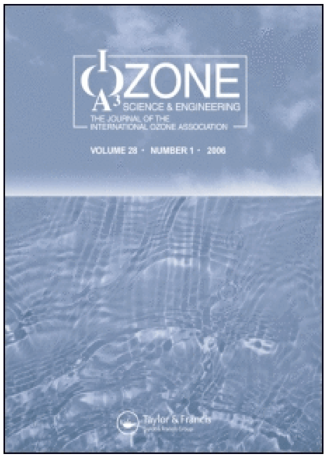

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Ozone in the Laundry Industry - Practical Experiences in the United Kingdom

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Ozone in the Laundry Industry—Practical Experiences in the United Kingdom

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Since the early 1990s, the use of ozone in many commercial and industrial laundering applications has been evolving rapidly. Ozone allows washing to be conducted using cold water, thereby saving considerable heat energy and water consumption. Additionally, ozone enhances the wash process, resulting in a significant reduction in detergent dosage and number of rinses, thus saving water. Ozone/cold water cycles are gentler to fabrics, thus extending linen life. Finally, ozone/cold water laundering is beneficial for effluents, resulting in reductions in COD (chemical oxygen demand). Microorganisms are destroyed effectively in ozone-wash waters, and washing and drying cycles are shorter, thus saving labor. In this paper, the authors describe some specific case studies at commercial laundering installations in the UK, whereby the users of ozone have reaped major benefits, including enhanced microorganism kills/inactivation and significant cost savings.

Keywords Ozone, Laundries, Bacteria Kills, Virus Inactivation, Economic Benefits, *Clostridium difficile*, MRSA

INTRODUCTION

(ClearWater Tech, 2003, 2006)

Over the years, commercial laundry operations have improved by achieving higher per-load capacities and automated cycle and chemical management to ensure consistent quality over many loads. These improvements are notable, yet many financial and regulatory pressures continue to face commercial laundering, including:

- Water consumption and conservation
- Energy conservation
- Waste products management
- Efficiency per laundry load
- Fabric lifetime cost

These issues apply in all commercial laundry settings, ranging from hospitals and institutional care to hospitality installations and for-profit commercial laundries. The number of commercial laundering facilities in the United States alone was estimated in 2003 at 140,400, categorized in Table 1 (ClearWater Tech, 2003).

Starting in the mid-to-late 1980s, work began to determine if ozone, O_3, a known powerful oxidant and disinfectant, would allow laundering to be performed using ambient temperature water. The strong oxidizing and bleaching properties of ozone might allow reduction or even elimination of laundering detergents, thus lowering the chemical loads in discharge wastewaters. Simultaneously, ozone's strong disinfecting capabilities might also kill or inactivate problematic microorganisms found in many soiled textiles, e.g., from hospitals, medical facilities, nursing homes, etc.

Two remarkable properties of ozone stand out in its application to laundry systems:

1. Because it leaves no chemical residue and because the amount of detergent needed with ozone treatment is much lower, ozone-sanitized wash needs far less rinsing, saving water; and,
2. Because ozone works so efficiently in cold water, sanitizing as well as cleaning can be done in cold water, saving energy.

With less rinsing, wash loads can be completed faster, thus utilizing the laundry equipment more efficiently and reducing the total staff hours per load.

Ozone's arrival for commercial laundries has proceeded on a normal innovation-adoption path.

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TABLE 1. U.S. Commercial Laundering Facilities (ClearWater Tech, 2003)

Category	Laundry Facilities
Hospitals	7,400
Nursing Homes	39,700
Hotels and Motels	47,000
Prisons	4,200
Commercial Laundries	7,100
Coin Operated Laundries	35,000

Ozone-based commercial laundries currently are operating in all segments of the commercial laundry market, in many places round the globe, with some in continuous operation since the early 1990s.

OBJECTIVES

In the United Kingdom, rapid and significant advances in developing the application of ozone in commercial laundries have been made in recent years. A leader in this effort has been JLA, Limited, of Ripponden, West Yorkshire, that has been marketing ozone systems to the institutional laundry business since mid-2004. The primary purpose of this publication is to document results from studies conducted by independent microbiological laboratories and other organizations to document the various aspects of ozone's application in commercial laundering equipment. Another objective is to document and quantify the cost savings obtainable by utilizing this revolutionary technology in commercial laundries.

OZONE (COLD WATER) WASHING

(ClearWater Tech, 2003, 2006)

When designing a commercial laundering system incorporating ozone and/or when retrofitting ozone systems into existing commercial laundering systems, there are three fundamentally different design approaches in use.

- Recirculation Injection—This design can handle the heaviest demands and saves the most water, energy and time. The break cycle uses conventional laundry methods with hot-warm water and chemicals. However, that's where conventional processes end. All other chemical cycles are replaced with cold water and low and at times no chemical injection. The rinse water is continually cycled back to the ozone system for extreme oxidation of the rinse water and a predetermined amount of dissolved ozone is sent back to the washer for sanitizing of the laundry.
- Direct Water Injection—Ozone is introduced directly by injection to the cold water supply line. This approach allows for effective concentrations of ozone for disinfection and odor control in any cold water cycle. This method offers good effectiveness with good return on investment through savings in chemicals and energy. A variation on this approach includes a contact tank in which ozone is mixed with cold water and stored until needed by the wash cycle. The contact tank approach makes it possible to achieve higher effective concentrations of ozone.
- Air Injection—Ozone gas is injected directly into the catch basin of the washer. A properly designed air injection system will activate traditional laundry detergents, allowing them to do their job with less water and at lower temperature. In this approach, ozone is relied on for disinfection and overall laundry quality with reduced costs. Disinfection is achieved with the ozone gas in solution as well as linen folding into the ambient ozone in the wash drum. An ambient air ozone monitor within the facility and/or within the wash drum will control ozone off-gas and eliminate any concerns of high ozone levels in the laundry facility. However, if applied correctly the air injection method of ozonating a commercial or institutional laundry will yield the highest return on investment of the three basic designs.

Figure 1 (California Urban Water Conservation Council, 2006) shows a schematic diagram of a direct injection laundry system with holding tank, (three washing machines) using ozone. This figure shows the optional installation of a Granular Activated Carbon filter to treat incoming municipal water.

Figure 2 (ClearWaterTech, 2006) shows more details of the air injection ozone equipment for a single washing machine (Figure 2a) and Figure 2b shows the same details for two washing machines fitted with a single ozone air injection system. The oxygen concentrator removes some of the nitrogen from ambient air, thereby concentrating the oxygen to levels above 90% by weight. Higher oxygen concentrations in the feed gas to ozone generators result in higher ozone concentrations being produced. The ambient ozone controller monitors ozone in the ambient air. Should the level of ambient ozone ever exceed local regulations, this controller automatically shuts off the ozone generator until the source of the ambient ozone can be found and repaired. The gaseous ozone produced by the generator is fed via a diffuser into water entering the washer. The ozone system turns on during any "step" within the wash formula via a "dry contact" (no voltage) signal or 120-240V AC signal to the main control board of the ozone generator.

