, alkanes, alkenes, alkynes, benzene and ethers (Massart et al 2005).

### ***Xenoestrogens and human fertility***

Professor Richard Sharpe, of the Medical Research Council, said xenoestrogens were responsible for feminising boys in the womb, and increasing rates of birth defects, testicular cancer and falling sperm counts. Elizabeth Salter Green, CHEM Trust director, said; "Chemicals that have been shown to act together to affect male reproductive health should have their risks assessed together" (BBC 2009).

### ***Xenoestrogens and cancer***

Fucic et al (2010) reviewed data on lung cancer and suggested that it must be hormone related, due to its sex-specific occurrence. They noted that many environmental chemicals can have dual biological effects of being genotoxins/carcinogens and xenoestrogens.

### ***Tolerogenic microorganisms, probiotics and diseases caused by their absence***

The human body contains about 100 trillion bacteria, more than 10 times the number of cells in the body. The ideal ratio of bacteria in the human gut is roughly 85% good and 15% bad. Bacteria help us with food digestion (eg carbohydrates) and nutrient production (eg B12), nutrient absorption, elimination of toxins, prevention of allergies and protection against over-growth of other opportunistic and pathogenic microorganisms (eg candida). Gut bacteria are sensitive to antibiotics, chlorinated water, antibacterial soap and sanitizers. An estimated 80% of the human immune system is located in the gut. It has been said that the gut is the second brain and the seat of the immune system (www.drmercola.com accessed 02.05.11).

According to Raison et al (2010) "inflammation is increasingly recognized as contributing to the pathogenesis of major depressive disorder (MDD). MDD may be so prevalent in the modern world not just because pro-inflammatory factors are widespread, but also because we have lost contact with previously available sources of anti-inflammatory immuno-regulatory signaling." Tolerogenic microorganisms, in soil, food and the gut, are increasingly missing from industrialized societies. Vulnerable individuals in excessively clean environments such as children, lacked immune training and had a significantly increased risk of inappropriate inflammatory attacks to harmless environmental antigens (leading to asthma), benign food contents and commensals in the gut (leading to inflammatory bowel disease) and/or self-antigens (leading to various autoimmune diseases for instance rheumatoid arthritis and lupus). Raison et al (2010) concluded that "loss of exposure to old friends may promote

MDD by increasing background levels of depressogenic cytokines and may predispose vulnerable individuals .... to mount inappropriately aggressive inflammatory responses to psychosocial stressors, leading to increased rate of depression" and and that "measured exposure to old friends or their antigens, may offer promise for the prevention and treatment of MDD...".

Ley et al (2008) also noted that humans have evolved to coexist with commensal and symbiotic bacteria, with a newborn infant, being rapidly and densely populated with complex forms of indigenous microbes. Hooper and Gordon (2001) said that this process contributed to developmental programming of epithelial barrier function, gut homeostasis & angiogenesis, and innate & host adaptive immune function. Another study by Heijtz et al (2011) also concluded that normal gut microbiota affect normal brain development and behavioural functions, with microbiota/gut-brain communication probably via the vagal nerve (Borovikova et al 2000) by way of modulation of transmitters such as serotonin, melatonin, gamma-aminobutyric acid, histamines, and acetylcholine.

Baerlen et al (2011) proposed that gut microbiota may be of therapeutic and clinical relevance, and using probiotics could reduce intestinal infection, allergies and atopic eczema, and relief from inflammatory bowel disease. From their research it appeared that "*Lactobacillus acidophilus* altered mucosal gene-expression networks that regulate immune responses, hormonal regulation of tissue growth and development, and water and ion homeostasis; *L casei* acted on mucosal gene-expression networks regulating cell proliferation and the balance between the Th1 and Th2 parts of the immune response, metabolism and hormonal activity involved in blood pressure; and *L rhamnosus* caused differential expression of genes participating in signaling networks involved in wound repair and healing, angiogenesis, interferon (IFN) response, calcium signaling an ion homeostasis.

