

OZONE IN THE LAUNDRY INDUSTRY - PRACTICAL EXPERIENCES IN THE UNITED KINGDOM

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Summary

Since the early 1990s, the use of ozone in commercial and industrial laundering applications has evolved rapidly. Four technical approaches to the addition of ozone to commercial laundry machines have been developed, each of which provides many of the benefits of ozone laundering. Employing ozone allows washing to be conducted using cold water, thereby saving considerable heat energy. Additionally, ozone enhances the wash process, resulting in significant reductions in detergent dosage and number of rinses, thus saving water. Ozone/cold water cycles are gentler to fabrics, thus extending linen life. Microorganisms, including the two current “super-bugs”, *Clostridium difficile* and Methicillin-Resistant *Staphylococcus aureus*, are destroyed within three minutes in ozone-wash waters, and washing and drying cycles are shorter, thus saving labor. Virus inactivation is complete in about 5-6 minutes.

Environmental benefits of ozone laundering include lowering the amounts of laundry chemicals discharged to waste, resulting in reductions in COD (chemical oxygen demand). Ozone-oxidized organic soils become more biodegradable upon ozonation, dissolved oxygen levels are higher in ozone laundry waste discharges, and fewer laundering chemicals require storage, thus reducing potential hazards for laundry workers.

In this chapter the authors describe some specific studies conducted in the UK, which have led to formal approval of a specific ozone laundering system by the UK Department of Health in September, 2009. More than 2000 of these ozone laundering systems had been installed in commercial, hospital, and health care facilities in the UK alone by early 2010. An estimated 2000 additional ozone laundry systems had been installed throughout the United States, and the Public Health Departments of two states (Missouri and Vermont) also have formally approved a particular Ozone Diffusion laundry system.

1. Introduction

Since the late 1990's it has become clear that a patient entering a hospital or health care facility stands a significant chance of becoming infected by one or both of two microorganisms [*Clostridium difficile* (*C. difficile*) and Methicillin-Resistant *Staphylococcus aureus* (MRSA)] that are resistant to the usual antibiotics and laundering procedures. These microorganisms have been termed "super bugs" by some in the media. *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 which damage the cells lining the bowel. *C. difficile* survives well outside the body because it is a spore-forming microorganism.

Similar infectious outbreaks are common in nursing homes, assisted living and other health care facilities. Although it has not yet been proven that there is a link between health care facility linens and infection of patients, the danger surely exists, particularly with microfiber mops and cloths used to clean soiled floors, walls, and surfaces in hospitals and health care facilities.

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.

Starting in the mid-to-late 1980s, studies began to determine if ozone, O₃, a known powerful oxidant and disinfectant, could 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 discharged laundry 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, health care facilities, 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 lower, ozone-sanitized wash needs far less rinsing, thus saving water, and
2. Because ozone works so efficiently in cold water, sanitizing as well as cleaning can be performed in cold water, thus saving energy required to heat wash and rinse waters.

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 along a normal innovation-adoption path. Ozone-based commercial laundries currently are operating in all segments of the commercial laundry market, in many places around the globe, with some in continuous operation since the early 1990s.

In the United Kingdom, rapid and significant advances in developing the application of ozone in commercial laundries have been made since the mid-1990s. A leader in this effort has been JLA, Limited, of Ripponden, West Yorkshire, that has been installing ozone systems at their institutional laundry customers that they service since mid-2004. The primary purpose of this chapter is to summarize results from studies conducted by independent United Kingdom microbiological laboratories and other organizations to document the various aspects of ozone application in commercial laundering equipment, and particularly to demonstrate the eradication of the two super bugs, *C. difficile* and MRSA. Another objective is to quantify the cost savings and environmental benefits obtainable by utilizing this revolutionary technology in commercial laundries.

2. Cold Water Laundering with Ozone

2.1. Fundamental Principles

Ozone is a gas at ambient temperatures, and is only partially soluble in water. It is unstable and decomposes in gas or aqueous phases, with decomposition being accelerated by increasing temperature, pH, and the presence of oxidizable materials (many laundry soils). On the other hand, in cold water (ambient temperatures for laundering), ozone's decomposition rates decreases considerably, and its water solubility (and therefore stability) also increases at the lower temperatures. These properties of ozone make it quite suitable for laundering at ambient temperatures.