Other LED units on the display panel indicate other functions of the equipment. Thus the operational status of this equipment can be checked and monitored visually

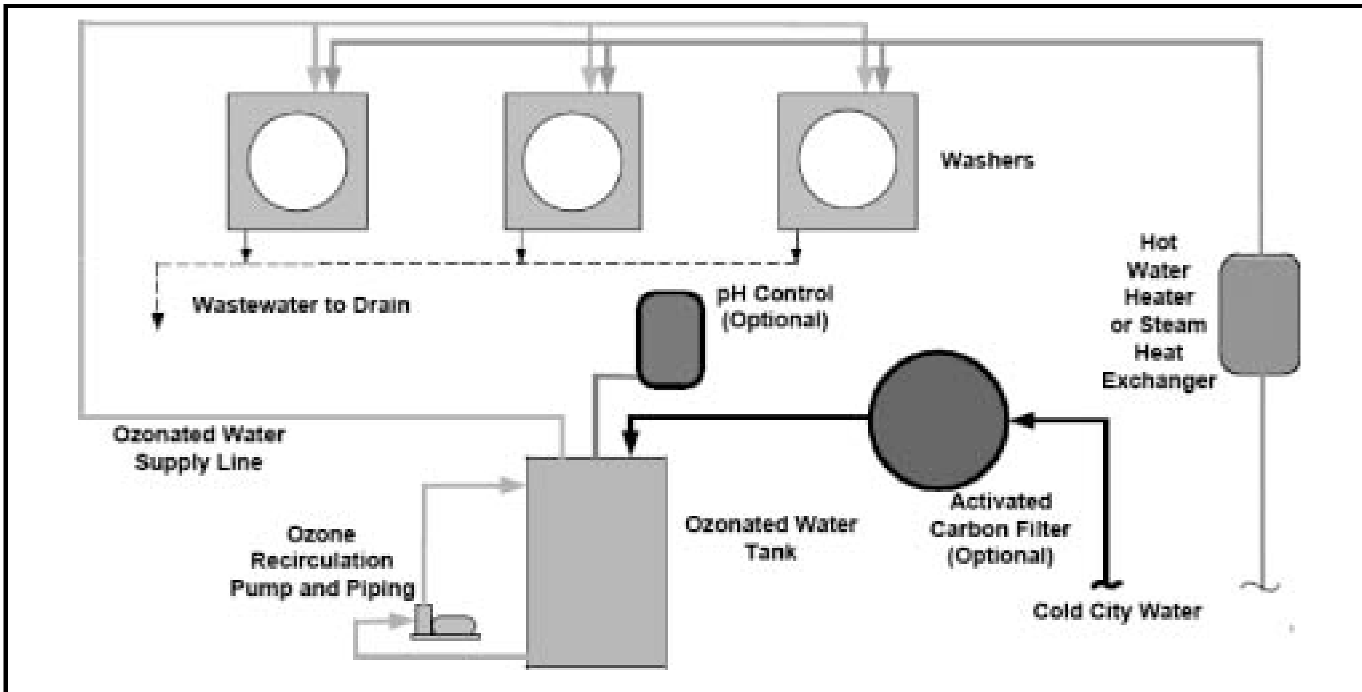

FIGURE 1. Ozone laundry systems (California Urban Water Conservation Council, 2006).

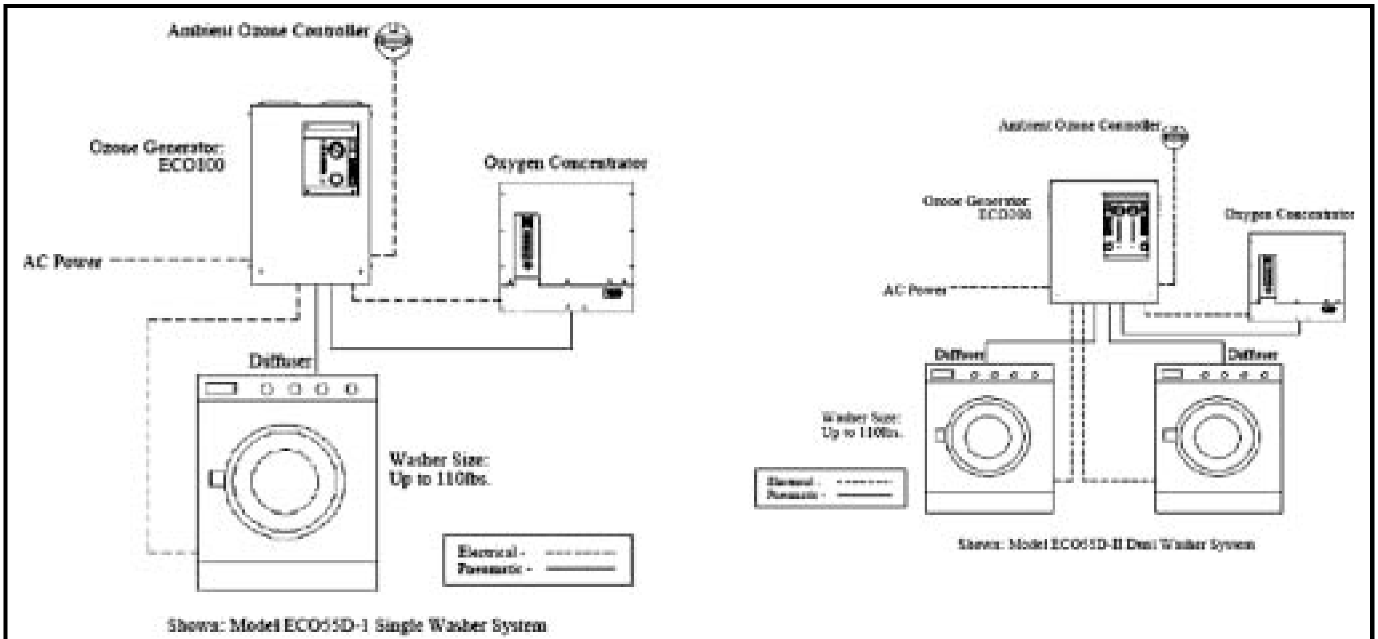

FIGURE 2. (a and b): Schematic drawings of two CWT ECOTEX ozone laundry systems (ClearWater Tech, 2006).

by personnel responsible for laundering without requiring detailed technical training.

The ozone output for any given wash load can be increased or decreased by turning a potentiometer or manual ozone output control knob located on the control panel of the ozone generator. As this potentiometer is turned clockwise, the LED bars illuminate one at a time. In this manner, the proper amount of ozone is applied to cope with the kind/type of soils on articles placed in the washer. The ozone output also can be varied by changing the flow rate of air entering the ozone generator.

The OTEX Ozone Washing System and Process

This process and complete laundering system is offered on a fixed-price rental basis, including full maintenance, in the United Kingdom by JLA, Ltd. The firm has been monitoring ozone technology since 1995, and developing and perfecting an ozone laundering system since 2002. Commercial ozone-laundering systems were introduced in 2004.

OTEX washing equipment ranges in size to allow laundering of from 16 lbs to 126 lbs, and each equipment component complies fully with all relevant UK water and health regulations. Materials of construction are resistant to ozone-containing gases and waters. Dryers handle capacities of from 20 lbs to 179 lbs, and include the S.A.F.E. (Sensor Activated Fire Extinguishing) system for dryers. Typically, the equipment installer sets the ozone output control knob for the desired ozone output for the degree(s) of soil likely to be encountered on linens at the facility. Personnel doing the laundering then only need choose the program number 1 through 4 (1 being for the heaviest soil and 4 for the lightest), then push "start."

Liquid detergent and other chemicals are injected according to measured doses into the wash cycle using peristaltic pumps supplied by detergent companies. Detergent control is important in ozone laundering because indiscriminate addition of more detergent than is needed will use up the ozone and will require more-than-necessary rinsing.

A proprietary ozone/water contacting system (the interfusor) is employed that creates a vortex effect, enabling more ozone to be dissolved in a given volume of water than by standard ozone contacting methods. In turn, this allows a higher degree of microorganism kills without producing excessive amounts of ozone off-gas.

An additional feature of the OTEX ozone laundry systems is the inclusion of a means to vary the amount of ozone fed to any wash water. As with household clothing and linens, some soils are heavy (oils, greases, mud, etc.) while other soils are light (personal garments). Heavier soils require more ozone than do light soils. Consequently, the OTEX display board contains a sequence of 10 LED bars, which indicate 0 to 100% of the ozone output available from the ozonation equipment installed. Each LED bar indicates an additional 10% of the ozone output available above that of the preceding LED bar.