### ***Environmental pollution***

Phosphorus can theoretically generate its weight 500 times in algae. Whereas the primary production in marine waters is mainly nitrogen limited, freshwaters are considered to be phosphorus limited. A large part of the sewage effluents in many countries is released untreated into freshwater recipients, and thus the use of phosphorus as a complexing agent is still an environmental hazard (Wetzel 1983) and has led to greater incidences of toxin laden "red tides" in fresh and marine waters (Ingraham 2010). Concerns about phosphorus-induced eutrophication in lakes and rivers led to a series of USA state-level bans in the 1990s that took phosphates out of most U.S. laundry detergents except automatic dishwashing detergents (ADW) of which many still contain 4-8% phosphorus (Going Green 2007).

Allerberger et al (2002) cite Swisher (1991) who said that QACs and phenolics are unsafe for the environment during manufacture as the process releases carcinogens such as benzene and other volatile organic chemicals. Their discharge into the waste stream is also hazardous as they are not readily biodegraded. Swisher (1991 in Allerberger et al 2002) reported 0.04 to 0.08 ppm QACs for the Ohio River and 0.01 to 0.004 ppm in other United States rivers for dialcylidimethyl quarternary compounds.

### ***Bacterial resistance***

Concern has been increasing that CHG, triclosan and other antibacterial compounds can lead to antibacterial resistance to these products and to antibiotics (Russell 2001). In particular triclosan, which is a bisphenol and xenoestrogen, can cause cross-resistance among different species of bacteria (Aiello et al 2007 in Todd et al 2010).

Pine oil disinfectant has also been shown to encourage *E coli* to become resistant to antibiotics such as tetracycline, ampicilin and chloramphenicol (Moken et al 1997 in Aiello & Larson 2003) and *S aureus* which are resistant to oxacilin and vancomycin (Price et al 2002 in Aiello & Larson 2003). Gram-negative bacteria on chlorhexidine soap dispensers in a New York hospital were resistant to both chlorhexidine and up to 15 different antibiotics (Brooks et al 2002 in Aiello & Larson 2003). Another study showed an inverse correlation with intensity of chlorhexidine use and antimicrobial susceptibility of *S aureus*, *Klebsiellapneumoniae*, *P aeruginosa*, *Acinetobacter baumannii*, and *Candida albicans*(Block et al 2002 in Aiello & Larson 2003). MRSA isolates with decreased susceptibility to benzalkonium chloride have been shown to be resistant to -lactam antibiotics. (Akimitsu et al 1999 in Aiello & Larson 2003). Russell et al (1998 in Aiello et al 2003) reported that *Pseudomonas stutzeri* adapted to chlorhexidine, also had cross-resistance to QACs. Loughlin et al (2002 in Aiello & Larson 2003) showed that *P aeruginosa* cells adapted to benzalkonium chloride exhibited resistance to chloramphenicol and tobramycin.

## **1.12 University of Canterbury's cleaning procedure**

### ***A resume of The University of Canterbury's cleaning procedures***

The University of Canterbury's cleaning procedures are widely and clearly detailed on posters around the university. The broad procedures for wet cleaning are as follows:

\*Floors. Floor are mopped with floor-cleaning chemical and air dried. Mop and bucket rinsed with clean water and stored.

\*Ablution surfaces. Toilets, urinals, hand basins, exposed pipe work, walls and doors are cleaned daily with hot water, cleaning chemicals and red cloths. Cleaning personnel rinse cloths daily in hot water and hang them to dry. Cloths laundered weekly.

\*Glass and mirrors. Surfaces are sprayed with chemical cleaners and wiped with yellow cloths. Cloths used daily and are hung to dry. Cloths laundered as required.

\*Food preparation surfaces. Surfaces are wiped daily with hot water, cleaning chemicals and blue cloths. Cloths are rinsed with hot water and hung to dry. Laundered weekly.

\*General surfaces. Surfaces are wiped daily with hot water, cleaning chemicals and green cloths. Cloths are rinsed with hot water and hung to dry. Cloths laundered as required.