For commercial laundering, ozone normally is generated by corona discharge (or plasma techniques) rather than by UV-radiation, for two primary reasons. With corona discharge ozone generation:

- Oxygen-enriched air will allow higher ozone production rates and higher gas phase concentrations of ozone to be produced than when feeding dried ambient air,
- Higher gas phase ozone concentrations will result in higher aqueous phase ozone concentrations in the washer water and gas phases, which results in more effective laundering.

2.2. Four Commercial Methods of Ozone Laundering

Experiences with ozone laundering to date have resulted in the development of four methods for applying corona discharge generated ozone to commercial laundry machines (Rice et al., 2009a):

2.2.1. Recirculation Injection System (sometimes called "side-arm injection") (Figure

1), whereby ozone is added to the wash water drawn from the commercial washer which then is sent back into the washer utilizing a continuous loop water flow.

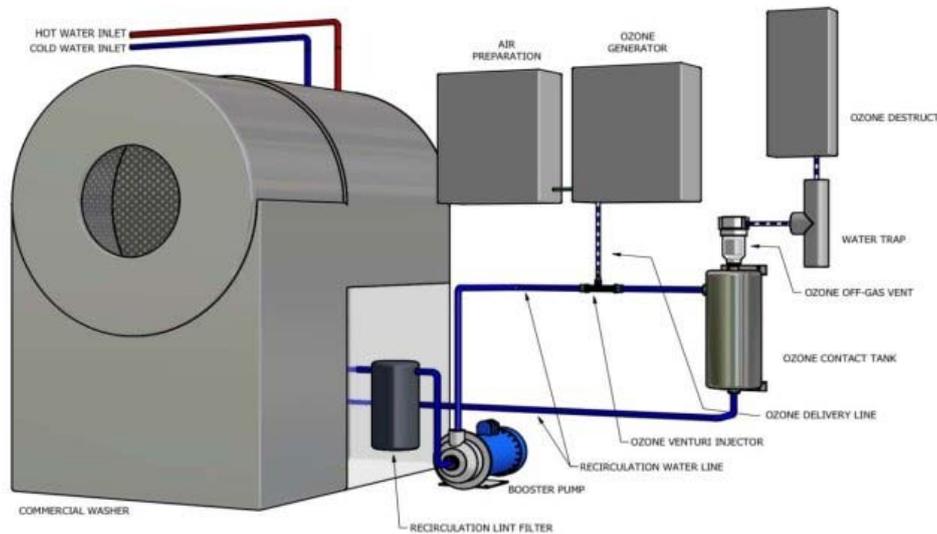


Figure 1. Schematic diagram of a typical Recirculation Injection (RI) ozone laundry system

Operating Principle: When the wash drum is filled with municipal tap water, a secondary drain valve opens, allowing water to flow to an ozone contacting system. This water is injected with ozone gas and then returned to the washer now containing a pre-determined level of dissolved ozone.

This recirculation and ozonation process can be activated during the wash and rinse steps, thus allowing the linen to be exposed to ozone-containing water throughout most of the wash cycle. Activation of the ozone system typically is initiated by a control signal from the washer, such as a chemical output signal. Continuous exposure of the linen to ozone-containing water provides beneficial disinfection, since the ozone system is essentially purifying the water, then sending ozone-laden water back to the washer for further contact with the linen.

2.2.2. Direct Injection System (Figure 2) – involving less peripheral equipment than Recirculation Injection, this method involves adding ozone directly to the water on its way to the washer.

Operating Principle: Ozone is injected into water which is sent to a contact chamber and thence to the washer. When the washer calls for water the fill valve opens, creating a cavitation effect and allowing ozone to be drawn (injected) into the water. Once the washer has been filled, the fill valve closes automatically, interrupting ozone production until the washer again requires filling with water. Activation of the ozone system typically is initiated by a control signal from the washer, such as a chemical output signal, or via vacuum activation. Because a vacuum is created at the ozone injector it can be sensed by a vacuum switch in the ozone generator, thus initiating ozone production.