The OTEX single reaction chamber ozone generator produces 4 g of ozone per hour at 3% ozone concentration in the gas phase at a gas flow rate of 4 scfh at 100% output (LED bar #10 illuminated). At a gas flow rate of 3 scfh, this same unit produces 3.1 g/h of ozone at 3.2% ozone concentration in the gas phase at 100% output. At 60% output (6th LED bar illuminated), this unit produces 1.86 g/h of ozone at 1.92% concentration in the gas phase at 3 scfh.

ADVANTAGES OF OZONE IN COMMERCIAL LAUNDERING SYSTEMS

(ClearWater Tech, 2006)

- Reduces Energy Use—Ozone enhances the effectiveness of the actions of chemicals, reducing the need for high temperature washing. Estimates of savings potential are as high as 90% in washing and 20% in drying. The Magnolia Manor, an assisted-living facility in Americus, GA (USA) using ozone laundering since 1993 has documented energy savings of 51.3%.
- Reduces Water Use—Ozone wash systems normally require fewer rinse steps, thus reducing water usage by an estimated 30–45%. Closed loop systems are more expensive but recover most of the water, so that reductions in water use can reach 70–75%.
- Reduces Chemical Use—Ozone makes existing chemicals work better, and reduces overall chemical demand in several ways.

    1. Ozone helps supply oxygen to the wash water, which increases chemical effectiveness and reduces chemical demand.
    2. Ozone oxidizes linen soils, making them easier to remove from the wash water.
    3. Ozone can reduce the need for harsh, high-pH chemicals traditionally used to remove Fats, Oils and Grease (FOG) by breaking some of the molecular bonds in FOG and reducing them to simpler carbon compounds. While virtually all ozone laundry systems use at least some chemicals, savings claims range from 25% to 70%. Actual savings will depend on the type of laundry being washed, the temperature and hardness of supply water and the design of the ozone-laundering system.
    4. Ozone in water solution performs the function of chlorine bleach, without producing by-products. Ozone works quite well and safely in conjunction with hydrogen peroxide if a separate bleach cycle is desired. Also, because ozone improves the removal of soils from wash water, it helps prevent redeposition of soil onto the wash (one of the major causes of fabric graying), which in turn reduces the need for bleaching.

- Purifies and Disinfects—Ozone is very effective against bacteria, viruses and other microorganisms. The key is achieving a "Ct" value (contact time in minutes multiplied by ozone concentration in mg/L) of 1 mg/L-min or more.
- Improves Textile Life and Quality—Shorter cycle times and cooler temperature water (because fewer rinse steps are required) means less wear and tear on textiles. Also, reduced exposure to chemicals can improve fabric life. Additionally, ozone assists in water softening by removing hardeners such as calcium and

magnesium from the water. This occurs by the complex mechanism of ozone adding oxygen moieties to some of the partially oxidized organic materials present in laundry soils. The oxygenated organic laundry soils can form insoluble complexes with polyvalent cations (Ca, Mg, Fe, etc.), thereby partially softening the ozone-treated laundry waters. Softer water produces a better feel in washed fabrics due to better sudsing and more complete rinsing action. Finally, ozone is an effective deodorizer that works by breaking molecular bonds of many organic and inorganic compounds typically responsible for odors.

- Improves Effluent Quality—Effluent surcharges can be reduced because ozone oxidizes bacteria, other microorganisms, and some dissolved organic compounds that make up biochemical oxygen demand (BOD). Also, because fewer chemicals are used in ozone laundry systems, chemical oxygen demand (COD) may be reduced as well.

These benefits will be quantified later in this paper.

SPECIAL TESTING CONDUCTED FOR THIS PAPER

Many test studies were conducted during 2004–2005 in the United Kingdom to determine particular effects and efficacy of ozone in commercial laundering systems. Several representative studies will be described next.

Microbiological Testing

Test #1. Comparison of hot water (75–80°C) to OTEX laundering process vs. C. difficile spores (Microsearch Labs., May 15, 2004). A laboratory test was conducted by Microsearch Laboratories Ltd., West Yorkshire, UK using the European Suspension Test (E.N., 1997) comparing the effects of hot water (75°C and 80°C) over 15 minutes to 2.5-minutes laundering using cold water in the OTEX ozone-laundering process on *Clostridium difficile* spores. *C. difficile* is an intestinal bacterium that causes hospital-acquired diarrhea. In elderly patients, this can result in serious illness, and even death. The bacterium produces toxins that damage the cells lining the bowel. *C. difficile* survives well outside the body because it is a spore-forming microorganism.

Data are presented in Figures 3 (hot water results) and 4 (OTEX results). Hot water testing was conducted at 75°C over 15 minutes, and at 80°C over 15 minutes. The reduction in levels of *C. difficile* spores was insignificant (Figure 3). Figure 4 shows data obtained from OTEX ozone laundry water at ambient temperature (cold water). Even after only 2.5 minutes, no viable trace of spores could be found.

Test #2. Testing of four OTEX laundering cycles–Microsearch Labs–Nov. 8, 2004. Four ozone laundering cycle studies (Test Codes) of various garments were conducted and the challenge organisms (*S. aureus MRSA strain* and *C. difficile*) recovered and analyzed post-washing. Cycle 1 (Test Code 1) is a heavy washing for foul and infected, heavily soiled clothing. This cycle also has a sluice cycle (high wastewater level flush). The machine fills up with cold water, does a wash action, and continuously drains through an overflow. This sluice cycle is followed by a normal wash cycle. Cycle 2 (Test Code 2) is for lightly soiled sheets and towels. Cycle 3 (Test Code 3) is for delicate items, such as personal clothing and woolens. Cycle 4 (Test Code 4) is a rewash cycle used for oil/grease stained articles. With this cycle, 50°C (122EF) water is used to emulsify the oils and aid washability.

The amount of ozone is constant for each washing program. The difference between cycles is that the more

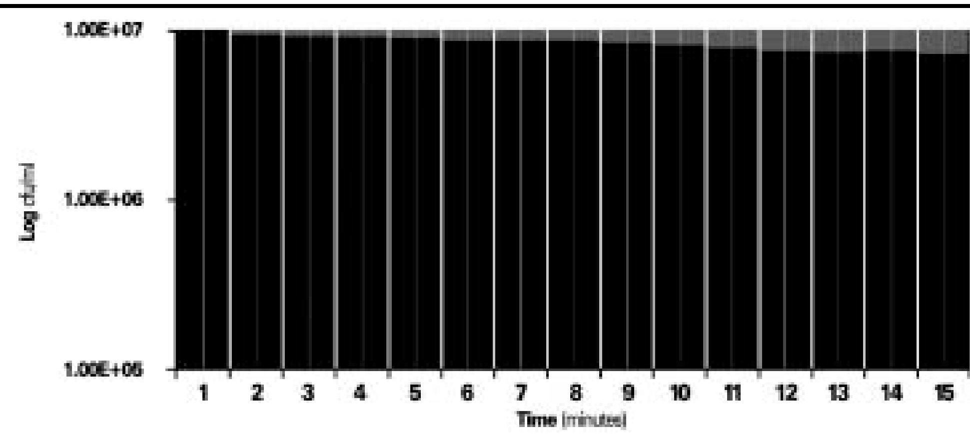

FIGURE 3. Data obtained during 16-min test on water that contained *C. difficile* spores at 75°C (Microsearch Laboratories Ltd., May 15, 2004).