### ***Drawbacks to the University of Canterbury's cleaning procedures***

It can be seen from the above outline of cleaning procedures that for ablution, food preparation and general surfaces, cloths are rinsed daily and hung to dry. Cloth drying occurs in locked cleaning

cupboards, with limited ventilation and warm temperatures. In these situations, the cloths will take a long time to dry thoroughly, if at all between cleanings, thus encouraging the re-growth of microbes. This situation was remarked on by one of the cleaners who said she always felt uncomfortable about using cloths that were not properly dried. Laundering of these cloths is done weekly, which, from reading the relevant literature, would appear to be insufficient to control microbial re-growth. As noted above, cleaning and disinfecting chemicals do not kill all germs completely. Daily laundering and thorough drying of cloths is important to prevent re-contamination of surfaces with pathogenic microbes. As regards floor mops, these are used daily, but never dried properly. The microbial counts of these mops are quite probably very high, so they will almost certainly be re-distributing pathogens daily. The storage of damp/wet floor mops in the same cleaning cupboards as cleaning cloths, probably does not help the latter to dry more quickly, if at all.

## **PART TWO - A MICROBIOLOGICAL COMPARISON BETWEEN TWO CLEANING REGIMES AT THE UNIVERSITY OF CANTERBURY**

### **2.1 Materials and Methods**

#### ***Objectives of this experiment***

1. To maintain the current physical appearance of cleanliness, which is of an acceptable standard.
2. To maintain the current acceptable level of hygiene.
3. To assess the cleaners' responses to using ENJO microfibre cloths, as compared to the conventional cleaning regime - for ease and convenience of use.

#### ***Sampling sites***

For this study, two floors were chosen in the English Building of Canterbury University, being levels 5 and 6 and the areas of sampling included the levels 5 and 6 kitchen/tea rooms and mens' toilets, both of which were of a comparable age, size and standard of fittings. Level 5 in the English Building provided office and study facilities mostly for university post-graduate students. There was also a reception office for the Political Science department. Level 6 in the English building provided office facilities for university lecturers.

The kitchen/tea rooms on both levels were almost identical in lay-out, fittings style and fittings provision and quality, with the exception of the kitchen worktops. Level 5 had varnished wooden worktops, whilst level 6 had old-fashioned vinyl worktops, in good condition. Both kitchens had identical kitchen sinks, hot water boilers, fridges, bins and coffee tables.

The mens' toilet facilities on both floors were also comparable. The level 5 mens' toilets had 2 toilet cubicles, 2 wash basins and a large urinal, necessary for the larger flow of people of on this floor. The level 6 mens' toilets had 1 toilet cubicle, 1 wash basin and a small urinal. The fittings on both floors were identical.

On each level; 9 sampling sites were chosen, 8 of which were identical, giving a total of 18 sites for both floors.

In the kitchen/tea rooms the sites sampled were:

- \*a heavy-duty plastic kitchen door handle, on corridor side;
- \*the handle area of a nearly new, handle-less, fridge door,
- \*the lid of a recycling bin for compostable waste;
- \*the top of a coffee table with a formica top;

\*a kitchen worktop (as mentioned above, the level 5 kitchen had varnished wooden worktops, and the level 6 kitchen had heavy-duty vinyl worktops);

In the mens' toilets the sites sampled were:

\*a stainless steel, cold tap handle (on level 5 the sample site was on the left hand wash basin);

\*a centre point on the urinal step, which had a heavy-duty, non-slip, raised surface;

\*a plastic toilet seat (on level 5 the sample site was in the left hand cubicle);

\*a centre point on the floor immediately in front of the toilet (on level 5 the sample site was in the left hand cubicle).

### ***Cleaning Regimes***

The 2 cleaning regimes compared were:

1) the usual cleaning regime, using standard cloths and chemicals, as detailed above in Part One of this Report.

2) a cleaning regime using only ENJO fibre-based cleaning cloths, with only water as a dirt solvent. The microfibre cloths were washed daily after use, in a warm (40°C) machine wash, using a washing detergent, as per the manufacturer's instructions.