Operating Principle: Ozone is added to municipal water supply by means of the Venturi injector, and this is passed into the pressurized contact vessel to allow further mixing of the ozone gas at municipal water line pressure. When ozone-containing gas is pressurized, higher concentrations of ozone can be dissolved in water. Water containing ozone then splits either to fill the washer or go to the recirculation pump to be returned to the Venturi injector for further ozonation. Addition of ozone to the water can take place within the contact vessel loop at any time, not only when the washer valve is open. This configuration allows for a higher dissolved ozone level to be attained and the ability to provide water containing ozone on demand.

2.2.4. Ozone Diffusion System (Figure 4) – in which gaseous ozone is added directly to the water inside the washer sump through a specially designed diffuser.

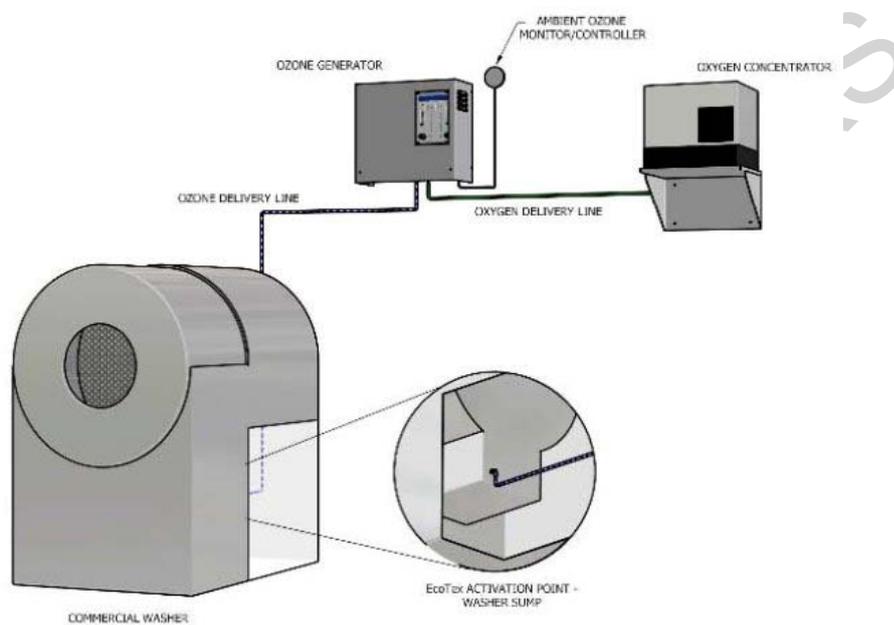


Figure 4. Schematic diagram of the Ozone Diffusion method of ozone laundering

Operating Principle: Ozone is generated from oxygen-enriched air (higher oxygen concentration). Gaseous ozone is diffused directly into the sump of the washer, not to water that is then fed into the washer. Ozone system output is automatically controlled by the washer, via a signal sent to the ozone generator to initiate ozone production and delivery to the washer. This signal can be generated by programming the on-off time sequence into the washer's on-board computer. This mode of operation allows for automatic production of ozone gas and its introduction into the washer throughout the duration of each step of the wash cycle. It also allows for monitoring and control of ozone in both the aqueous and gas phases inside the washer.

Each of the first three techniques involves injecting ozone into water that is outside of the washer, then passing the ozone-containing water into the washer. During washing, no additional ozone is added except that which enters when ozone-containing water is added either for washing or for rinsing. The fourth procedure (Ozone Diffusion) allows ozone to be added and controlled in both the aqueous and washer gas phases at all

times.