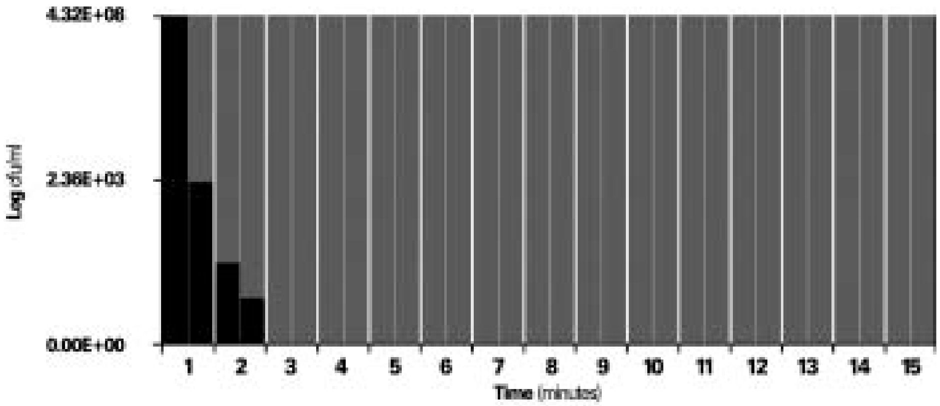

FIGURE 4. EU Suspension Test conducted on OTEX ozone laundry water with *C. difficile* spores (Microsearch Laboratories Ltd., May 15, 2004).

heavily soiled items require more detergent, which destroys some of the ozone. It is important to know that satisfactory microorganism kills can be attained by the four washing cycles, regardless of the degree of soil. A control untreated batch also was tested for these microorganisms in duplicate. Results are listed in Table 2. All ozone launderings resulted in > 5-logs kill (> 99.999%), whereas washing without ozone (Controls) gave < 99.999 % kill.

Test #3. – Microsearch labs – MRSA contamination of nurses uniforms test – 2004. Microsearch Laboratories carried out comparative tests on nurses' uniforms impregnated with a strain of the superbug MRSA (methicillin-resistant *Staphylococcus aureus*). This microorganism is being detected with increasing frequency in USA hospitals and care homes (TIME Archive, 2006).

The care labels of nurses' uniforms commonly carry the recommendation that they should be washed at 40°C (104EF). Therefore, one test was carried out using a conventional 40°C wash cycle (without ozone). A second test was carried out with an OTEX (cold water) cycle.

Figure 5 is a photograph showing the MRSA microorganism which had been impregnated onto a membrane. The membranes were implanted into the garments prior to the uniforms undergoing any laundry process. Figure 6 shows the residual MRSA culture on the recovered membrane after having been washed at 40°C (104EF). Figure 7 shows the absence of residual MRSA culture on the recovered membrane after an OTEX ozone-laundering cycle.

Results

These results indicate that a greater than log-8.0 reduction (99.999999%) in MRSA was obtained on populations of garments washed by the OTEX process. The average log reduction achieved by the 40°C (104EF) wash was only 3.3 (99.93%). To clarify, the reduction of MRSA achieved by the OTEX procedure was greater than log-8.0. Microsearch personnel were unable to

TABLE 2. Recovery of Challenge Organisms from Garments Process by a Variety of OTEX Processes

			S. aureus MR	*S aureus* MR	*C. difficile*	*C. difficile*
Trial	Clothing Item	Test Code	Cfu/25 cm^2	% kill	Cfu/25 cm^2	% kill
OTEX1	ITEM 1	TEST 1	< 1	> 99.999	< 1	> 99.999
OTEX1	ITEM 2	TEST 1	< 1	> 99.999	< 1	> 99.999
OTEX2	ITEM 1	TEST 2	< 1	> 99.999	< 1	> 99.999
OTEX3	ITEM 2	TEST 2	< 1	> 99.999	< 1	> 99.999
OTEX3	ITEM 1	TEST 3	< 1	> 99.999	< 1	> 99.999
OTEX3	ITEM 2	TEST 3	< 1	> 99.999	< 1	> 99.999
OTEX4	ITEM 1	TEST 4	< 1	> 99.999	< 1	> 99.999
OTEX5	ITEM 1	TEST 4	< 1	> 99.999	< 1	> 99.999
Lab Control	Untreated	TEST 5	7.10E + 07		2.10E + 07	

FIGURE 5. MRSA impregnated onto membrane (Microsearch Labs, 2004).

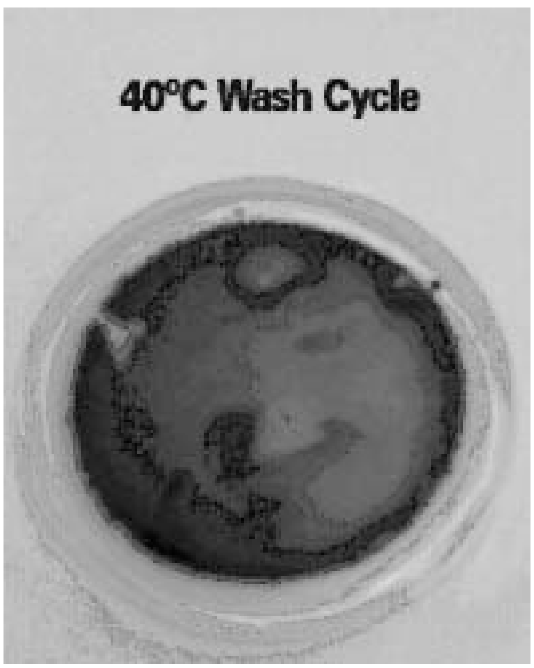

FIGURE 6. MRSA on membrane after 40EC wash.

isolate any survivors from the OTEX treated garments (Microsearch Laboratories, 2004).

Test #4. Antimicrobial efficacy of the OTEX process at 60% ozone output against Escherichia coli *- Microsearch labs, April 29, 2005.* A validation trial was conducted to determine the antimicrobial activity of an OTEX treatment at 60% of the maximum ozone output

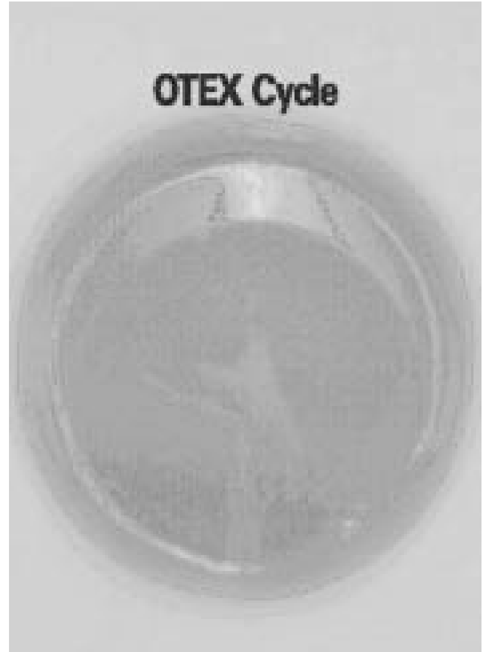

FIGURE 7. Absence of MRSA after OTEX.

of the OTEX system against *Escherichia coli*. In this trial, *E. coli* was added as liquid culture directly to the input flow of a JLA washing machine. This culture was added in sufficient volume to produce a contamination level of the order of log-7 cells/mL.

This work and the reconsideration of the optimum operating ozone level was prompted by confounding adverse evidence produced during a third-party evaluation during which poor log kill data was obtained for *E. coli*. The initial aim in this trial was to produce evidence of a baseline log kill potential with *E. coli* as a direct contaminant of wash waters with no additives running at ambient temperature, then to demonstrate the effect of ozone under identical conditions.

