

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

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Abstract

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.

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. Using the European Suspension Test (E.N. 1997) comparing the effects of hot water (75_ 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 diarrhoea. In elderly patients, this can result in serious illness, and even death. The bacterium produces toxins which 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.

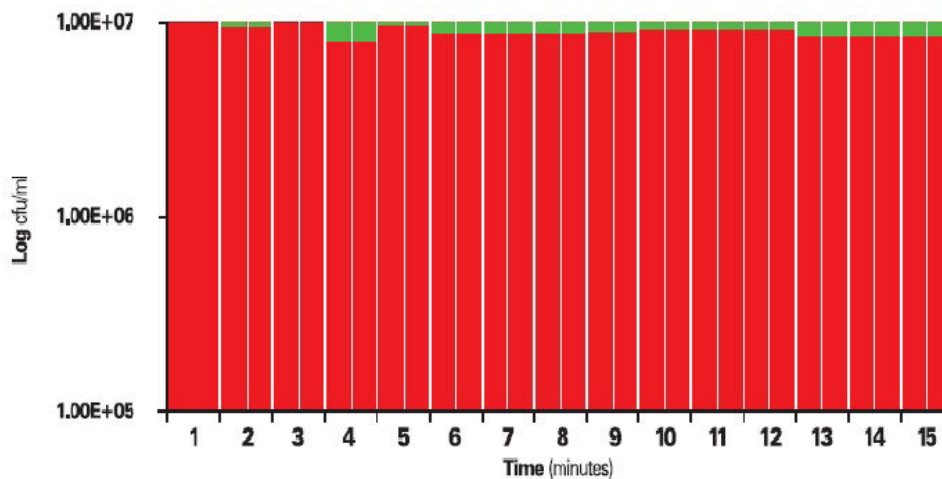


Figure 3. Data obtained during 16-min test on water that contained *C. difficile* spores at 75°C (Microsearch Laboratories Ltd., May 15, 2004).

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 postwashing. 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 woollens. Cycle 4 (Test Code 4) is a rewash cycle used for oil/grease stained articles. With this cycle, 50_C (122°F) water is used to emulsify the oils and aid washability.

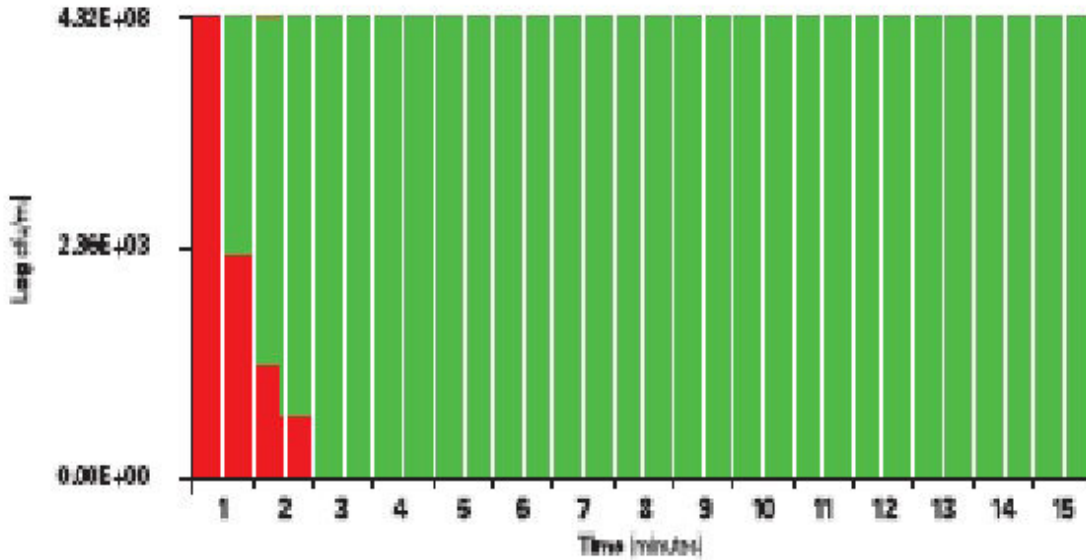


Figure 4. EU Suspension Test conducted on OTEX ozone laundry water with *C. difficile* spores (Microsearch Laboratories Ltd., May 15, 2004).