In order to compare the microbiological cleaning efficacy of each cleaning regime, levels 5 and 6 were cleaned differently for 4 weeks; then the regimes were swapped, followed by further testing. For the weeks 1 - 4, level 5 was cleaned with ENJO cloths only and level 6 was cleaned with the conventional regime. For weeks 5-8, level 5 was cleaned with the conventional regime and level 6 was cleaned with ENJO cloths only. All the testing sites chosen were cleaned daily at the same time of day. Sampling occurred twice a week at the same times. Both levels 5 and 6 were cleaned by the regular cleaners, and they were both enthusiastic and diligent in their efforts to help us in this experiment.

### ***Sampling dates and regimes***

13.12.2010

Level 5: ENJO. Level 6: chemical

16.12.10

Level 5: ENJO. Level 6: chemical

17.01.11

Level 5: ENJO. Level 6: chemical

20.01.11

Level 5: ENJO. Level 6: chemical

25.01.11

Level 5: ENJO. Level 6: chemical

27.01.11

Level 5: ENJO. Level 6: chemical

31.01.11

Level 5: ENJO. Level 6: chemical

03.02.11

Level 5: ENJO. Level 6: chemical

.....

10.02.11

Level 5: chemical. Level 6: ENJO

15.02.11

Level 5: chemical. Level 6: ENJO

### ***Sampling***

Sampling occurred immediately after cleaning. Cleaning started at 6.30am and was finished by 7.00am. In order to avoid any possibility of contamination of the sites prior to testing, notices were put up by the cleaners each day, warning "Microbiological Testing in Process - keep out".

The order for testing was: first - level 5 kitchen/tea room; second - level 6 kitchen/tea room; third - level 5 mens' toilets; fourth - level 6 mens' toilets. The samples were later processed in the same order they had been taken.

At each sampling site, 2 adjacent, replicate samples were taken, using as templates, identical aluminium rings of 35mm diameter, with the exceptions of the kitchen door handle and toilet tap handle. For the kitchen door handle a template of the same shape and size as 2 aluminium rings was made out of flexible plastic and clipped onto the handle, in order to give 2 identical sites. For the toilet tap handle, 4 half-circle plastic templates, equating to 2 circles of the same dimensions as the aluminium rings above, were made. These fitted on the four sides of the toilet tap handles.

Before sampling the aluminium rings were sterilized by autoclaving at 121°C in a covered container. The plastic templates for the kitchen door handle and toilet tap handle were sterilized by wiping with 95% ethanol and air drying prior to each use. Gloves were worn during samplings.

Samples were taken using a cotton swab dipped in 3ml of sterile, buffered peptone water (Peptone, Oxoid) in Bijoux bottles. Each site was swabbed in a cross-hatch manner, taking care to use the same number of strokes with the same pressure for each site and turning the swab for each direction of wiping. After sampling, the swab heads were snapped off aseptically and the Bijoux bottles re-sealed. Sample bottles were stored at 4°C pending plating.

### ***Growth of Microorganisms***

Plating commenced immediately after sampling. In order to thoroughly mix the samples before plating, each sample bottle was vortexed , for 5 seconds, followed by 20 shakes by hand, followed by 5 more seconds of vortexing. For each sample, 100µL was spread onto 3 plates each of Standard Plate Count

Agar (PCA, Oxoid), Sabourauds Dextrose Agar (SDA, Oxoid) and Eosin Methylene Blue Agar (EMB, Oxoid). Each sample was spread seven times as a figure of 8, followed by a quarter turn, then 7 more figures of 8.

PCA was used to give a general bacterial count. The PCA plates were counted at 24 and 48 hours. SDA was used to give a general count of yeasts and moulds. The SDA plates were counted generally at 7 and 14 days. EMB was used to show the presence of *Escherichia coli* and hence the possibility of any other coliforms or enteric bacteria. The EMB plates were counted at 24 hours. Before plating, the urinal step samples were diluted into saline solution at a 1:1000 concentration, in order to get a countable number of colonies.

After each sample was plated, it was stored at 4°C, until all the samples were processed, at which time the plates were incubated: PCA at 30°C, SDA at 30°C (to facilitate yeasts) and EMB at 37°C. The results were put on spreadsheet.