An ambient temperature wash trial was conducted which contained no additives and which was of 20 minutes duration. Estimates of the *E. coli* levels in the wash water were obtained by the analysis of samples collected at 3, 10 and 20-minute intervals. In an identical wash program after the first sample was recovered (i.e., 3 minutes) the OTEX device was activated and thereafter produced a continuous charge of ozone at 60% of the maximum available ozone output. Subsequent sampling occurred as described previously. Each trial was preceded by a hot sanitizing wash and rinse cycle. Data obtained are reported in Table 3 and Figure 8.

In the control experiment with no additives or ozone treatment, these data show an *E. coli* log-reduction of approximately 1 log cycle during the 20-minute wash period. During the treatment with ozone, *E. coli* could not be recovered after the initial dosing period. In fact

TABLE 3. OTEX Revalidation Trial 60% Ozone Output Treatment

Treatment	T = 3 min *E. coli* Cfu/mL	T = 10 min *E. coli* Cfu/mL	T = 20 min *E. coli* Cfu/mL
Ambient Wash No Ozone No Additives	9.30E + 07	8.40E + 07	6.20E + 06
Ambient OTEX Only 60% Ozone Output Wash	7.80E + 07	< 1	< 1

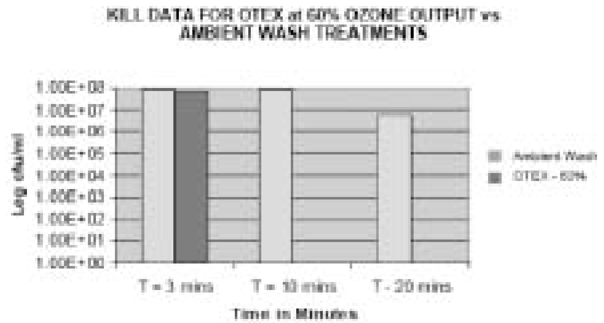

FIGURE 8. *E. coli* kill data for OTEX at 60% of the available ozone output vs. ambient wash treatments. Microsearch Labs, April 29, 2005.

by the 10-minute mark, these data indicate that a 7-log reduction was obtained corresponding to 7 minutes of ozone dosing at 60% of the maximum available output.

Test #5. OTEX bacteriological and viral investigation: OTEX laundry system solution test (OTEX report Sept. 2005). A laboratory investigation was carried out with the objective of providing documentary evidence of the bactericidal and virucidal activity of the OTEX system at ambient temperature against thermal disinfection (75EC = 167EF)) wash processes. The work was carried out on 1 July 2005 at JLA's R & D Technical Laboratory, Ripponden, West Yorkshire, UK. The microorganisms and viruses employed (Table 4) were independently prepared by Microsearch Laboratories Ltd. for testing. The four virus particles selected for testing represent both single- and double-strand RNA and DNA, which is the structure of the vast majority of all virus types.

Program Details and Test Conditions

Tests were carried out using an extended sluice program in a JLA model HW164 (16 k dry weight) washing machine. No detergent was employed during this series of tests. Details are tabulated below. Tests were conducted with water temperatures at both ambient, i.e., as supplied, and at 75EC (167EF), which is above the recommended thermal disinfection temperature of 71EC (160EF). Domestic supply water was employed with a water hardness of 60 ppm $CaCO_3$ for all tests.

Program Details:	Cycle Time (mins)	Temp (°C)	Wash Action
Program 1: Cold Sluice	30	Ambient	12 sec wash 3 sec stop time
Program 2: Thermal Sluice	30	75°C	
Detergent Volumes		No Detergent in use.	

A single unit OTEX system was employed and was maintained at the following settings throughout the trial with the exception of the control test with no ozone:

Ozone Concentration Setting	8 (highest)
Pressure	5 psi
Flow Rate	3.5 cfh

TABLE 4. Solution Challenge Test Organisms

Microorganism	Cfu/mL
Staphylococcus aureus	1.3E+08
Pseudomonas aeruginosa	3.1E+09
Candida Albicans	3.1E+08
Escherichia coli	5.2E+08
Streptococcus faecalis	5.0E+08
Aspergillus niger	3.1E+08
Clostridium difficile	4.2E+08
Clostridium perfringens	9.2E+08
Campylobacter jejuni	6.0E+08
Aeromonas mixed species	8.2E+08
Actinobacter sps	4.3E+08
Lactobacilli sps	3.9E+08
Virus particle	Particles/mL
Lambda phage	3.8E+24
FCoVA	2.6E+24
Saccharomyces virus ScV-L-BC	3.1E+23
Vibrio phage fs1	2.6E+28

Test samples were taken from the wash drum throughout the wash cycle to determine the concentration of dissolved ozone in the water. This was measured by using the Chemets method, which employs DPD chemistry. Dissolved ozone levels increased from 0.2 ppm at the start to 0.6 ppm after 15 minutes, with samples being taken at 3, 7, 11, and 15 minutes of washing.

Data obtained are presented in Figures 9–14. Figures 9, 10 and 11 show results of bacterial sampling at ambient temperature-no ozone (control), 75EC (167EF = thermal washing), and ambient temperature with ozone (OTEX), respectively. Note that without ozone and at ambient temperature (Figure 9), only small amounts of bacterial kills were obtained. With thermal washing (Figure 10), three strains of bacteria remained at significant levels even after 15 minutes. But with ozone at ambient temperature (Figure 11), no bacteria were present after 3 minutes of washing.

Figures 12, 13 and 14 show similar results of virus and phage sampling at ambient temperature-no ozone (control), 75EC (167EF = thermal washing), and ambient temperature with ozone (OTEX), respectively. Note that without ozone and at ambient temperature (Figure 12), only small amounts of viral inactivation were obtained. With thermal washing (Figure 13), viral inactivation was obtained after 5 minutes, and the same results were obtained with ozone at ambient temperature (Figure 14) after 5 minutes (but at lower costs).

NOTE: United Kingdom guidelines for thermal disinfection of laundry require a temperature of 71°C (160EF) to be held for only 3 minutes, which is below the time found to be required for inactivation of the four viruses tested. In the United States, each state has developed its own regulations or guidance, which may differ from state to state. For example, the Illinois General Assembly, Joint Committee on Administrative Rules, Administrative Code (undated) offers the following:

> "All linens shall be mechanically washed using soap or detergent and warm or hot water. Linens shall be disinfected by using one of the following procedures:
>
> 1. *Thermal Disinfection*: Linen must be exposed to hot water of at least 160EF (71EC) for a cumulative time of at least 25 minutes.

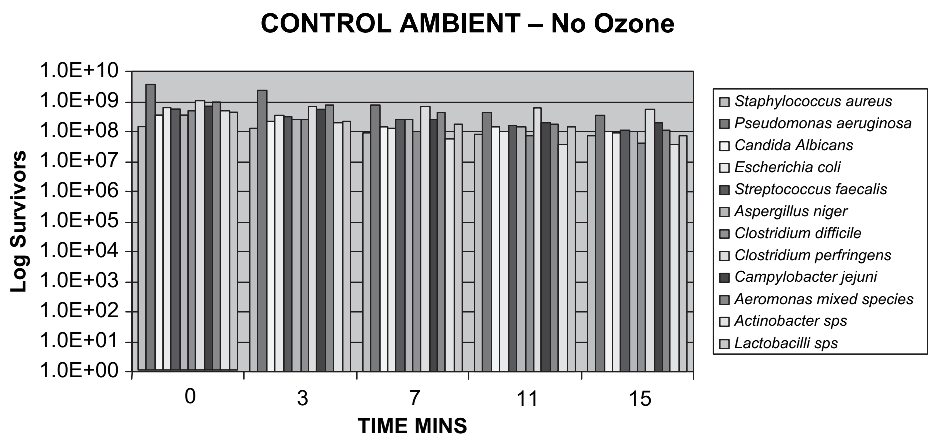

FIGURE 9. Test results—control @ ambient temperature–no ozone–bacteria.