The amount of ozone is constant for each washing programme. The difference between cycles is that the more 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 1. 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 Magazine Archive, 2006).

The care labels of nurses’ uniforms commonly carry the recommendation that they should be washed at 40°C (104°F). 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.

Table 1. RECOVERY OF CHALLENGE ORGANISMS FROM GARMENTS PROCESSED BY A VARIETY OF OTEX PROCESSES						
TRIAL	CLOTHING ITEM	TEST CODE	S.aureus M	S.aureus M	C.difficile	C.difficile
			S.aureus M	% kill	cfu/25 cm 2	% kill
OTEX 1	ITEM 1	TEST 1	< 1	> 99.999	< 1	> 99.999
OTEX 1	ITEM 2	TEST 1	< 1	> 99.999	< 1	> 99.999
OTEX 2	ITEM 1	TEST 2	< 1	> 99.999	< 1	> 99.999
OTEX 3	ITEM 2	TEST 2	< 1	> 99.999	< 1	> 99.999
OTEX 3	ITEM 1	TEST 3	< 1	> 99.999	< 1	> 99.999
OTEX 3	ITEM 2	TEST 3	< 1	> 99.999	< 1	> 99.999
OTEX 4	ITEM 1	TEST 4	< 1	> 99.999	< 1	> 99.999
OTEX 5	ITEM 1	TEST 4	< 1	> 99.999	< 1	> 99.999
LAB CONTROL	UNTREATED	TEST 5	7.10E+07		2.10E+07	

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.

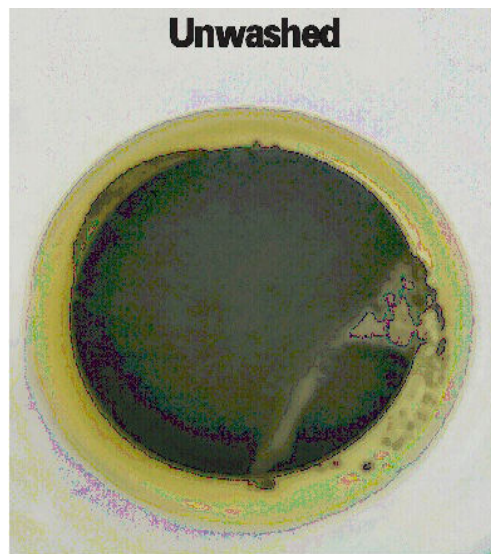


Figure 5. MRSA impregnated onto membrane. Microsearch Labs, 2004.

Figure 6 shows the residual MRSA culture on the recovered membrane after having been washed at 40°C (104°F). Figure 7 shows the absence of residual MRSA culture on the recovered membrane after an OTEX ozone-laundrying cycle.