## **2.2 Results and discussion**

The means for each sample were calculated. The totaled means were arranged to compare equivalent means of samples for the two cleaning regimes (see Appendix 1). A Microsoft Excel two-tail t-test which assumed equal variance was used, to find a P value (Appendix 2). All the samples, except for one on 17.01.11 for SDA at 7 days, had a probability greater than 0.05, which therefore overall, supported a null hypothesis that there was no significant difference between the two cleaning regimes.

This project was originally planned to have eight samplings before Christmas 2010 and eight samplings after Christmas 2010. Due to various unforeseen circumstances, this did not transpire, however it is likely that the results would not have been any different if the experiment had been followed as originally planned. All the samples were taken when there was a reasonable number of students and staff occupying the building. As level 6 provided office space for lecturers and level 5 provided rooms for post-graduate students the quiet times over the holidays were avoided, in case these affected the results.

This experiment was unfortunately truncated, due to the major earthquake on 22 February 2011, which stopped sampling and meant that several samples which were being incubated or were in the refrigerator were destroyed. It is probable that even if all the samples had been completed, the results would not have been any different because the results obtained above suggest that there is no significant difference between the two cleaning regimes.

## **PART THREE - CONCLUSION**

In summary, it is the author's opinion, after doing the above experiment and reviewing the literature, that in order to maintain a good level of environmental hygiene that will minimize the transmission of infectious diseases in public buildings, such as the University of Canterbury it is necessary to:

- 1) vigorously clean surfaces with soap and water, followed by thorough rinsing and drying;
- 2) as soon as possible after cleaning, all cleaning cloths or sponges should be laundered, thoroughly dried and stored dry;
- 3) people need to be continually educated about the importance of washing their hands, using plenty of soap, followed by thorough rinsing and drying.

Since many infectious illnesses are the result of incorrect food storage, ie: keeping foods uncovered or too warm, or at an insufficiently low pH, the use of disinfectants will not necessarily avoid these types of illnesses. Routine disinfection of surfaces is only necessary in commercial food preparation premises, hospitals, and in homes where there are people who are very young, very old, immunocompromised or who have highly infectious illnesses.

The use of harsh chemicals such as organo-phosphates, QACs GCH and triclosan, to clean and routinely disinfect, is of arguably marginal or no advantage over not disinfecting. As noted above by Allerberger et al (2002) "there are insufficient scientific data to support the strong recommendation to routinely disinfect environmental surfaces in health care facilities except in certain high risk areas (eg., isolation units) or possibly to prevent transmission of high-risk organisms (eg., MRSA, VRE)". If general hospital areas do not require routine disinfection with hazardous chemicals, then why should a university? For routine cleaning purposes, these chemicals are arguably no better than natural cleaning products for removing surface soil. All of the chemicals discussed above, pose one or all of the following risks: environmental pollution, increased bacterial resistance, cancer, DNA damage, infertility, endometriosis, respiratory impairment, immune malfunction, depression and candidiasis.

The author suggests that we should stop seeing microbes as 99.9% opportunistic and pathogenic, but instead appreciate that 99.9% of microbes are harmless and many are positively beneficial, and without them we would not survive, let alone thrive. This author also suggests that The University of Canterbury would be a much healthier place if hazardous chemicals were not used for cleaning. Instead, the University could use soap and water or fibre-based cloths and water. The use of natural cleaning products, and cotton cloths which can be boiled for disinfection and finally composted, is particularly appealing as they will ultimately go back to the soil from where they, and all of us, including our microbe friends, came.

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[www.epa.gov/ncepihom](http://www.epa.gov/ncepihom) (info: indoor air quality, mould, pesticides, etc)

United States Dept of Labour, Occupational Safety and Health Administration - <http://www.osha.gov>