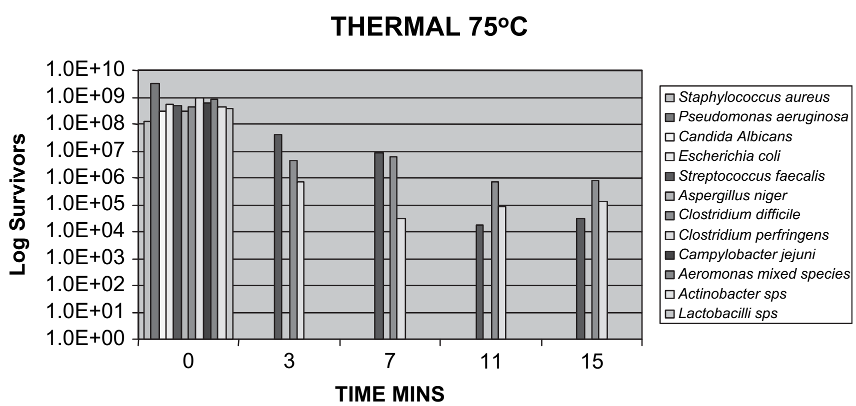

FIGURE 10. Test results - Thermal @ 75EC - no ozone – bacteria.

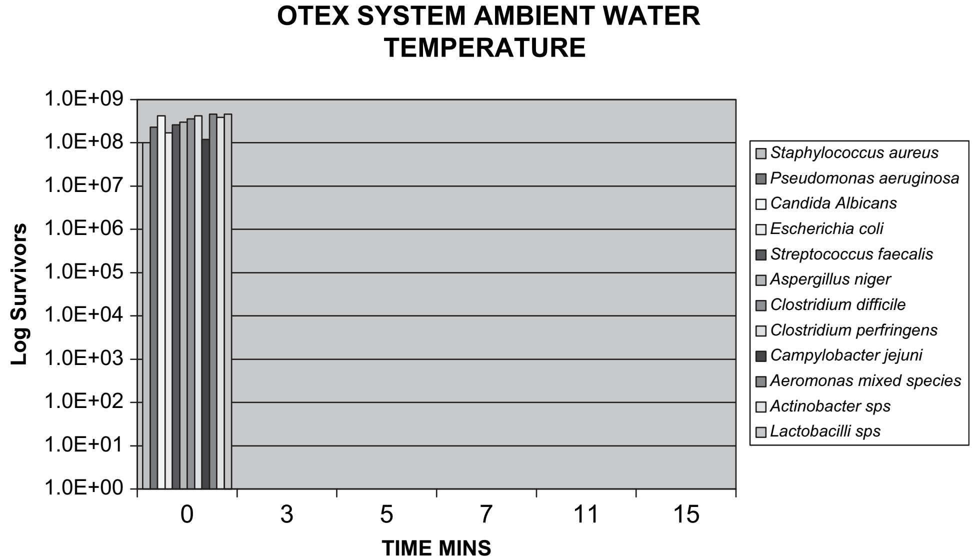

FIGURE 11. OTEX System—Ambient Water Temperature–bacteria.

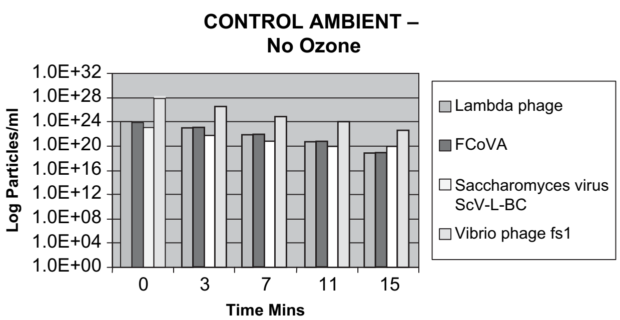

FIGURE 12. Test results—control @ambient temperature–no ozone–viruses and phages.

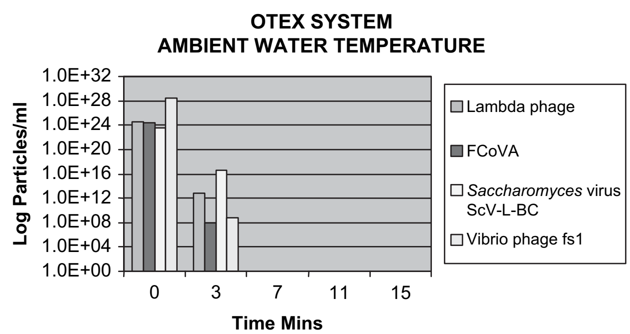

FIGURE 14. Test Results—OTEX System–Ambient Water Temperature–viruses and phages.

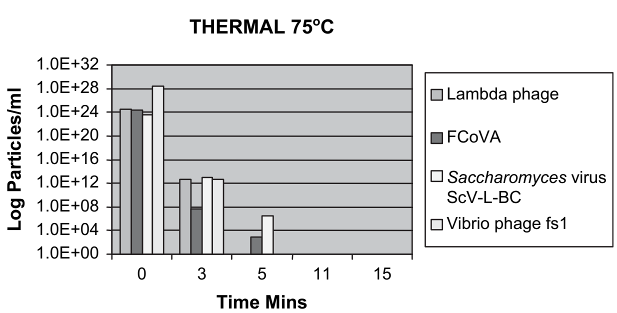

FIGURE 13. Test results—Thermal @ 75EC (167EF)–viruses and phages.

2. *Chemical and Thermal Disinfection*: Linen must be exposed to wash and bleach bath water at least 140EF (60EC). The bleach bath must be at least 10 minutes long and have a starting bleach concentration of 100 ppm. This bleach concentration should be measured by titration on a periodic basis.
3. *Other*: A stepwise wash process that has been previously documented by microbiological study published in a scientific journal. The results must indicate no surviving pathogenic microorganisms and a low level of other organisms. Low level is defined as 9 out of 10 samples with less than 2 colonies per 10 square centimeters of test surface."

Test #6. Microsearch Labs–6-Month QE II hospital bacterial test–completed November 2005. Preliminary testing of microfibre mops and cloths contaminated with various microorganisms found in hospitals by conventional laundering (thermal disinfection at 71EC = 160EF) showed the mops and cloths to be still contaminated. *C. difficile* counts were over 150,000 TVC (total viable counts). An OTEX system was installed in the QE II Hospital, Welwyn Garden City, Herts., UK, and a 6-month trial of the OTEX ozone laundering system began on May 17, 2005, and was concluded successfully.

Throughout the 6-month OTEX trial, no residual target organisms, as set by the East and North Hertfordshire NHS Trust Infection Control, were detected, including

Clostridium difficile, after processing with the OTEX system. In addition the OTEX system provided a simple laundering process with one cycle, which can also accommodate traditional cotton mops while using less detergent and being energy efficient. The hospital adopted the OTEX ozone laundering system as their method of decontamination on Dec. 12, 2005.

Test #7 – Laundering tests on marquee linings (JLA Ltd., July 2005). A mildew-soiled marquee lining was submitted for cleaning, the condition being so bad that the lining was considered only fit for disposal. The current practice is to treat the linings with chemicals individually to remove the mildew. Stains which are not normally removed by conventional washing processes are likely to need treatment in a cold solution containing 700 ppm of hypochlorite bleach acidified with acetic acid. This technique has its own inherent safety implications, i.e., reaction between an acid and an oxidizing agent liberating chlorine gas. Commercially available alternative products are based on hypochlorite or citric acid.