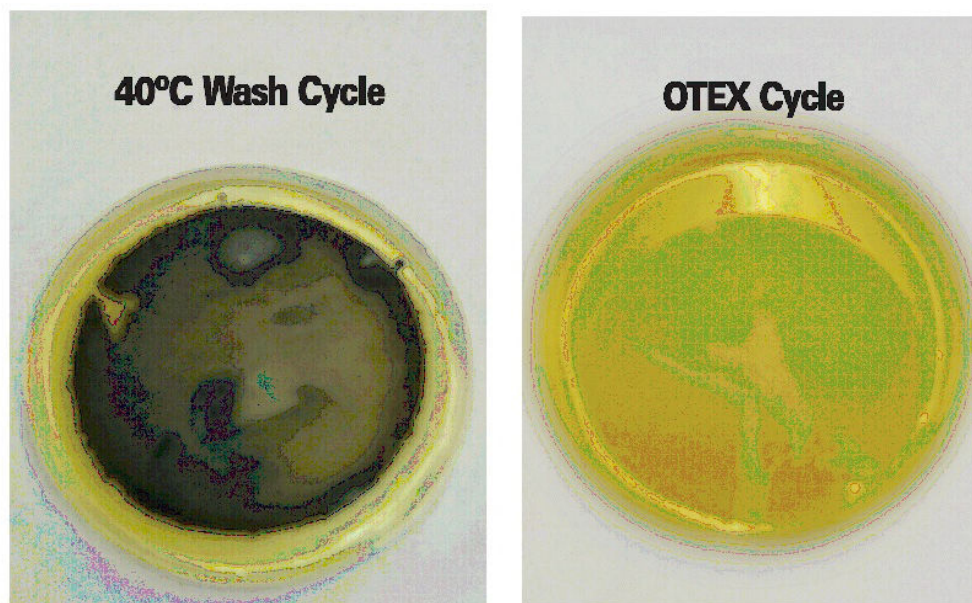


Figure 6. MRSA on membrane after 40°C wash. Figure 7. Absence of MRSA after OTEX.

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 (104°F) 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 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 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 above.

Each trial was preceded by a hot sanitizing wash and rinse cycle. Data obtained are reported in Table 2 and Figure 8.

Table 2. OTEX Revalidation Trial 60% Ozone Output Treatment

Treatment	T= 3 min	T= 10 min	T= 20 min
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

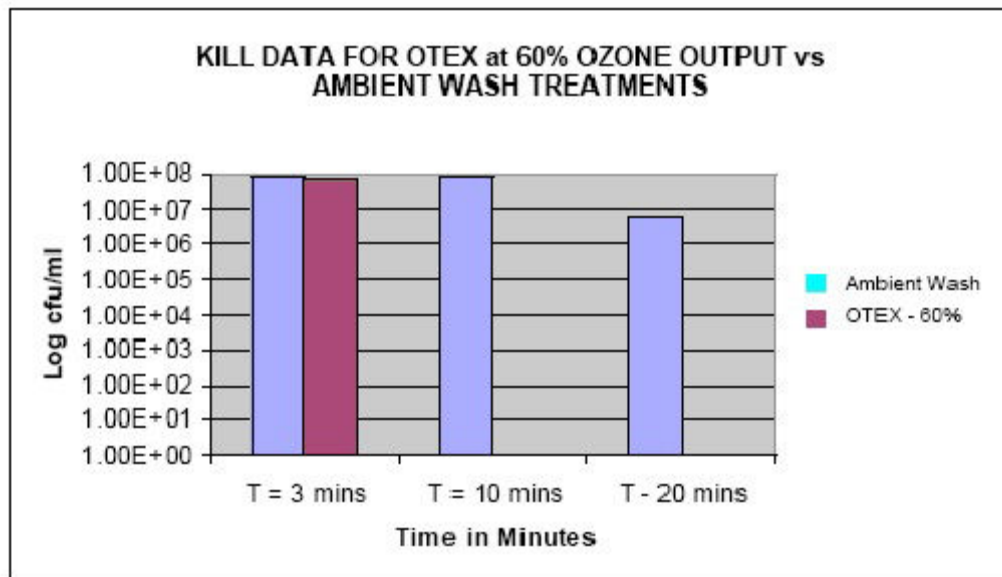


Figure 8. *E. coli* kill data for OTEX at 60% of the available ozone output vs ambient wash treatments. Microsearch Labs, April 29, 2005.

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 by the ten-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 (75°C = 167°F) 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 3) were independently prepared by Microsearch Laboratories Ltd. for testing.