USA: Green Seal Certified

**Appendix 1: Means Comparisons**

Mean PCA	24 hrs		48 hrs		Mean SDA	7 days		14 days	
	Enjo (5)	Chemical (6)	Enjo (5)	Chemical (6)		Enjo (5)	Chemical (6)	Enjo (5)	Chemical (6)
Kitchen door handle	8.84	10.17	51.67	27.17	Kitchen door handle	0.00	0.00	0.33	0.00
Kitchen worktop	0.83	0.00	177.50	2.50	Kitchen worktop	0.00	0.33	0.00	0.33
Kitchen fridge door	1.00	0.17	4.34	79.00	Kitchen fridge door	0.00	0.00	0.00	0.00
Kitchen bin lid	103.00	6.67	165.17	34.50	Kitchen bin lid	0.00	0.00	0.00	0.00
Kitchen coffee table	0.84	0.00	4.84	190.84	Kitchen coffee table	0.00	0.00	0.00	0.00
Toilet seat	2.50	11.17	34.00	31.83	Toilet seat	0.00	0.00	0.00	0.00
Urinal (1:100)	0.00	650.00	950.00	1683.34	Urinal (1:100)	0.00	0.00	0.00	0.00
Toilet cold tap	2.00	178.00	598.50	283.67	Toilet cold tap	0.84	0.00	1.34	0.00
Toilet floor (1:100)	0.00	183.34	6350.00	3133.34	Toilet floor (1:100)	0.34	0.00	6.00	0.00
<b>Sample 25.01.11</b>	<b>Checked</b>				<b>Sample 25.01.11</b>	<b>Checked</b>			
Mean PCA	24 hrs		48 hrs		Mean SDA	7 days		14 days	
	Enjo (5)	Chemical (6)	Enjo (5)	Chemical (6)		Enjo (5)	Chemical (6)	Enjo (5)	Chemical (6)
Kitchen door handle	208.34	1.83	214.33	6.17	Kitchen door handle	0.00	3.67	22.67	24.67
Kitchen worktop	1.67	0.50	4.17	2.84	Kitchen worktop	0.00	0.50	1.17	2.00
Kitchen fridge door	0.83	0.00	4.00	0.84	Kitchen fridge door	0.83	0.17	12.67	2.34
Kitchen bin lid	0.17	5.17	5.50	19.00	Kitchen bin lid	0.00	2.17	2.00	5.33
Kitchen coffee	17.00	24.00	22.67	26.17	Kitchen coffee	0.00	0.34	1.50	11.84

table					table				
Toilet seat	67.33	24.67	74.00	33.17	Toilet seat	0.00	0.00	6.83	0.50
Urinal (1:100)	14.17	17.17	31.17	17.33	Urinal	2.17	11.17	9.00	42.84
Toilet cold tap	N/A	N/A	N/A	N/A	Toilet cold tap	N/A	N/A	N/A	N/A
Toilet floor (1:100)	2.84	0.17	3.00	1.17	Toilet floor	0.00	0.33	16.84	10.33

Sample 27.01.11	Checked		Chemical (6)	Sample 27.01.11	Checked		Chemical (6)
	24 hrs	48 hrs			7 days	14 days	
Mean PCA	Enjo (5)	Chemical (6)	Enjo (5)	Mean SDA	Enjo (5)	Chemical (6)	Enjo (5)
Kitchen door handle	0.00	1.34	6.67	Kitchen door handle	0.17	0.00	0.17
Kitchen worktop	0.00	2.00	2.67	Kitchen worktop	0.00	0.00	0.17
Kitchen fridge door	0.00	2.00	10.00	Kitchen fridge door	0.00	0.00	0.00
Kitchen bin lid	174.84	9.17	204.83	Kitchen bin lid	0.00	0.67	0.00
Kitchen coffee table	0.34	10.17	5.67	Kitchen coffee table	0.17	0.00	0.17
Toilet seat	0.00	6.17	2.34	Toilet seat	0.00	0.00	0.00
Urinal (1:100)	0.00	3.17	1.84	Urinal	121.50	3.84	124.00
Toilet cold tap	1.67	80.67	9.83	Toilet cold tap	0.17	0.17	0.17
Toilet floor (1:100)	0.17	2.34	2.00	Toilet floor	0.00	1.34	0.00