Methodology

The lining was cut into samples for cleaning by various wash programs. A control sample was retained. Tests were carried out in a 16 kilo JLA Model HW164 washing machine. Tests were carried out as follows:

Traditional Wash at 40EC (104EF) – no ozone
Traditional Wash at 60EC (140EF) – no ozone
OTEX wash – detergent only
OTEX wash – detergent and destainer

Reflectance readings were taken on the control and test samples to provide numerical data on the effectiveness of the wash cycles. Reflectance measurements allow a numerical value to be assigned, 0 being black and 100 white. Since mildew tends to discolor surfaces black, the higher the reflectance reading (or closer to 100), the better the cleaning process. It should be noted that the presence of mildew was more pronounced at bottom of the lining. Reflectance readings are plotted in Figure 15.

CONCLUSIONS

The results indicate that the OTEX system was successful in removing a high buildup of mildew, which was not removed as effectively with conventional wash programs. In addition, the brightness and odor of the lining was improved with the process, as shown by the higher reflectance readings of the three OTEX-washed test samples.

ECONOMIC BENEFITS OF OZONE LAUNDERING

Estimated Cost Benefits in the USA

National averages (USA) as of December 2005 for consumables and labor costs were used to project cost savings (in U.S. dollars) obtainable with four production models of the ClearWater Tech ECOTEX ozone-laundering system. Actual savings may vary based on geographical locations and actual washing programs used at specific facilities.

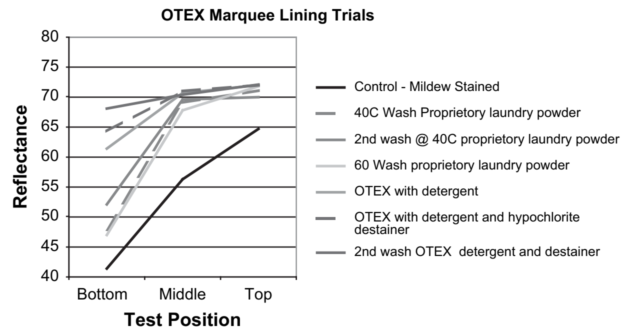

FIGURE 15. Reflectance data on laundered marquee linings (JLA, July 2005).

Facility Costs

Water/Sewer:	$0.006/gallon
Natural Gas, 2005:	$1.24/therm
Chemical Costs:	$0.25/oz
Av. Facility Labor Cost:	$10.00/hr

Table 5 shows the total estimated cost savings for ozone washing projected on the basis of detailed calculations for each cost item. Tables 6 and 7 show the Return-on-Investment calculation results for the ClearWater Tech ECOTEX ozone laundering system based on these cost savings at 10 loads per day per washing machine.

ESTIMATED COST BENEFITS IN THE UK

In contrast to the United States, where ClearWater Tech sells ECOTEX ozone laundering equipment outright, JLA Ltd. rents OTEX ozone laundering equipment to their several thousand clients. The rental fee includes a service contract. Consequently, some specifics

TABLE 5. Total Estimated Cost Savings for Ozone Washing

	Savings		
Item Saved	per load	per day	percent
Water/Sewer	$0.54	$5.40	47%
Water Gas	$1.14	$11.44	90%
Hot Water	165 gal/load		86%
Dryer Gas	$0.34	$3.40	20%
Chemicals	$0.25	$2.50	42%
Labor	$4.93	$49.30	31%

TABLE 6. Laundering Savings With ECOTEX Ozone Systems

ECOTEX Return on Investment (ROI)				
	Potential ROI			Costs
System - Model ECO55D	per Load	per Month	per Year	Sug. Retail Price
- I	$2.27	$635.60	$7,627.20	$11,066
- II	$4.54	$1,271.20	$15,254.40	$13,634
- III	$6.81	$1,906.80	$22,881.60	$20,110
- IV	$9.08	$2,542.40	$30,508.80	$23,110

TABLE 7. ECOTEX Time to Return-On-Investment—Consumables Only

System	Estd Time to ROI (months)	Estd Time to ROI (years)
Model ECO55D-I	17.41	1.45
Model ECO55D-II	10.72	0.89
Model ECO55D-III	10.54	0.87
Model ECO55D-IV	9.08	0.75

Note: Labor and Linen Savings NOT Included.

in estimated ozone benefits will vary as a result. Additionally, the amounts of estimated savings in the United Kingdom are expressed below in pounds Sterling. Nevertheless, the estimated savings as a result of ozone laundering are strikingly similar on either side of the Atlantic Ocean.

Tables 8–10 show weekly savings in three different establishments having OTEX ozone laundering equipment installed, a 50-bed care home (70% incontinence) (Table 8), a 90-bed care home (85% incontinence) (Table 9), and an 800-bed hotel (Table 10).

THIRD-PARTY TESTING/EVALUATION

The Laundry Technology Centre

The Laundry Technology Centre, Ilkley, West Yorkshire, UK tested an OTEX laundering system installed in the laundry of a 90-bed care home, just to the north of Manchester in early 2004 (Laundry Technology Centre, 2004). Measurements were taken by the Laundry Technology Centre to assess the disinfection and washing performance of the new system against recognized national standards for healthcare work.

Objectives

Wash quality was assessed using Swiss EMPA (Swiss Federal Laboratories for Material Testing and Research) calibrated test fabric for (a) protein removal (blood, urine, feces, perspiration, skin sebum), and (b) vegetable dye removal (red wine, tea, coffee, beer, beetroot, black currant). Disinfection was assessed for (a) total viable count (TVC) of all surviving microorganisms, (b) an indication of mold and fungal growth (including athletes foot and prickly itch), and (c) an indication of coliforms, including *E. coli*.

Methodology

Every load processed through each of the three 16-kg washer extractors in the laundry was monitored. Microorganism counts were taken on the line before washing and immediately after the end of the final spin after washing. The EMPA test pieces were used in 10 cm squares, securely pinned to a carrier towel and placed in the center of each load. Each load contained one protein piece and one vegetable dye piece. Replication was achieved by having a test piece in every load rather than by having multiple pieces in a single load. The wash quality was measured by assessing the "whiteness" of the EMPA test pieces using a standard laundry reflectometer. Each measurement was performed four times at right angles to eliminate weave effects. During testing, it was found that the ozone generator had been inadvertently switched out of circuit for one machine thereby affecting two of the test runs. This was corrected for the rest of the trial.

RESULTS

The measurement results both before and after for microorganism counts were remarkably consistent, so the contact techniques and the replication were both considered adequate. The wash quality results obtained by measuring the reflectance of the EMPA test pieces were consistent, taking into account the different wash programs used.

Conclusions

The trial wash processes effectively disinfect the linen, even at temperatures well below 71EC, using relatively gentle cycles designed to protect garments from damage. The ozone generation plays a significant part in the disinfection process, as demonstrated by the poor results obtained with no ozone supply to machine number 2 for two of the trial runs.