Table 3. 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

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 75°C (167°F), which is above the recommended thermal disinfection temperature of 71°C (160°F). Domestic supply water was employed with a water hardness of 60 ppm CaCO₃ 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

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), 75°C (167°F = 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.

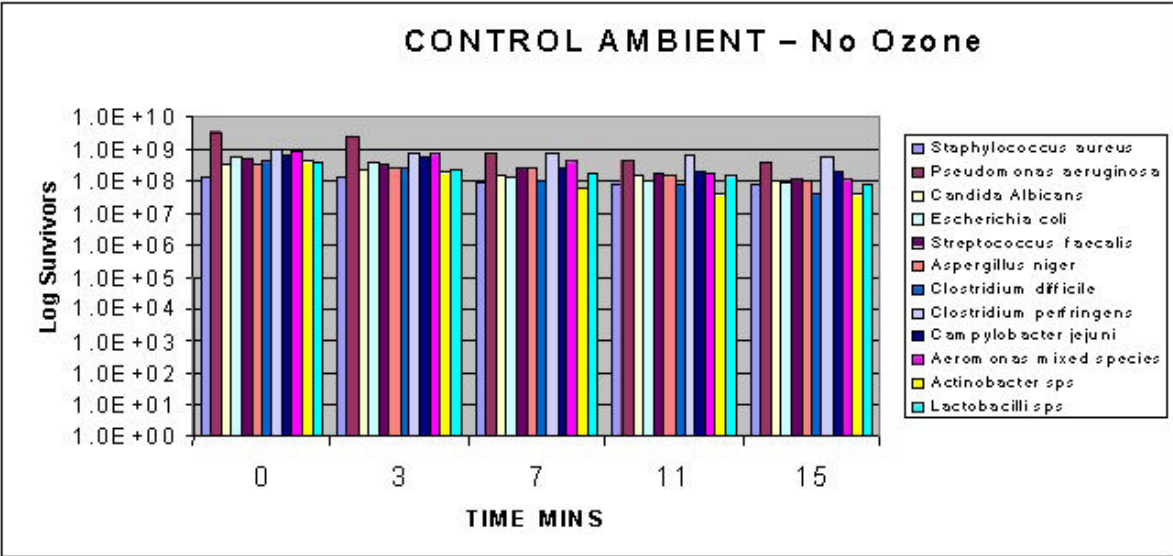


Figure 9. Test results - control @ ambient temperature - no ozone – bacteria.