Sample 31.01.11	Checked		Chemical (6)	Sample 31.01.11	Checked		Chemical (6)
	24 hrs	48 hrs			7 days	14 days	
Mean PCA	Enjo (5)	Chemical (6)	Enjo (5)	Mean SDA	Enjo (5)	Chemical (6)	Enjo (5)
Kitchen	199.67	8.30	242.34	Kitchen	0.00	0.00	0.00

door handle			
Kitchen worktop	3.17	9.00	9.50
Kitchen fridge			
door	1.17	1.30	1.17
Kitchen bin lid	30.84	0.30	1.00
Kitchen coffee table	5.34	8.25	0.84
Toilet seat	23.17	2.84	50.00
Urinal (1:1000)	0.00	1.50	1330.00
Toilet cold tap	2.17	5.50	3.84
Toilet floor (1:1000)	13.83	101.17	195665.00

door handle				
Kitchen worktop	0.00	0.00	0.00	0.00
Kitchen fridge				
door	0.00	0.00	0.00	0.00
Kitchen bin lid	0.00	0.00	0.00	0.00
Kitchen coffee table	0.00	0.00	0.00	0.00
Toilet seat	0.00	0.00	0.00	0.00
Urinal (1:1000)	90.50	1.00	94.00	1.67
Toilet cold tap	0.17	0.00	0.34	1.17
Toilet floor (1:1000)	0.00	0.00	0.17	32.00

Sample 03.02.11	Checked		Chemical (6)
	24 hrs	48 hrs	
Mean PCA	Enjo (5)	Enjo (5)	Chemical (6)
Kitchen door handle	0.00	55.00	4.17
Kitchen worktop	0.67	4.84	9.67
Kitchen fridge door	0.00	0.67	39.00
Kitchen bin lid	1.67	16.83	1.34
Kitchen coffee table	0.17	8.83	2.17
Toilet seat	0.00	6.34	6.34
Urinal (1:1000)	0.00	66.50	216.50
Toilet cold tap	0.00	22.83	10.50

Sample 03.02.11	Checked		Enjo (5)	Chemical (6)
	7 days	14 days		
Mean SDA	Enjo (5)	Enjo (5)	Chemical (6)	Chemical (6)
Kitchen door handle	0.17	156.17	0.34	55.33
Kitchen worktop	0.00	71.00	0.15	30.17
Kitchen fridge door	0.00	55.50	1.00	29.67
Kitchen bin lid	0.00	15.17	0.17	38.50
Kitchen coffee table	0.00	28.33	0.00	28.67
Toilet seat	0.00	25.17	0.00	107.34
Urinal (1:1000)	0.33	13.17	1.34	49.34
Toilet cold tap	0.33	12.17	0.34	142.17

tap					tap				7
Toilet floor (1:1000)	2.17	0.00	733.50	100.00	Toilet floor	2.17	1.00	58.84	122.67

Sample 10.02.11	Checked				Sample 10.02.11	Checked			
Mean PCA	24 hrs	48 hrs		Mean SDA	7 days	14 days			
	Chemical (5)	Enjo (6)	Chemical (5)	Enjo (6)	Chemical (5)	Enjo (6)	Chemical (5)	Enjo (6)	
Kitchen door handle	0.00	0.00	0.67	16.84	Kitchen door handle	0.00	0.34	13.00	75.17
Kitchen worktop	0.00	0.00	3.67	11.34	Kitchen worktop	0.00	0.00	1.00	46.50
Kitchen fridge door	0.00	0.00	9.00	6.84	Kitchen fridge door	0.00	0.84	49.50	27.17
Kitchen bin lid	0.83	0.00	4.17	12.33	Kitchen bin lid	0.00	0.34	0.50	109.33
Kitchen coffee table	0.00	0.00	5.50	5.17	Kitchen coffee table	0.00	0.00	0.33	38.84
Toilet seat	0.00	0.00	4.67	2.83	Toilet seat	0.00	201.84	124.00	202.17
Urinal (1:1000)	0.00	0.00	4500.00	3.50	Urinal	34.34	1.50	150.50	69.17
Toilet cold tap	2.17	0.00	10.33	60.00	Toilet cold tap	6.00	3.50	70.34	35.33
Toilet floor (1:1000)	0.00	0.00	274833.17	1833.34	Toilet floor	195.33	1833.34	210.33	294.00