Discharge of Ozone-Treated Laundering Wastewaters—WRc-NSF Ltd. Assessment

WRc-NSF Ltd. (Water Research Council - National Science Foundation) were commissioned by JLA, Ltd. to assess independently the impact of discharging spent wash water that had been treated with ozone. The following statements form the basis of the WRc-NSF report (WRc-NSF, May 22, 2005):

TABLE 8. Weekly Savings with OTEX—50-Bed Care Home—70% Incontinence

Period	Pre-OTEX	1-week	Post-OTEX	1-week	% Saving	Weekly Saving	Notes
Electric kw	360	£21.60	119	£7.14	67%	£14.46	
Gas kw	1150	£13.80	691	£8.29	40%	£5.50	Incl. 369 kw hr to heat water
Hot Water L	8026		992		88%		
Total Water L	44015	£66.02	26633	£39.95	39%	£26.07	
Chemicals mL	36280	£90.70	11682	£29.21	68%	£61.50	
Subtotal		£192.12		£84.59		£107.53	
Linen Saving						£10.00	Based on 20% extra linen life
Labor	72	£360.00	52	£260.00		£100.00	
Weekly Cost		£552.12		£344.59			
Total Weekly Saving						£217.53	
Total Annual Saving						£11,311.46	
Costs							
Electric kw	0.06						
Gas kw	0.012						
Water/effluent L	0.0015						
Chemicals mL	0.0025						
Labor £/hr	5						

TABLE 9. Weekly Savings with OTEX—90-Bed Care Home—85% Incontinence

Period	Pre-OTEX		OTEX		% Saving	Weekly Saving	Notes
Electric kw	529	£28.57	319	£17.23	40%	£11.34	
Gas kw	1764	£19.04	1166	£12.59	34%	£6.45	Incl. 436 kw hr to heat water
Hot Water L	13580		1670		88%		
Cold Water L	63980		34250		46%		
Total Water L	77560	£116.34	35920	£53.88	54%	£62.46	
Chemicals mL	58215	£145.54	27488	£68.72	53%	£76.82	
Sub Total		£309.48		£152.42		£157.07	
Linen Costs		£50.00		£40.00		£10	Based on 20% extra linen life
Labor Saving	112	£560.00	84	£420.00	25%	£140.00	
Weekly Cost		£919.48		£612.42			
Total Weekly Saving						£307.07	
Total Annual Saving						£15,967.51	
Costs							
Electric kw	0.054						
Gas kw	0.0108						
Water/effluent L	0.0015						
Detergent mL	0.0025						

Ozone rapidly decomposes to oxygen. The rate of decay depends on several factors including temperature, pH and quality of water. In natural freshwater, ozone has a half-life of around 10 minutes at 20°C (68EF). Lower temperatures will encourage greater stability of ozone, but the time scales are not significantly greater. Predictions based on published sources indicate that in clean water, the half-life of ozone increases from 20 minutes at 20°C (68EF) to around 60 minutes at 5°C (41EF).

TABLE 10. Weekly Savings with OTEX—at an 800-Bed Hotel

Period	Before OTEX W/C 30 March 2004		After OTEX W/C 18 May 2004		% Saving	Saving (£)	Notes
Electric kw	1127	£67.62	585	£35.10	48%	£32.52	
Gas kw	3337	£40.04	1739	£20.87	48%	£21.26	Includes 173 kw hrs to heat water
Hot Water L	22700		3322		85%		
Total Water L	65100	£97.65	31465	£78.66	52%	£18.99	
Chemicals mL	180810	£452.03	54256	£135.64	70%	£316.39	
Total		£657.34		£270.27	59%	£389.15	
Avg cost/cycle		£2.96		£1.40		£1.56	
Estd Linen Saving						£20.00	
Total Weekly Saving						£409.15	
Total Annual Saving						£21,275.72	
Machine Operating Hours		136	114		16%		
Type of Laundry Equipment			Industry-Based Costs				
Washers		2x HF304	IPSO65 & 50		Electric kW	0.06	
Dryers		4x ADC 75 Gas			Gas kW	0.012	
					Water/effluent L	0.0015	
					Chemicals mL	0.0025	
					Labor £/hr	5	

When the spent (OTEX) wash water is discharged to the sewer system, the residual ozone will also rapidly react with any organic matter in raw sewage. At the point of discharge from a washing machine, the residual ozone concentration varies between 0.5 to 3.0 parts per million, (milligrams per liter), and in volumes of between 140 and 240 liters per cycle dependent on the wash cycle selected and capacity of machine.

These concentrations of ozone are similar to those applied to drinking water and, with the considerable dilution encountered in the sewer system, will become insignificant. Also, any residual ozone will rapidly disappear immediately on contact with sewage.

Conclusion

On the basis of information in the literature and data supplied by JLA, the conclusion from this risk assessment is that spent wash water treated with ozone is safe to discharge to the sewer system; indeed, any such aeration of sewage can be seen as beneficial since it encourages the breakdown of the organic matter and aids the sewage treatment process.

Hong Kong Environmental Protection Department

On November 11, 1997, the Hong Kong Government, Environmental Protection Department, sent a letter to E Technologies Ltd. (Hong Kong) confirming compliance of effluents of the laundry system at the Chi Lin Monastery (with an E-Technologies ozone laundry system installed) with the required discharge limits for foul sewers under the (Hong Kong) Water Pollution Control Ordinance (<www.ETechnologies.com>).

WORKPLACE HEALTH AND SAFETY ASPECTS OF OZONE

The OTEX and ECOTEX™ systems are fully automatic and require very little operator input. Ozone is automatically generated and injected into the wash water at a stable concentration throughout the wash programs within the washing machine. It is generated *only* when the washers are activated and *only* during washing and rinsing cycles of the program.

Ozone sensors and detectors continually monitor the exposure levels of ozone within the laundry room. These monitors are located within the laundry to measure exposure levels within the breathing zone of the operator, i.e., by inhalation. These will automatically shut down the ozone generating system, not the washing machines, if the level of ozone reaches a specified level of 0.2 ppm ozone (UK standard) or 0.1 ppm (U.S. OSHA standard). The system will restart automatically once the levels have fallen below the particular standard level. The sensors are calibrated and regular visits by trained specialist engineers (OTEX System

Technicians) are programmed to check all aspects of the OTEX system. In the event of a fault on the OTEX system, back-up programs for thermal disinfection are provided.

SUMMARY AND CONCLUSIONS

The use of ozone for laundering is a cost-effective boon to commercial, particularly Nursing Care Homes, hotels, and other facilities that must rely on laundering for the health and safety of their guests. Incorporation of ozone into laundering cycles allows washing to be conducted using cold water, thereby saving considerable heat energy and water consumption. Additionally, ozone enhances the wash process, resulting in a significant reduction in detergent dosage and number of rinses, thus saving water. Ozone/cold water cycles are gentler to fabrics, thus extending linen life. Ozone/cold water laundering is beneficial for effluents, resulting in reductions in COD (chemical oxygen demand).

Microorganisms are destroyed effectively in ozone-wash waters, and washing and drying cycles are shorter, thus saving labor. The use of ozone and cold water allows three traditional washing steps to be eliminated (the initial flush, one rinse, and the softener steps). Depending upon the size of ozone-laundering units installed, a customer can obtain a full Return on Investment in 8 to 16 months from cost savings.

Of particular significance is the ability of ozone/cold water to destroy/inactivate a wide variety of microorganisms within several minutes. The "usual suspects" (*S. aureus, Ps. aeruginosa, Candida albicans, E. coli, Streptococcus faecalis, A. niger, C. perfringens, Campylobacter jejuni*, and *Aeromonas, Actinobacter* and *Lactobacilli* species) are destroyed, and four virus strains (representative of single- and double-strand RNA and DNA) are quickly inactivated.

The recent "superbug" (described by Time Archive as the "new killer bug," MRSA (methicillin-resistant *Staphylococcus aureus*), that is prevalent in hospitals and nursing homes, is quickly eradicated during ozone/cold water washing. This infectious microorganism is not affected by standard techniques of thermal washing with bleaching.

An organism particularly resistant to conventional laundering is *Clostridium difficile*, a cause of diarrhea, which is usually acquired in – hospital. It is sometimes referred to as C.D.A.D. (*Clostridium difficile*-acquired diarrhea). Although in most cases it causes a relatively mild illness, occasionally and particularly in elderly patients, especially those who have recently taken or are on a course of antibiotics, it may result in serious illness and even death. The bacterium produces toxins that are responsible for the diarrhea and that damage the cells lining the bowel. Because it is a spore-former, *C. difficile* can survive outside the human body. It is totally eradicated from soiled linens within minutes during ozone/cold water laundering.

ACKNOWLEDGMENT

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