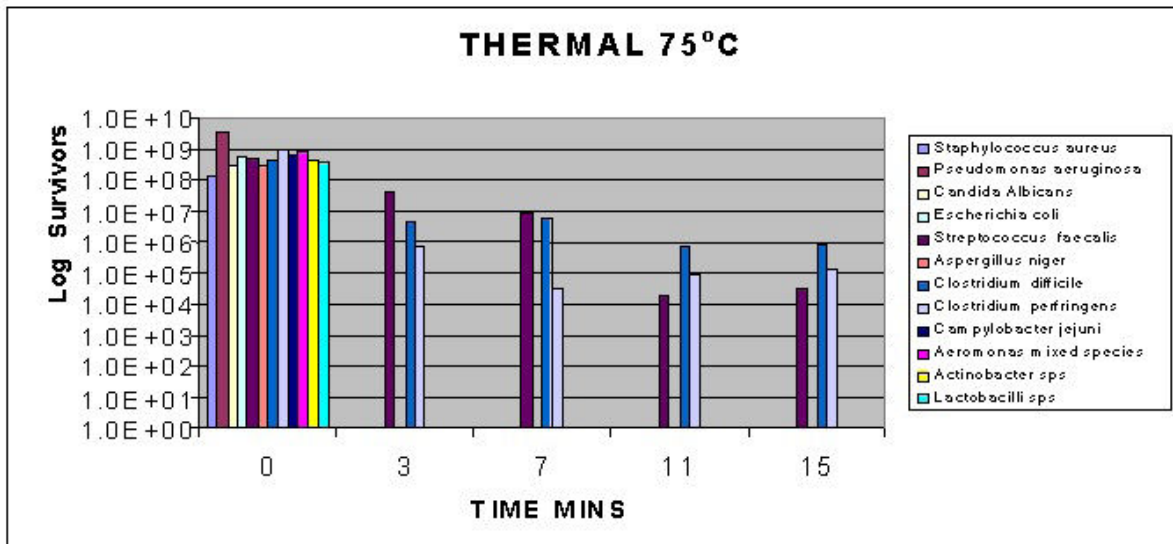


Figure 10. Test results - Thermal @ 75°C - no ozone – bacteria.

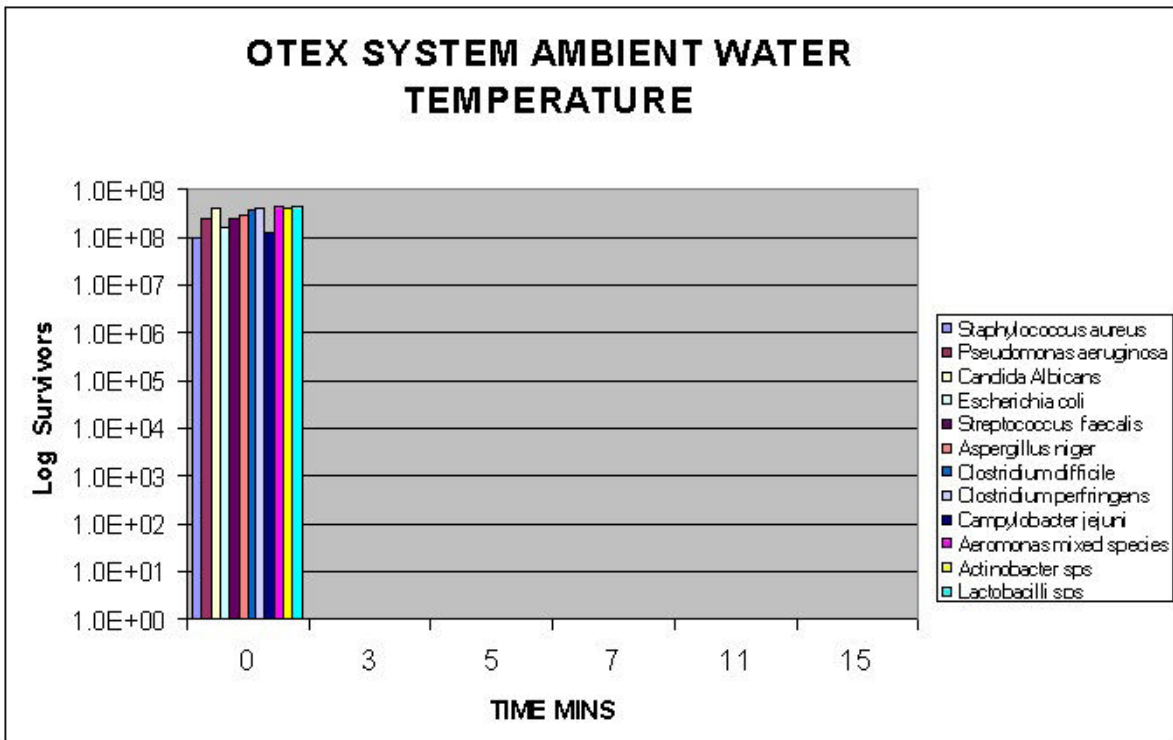


Figure 11. OTEX System - Ambient Water Temperature - bacteria.

Figures 12, 13 and 14 show similar results of virus and phage sampling at ambient temperature - no ozone (control), 75°C (167°F = thermal washing), and ambient temperature with ozone (OTEX), respectively. Note that without ozone and at ambient temperature (Figure 12), only

small amounts of viral inactivations were obtained. With thermal washing (Figure 13), viral inactivations were obtained after 5 minutes., and the same results were obtained with ozone at ambient temperature (Figure 14) after 5 minutes (but at lower costs).