Sample 15.02.11	Checked				Sample 15.02.11	Checked			
Mean PCA	24 hrs	48 hrs		Mean SDA	7 days	14 days			
	Chemical (5)	Enjo (6)	Chemical (5)	Enjo (6)	Chemical (5)	Enjo (6)	Chemical (5)	Enjo (6)	
Kitchen door handle	0.67	0.00	2.17	1.67	Kitchen door handle	N/A	N/A	N/A	N/A
Kitchen worktop	3.34	3.67	8.33	16.17	Kitchen worktop	N/A	N/A	N/A	N/A
Kitchen	1.17	0.00	20.17	0.50	Kitchen	N/A	N/A	N/A	N/A

fridge door					fridge door				
Kitchen bin lid	2.17	0.17	4.16	3.67	Kitchen bin lid	N/A	N/A	N/A	N/A
Kitchen coffee table	0.50	0.00	7.16	0.67	Kitchen coffee table	N/A	N/A	N/A	N/A
Toilet seat	2.67	0.34	9.33	6.50	Toilet seat	N/A	N/A	N/A	N/A
Urinal (1:1000)	0.00	0.83	0.33	1.34	Urinal (1:1000)	N/A	N/A	N/A	N/A
Toilet cold tap	2.34	0.17	22.00	0.50	Toilet cold tap	N/A	N/A	N/A	N/A
Toilet floor (1:1000)	0.17	0.50	0.50	1.17	Toilet floor (1:1000)	N/A	N/A	N/A	N/A

- Note on Level 6. The cleaner is very thorough and cleans the bins with boiling water, which may give anomalous results

**Appendix 2: t-Test: Two-Sample Assuming Equal Variances**

t-Test: Two-Sample Assuming Equal Variances

	<i>PCA 17.01.11 24hrs ENJO (5)</i>	<i>PCA 17.01.11 24hrs Chemical (6)</i>
Mean	440.65	492.7455556
Variance	879375.3087	1056777.155
Observations	9	9
Pooled Variance	968076.2319	
Hypothesized Mean Difference	0	
df	16	
t Stat	-0.112318722	
P(T<=t) one-tail	0.455983891	
t Critical one-tail	1.745883669	
P(T<=t) two-tail	0.911967782	
t Critical two-tail	2.119905285	

Null accepted

t-Test: Two-Sample Assuming Equal Variances

	<i>PCA 17.01.11 48 hrs ENJO (5)</i>	<i>PCA 17.01.11 48hrs Chemical (6)</i>
Mean	875.9088889	1105.204444
Variance	3371161.487	5286531.316
Observations	9	9
Pooled Variance	4328846.401	
Hypothesized Mean Difference	0	

t-Test: Two-Sample Assuming Equal Variances

	<i>SDA 17.01.11 3d ENJO (5)</i>	<i>SDA 17.01.11 3d Chemical (6)</i>
Mean	0.314444444	0.092222222
Variance	0.50460277	0.021269444
Observations	9	9
Pooled Variance	0.26293611	
Hypothesized Mean Difference	0	
df	16	
t Stat	0.91932405	
P(T<=t) one-tail	0.18578931	
t Critical one-tail	1.74588366	
P(T<=t) two-tail	0.37157863	
t Critical two-tail	2.11990528	

Null accepted

t-Test: Two-Sample Assuming Equal Variances

	<i>SDA 17.01.11 7d ENJO (5)</i>	<i>SDA 17.01.11 7d Chemical (6)</i>
Mean	6.14777777	0.184444444
Variance	58.9234944	0.037427778
Observations	9	9
Pooled Variance	29.4804611	
Hypothesized Mean Difference	0	

Mean Difference	
df	16
t Stat	-0.233784549
P(T<=t) one-tail	0.409058611
t Critical one-tail	1.745883669
P(T<=t) two-tail	0.818117222
t Critical two-tail	2.119905285
<hr/>	
Null accepted	

Mean Difference	
df	16
t Stat	2.32985131
P(T<=t) one-tail	0.01661641
t Critical one-tail	1.74588366
P(T<=t) two-tail	0.03323283
t Critical two-tail	2.11990528
<hr/>	
Null declined	