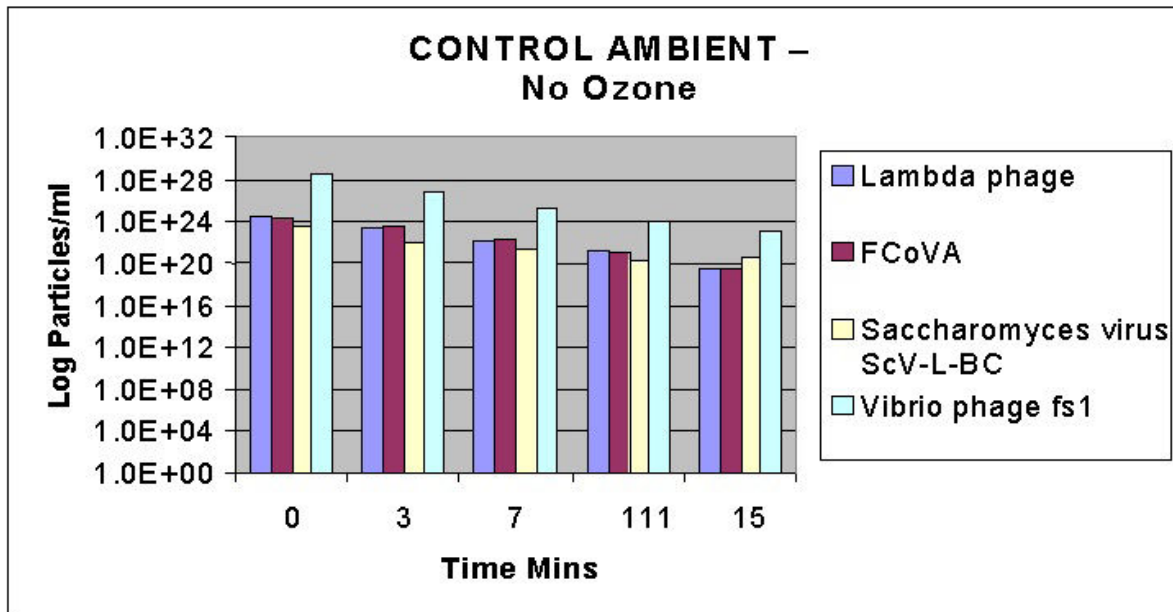


Figure 12. Test results - control @ ambient temperature - no ozone – viruses and phages.

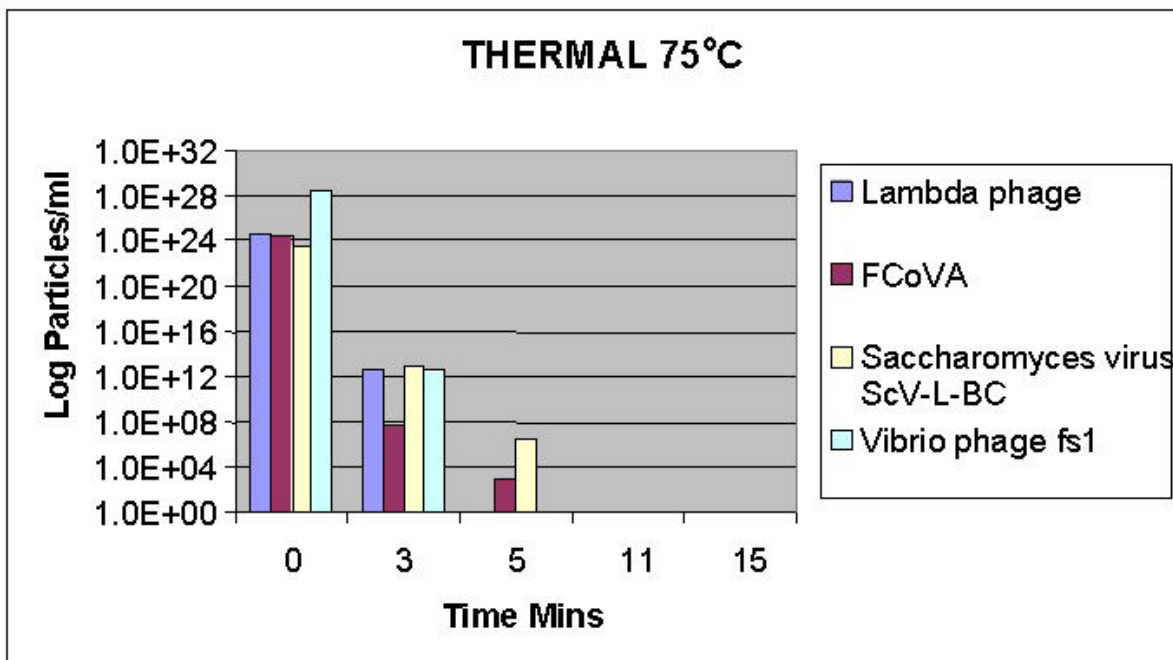


Figure 13. Test results – Thermal @ 75°C (167°F) – viruses and phages.

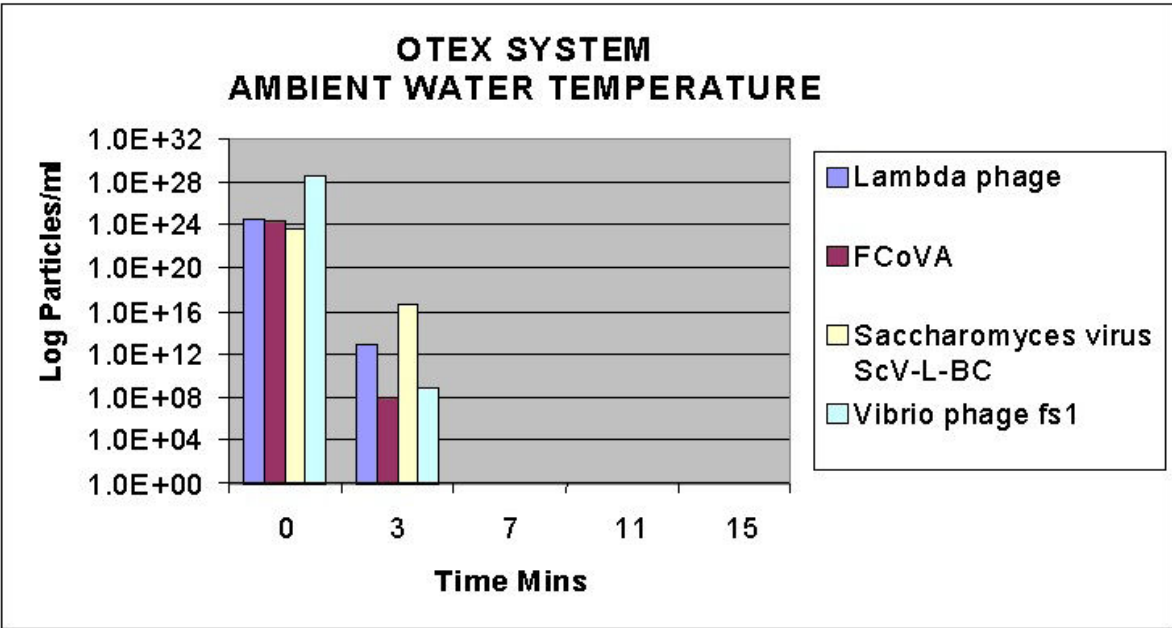


Figure 14. Test Results - OTEX System - Ambient Water Temperature – viruses and phages.