3. The OTEX Ozone Laundering System and Process

This process and complete laundering system is offered in the United Kingdom by JLA, Ltd. on a fixed-price rental basis, including full maintenance. 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. The OTEX laundry system incorporates the Ozone Diffusion design. Ozone gas (generated in 90-93% oxygen) is injected directly into the water employed in the wash process in the washer sump via a patented Interfusor™ ozone diffusion device. This technique provides a continual replenishment flow of ozone-containing water throughout the wash and rinse cycles. One advantage of this system design is that the bioburden is continually treated with ozone, thus providing constant disinfection both in the wash water and in the washer air that is continually being folded into the laundry being washed. At the same time, the amount of ozone in washer gas phase can be monitored and controlled, thus controlling the dissolved ozone level in the washer water.

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 all soiled 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 ten LED (Light Emitting Diode) bars, which indicate 0 to 100% of the total ozone output available from the ozonation equipment installed. Each LED bar indicates an additional 10% of the ozone output available above the preceding LED bar. The single reaction chamber ozone generator attached to the washer produces four grams of ozone per hour at 3% ozone concentration in the gas phase at a gas flow rate of 4 scfh (standard cubic feet per hour) 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.

OTEX laundering equipment ranges in size to allow from 16 lbs to 126 lbs of soiled linens/garments to be laundered. 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 of laundry, 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 necessary will use up ozone to no benefit and will require more-than-necessary rinsing.

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Bibliography

* Note: All JLA Ltd documents and/or reports can be accessed and downloaded from the JLA Ltd web site:

D. Cardis, C. Tapp, M. DeBrum, and R.G. Rice, (2007) "Ozone in the Laundry Industry – Practical Experiences in the United Kingdom", *Ozone: Science & Engineering*, 29(2):85-99. DOI: 10.1080/01919510601186048. [Reviews status of ozone laundering in UK through 2006]

DOI: 10.1080/01919510903091839. [Economic and environmental benefits of ozone laundering]

E.N. (European Standard, 1997), "Chemical Disinfectants and Antiseptics – Quantitative Suspension Test for the Evaluation of Basic Bactericidal Activity of Chemical Disinfectants and Antiseptics – Test Method and Requirements (Phase 1)", superseded in 2005. [A European Standard]

Engineering, 31(5):339-347. DOI: 10.1080/01919510903091318. [Synopsis of the Ozone Laundry Handbook – includes the four commercial methods of applying ozone to laundry systems]

Hook J, (2005e) "Bacteriological Test Results Following Disinfection of Microfibre Mops & Cloths Using JLA's OTEX System at the QE II Hospital, Welwyn Garden City. 6 Month Final Report, November 2005". [Hospital testing of ozone laundering of microfiber cleaning materials] Report No RRP94 LD03

Hook, J., (2007a), "Condition Monitoring of Microfibre Cloths within Healthcare Environments JLA Report RRP MED1, February 2007, Amended May 2009. [Effects of repeated ozone laundering on microfiber cloths]

Hook, J., (2007b), "Microfibre Condition Investigation Following Healthcare Laundry Process", JLA Ltd. Report RRP MED2, May 2007. [Effects of repeated ozone laundering on microfiber cloths]

Humphreys, P., (2009), "The Impact of Washing Regimes on the Efficiency of Microfiber Cloths", JLA Report No. RRP MED8 HMS/1/JLA/09, prepared by Univ. of Huddersfield for JLA Ltd., 27 Aug. 2009. [Effects of repeated ozone laundering on microfiber cloths]

LAUNDRY TECHNOLOGY CENTRE, (2004), "Assessment of Disinfection and Wash Performance in Care Home Laundry", report by Richard Neale (LTC), Ilkley, West Yorkshire, UK, May 7. [Third party testing of ozone laundering system] Report No LD11

MICROSEARCH LABORATORIES LTD., Mytholmroyd, Halifax, UK, (2004a) "MRSA Contamination of Nurses Uniforms Test". [Eradication of MRSA on nurses' uniforms by ozone laundering] Report No LD07

MICROSEARCH LABORATORIES LTD., Mytholmroyd, Halifax, UK, (2005b) "The Antimicrobial Efficacy of the OTEX Process at 60% Ozone Output with *Escherichia Coli*", April 29. [Efficacy of ozone laundering on microorganisms at 60% ozone output] Report No MLL2

MICROSEARCH LABORATORIES LTD., Mytholmroyd, Halifax, UK, (2005c) "Pretreatment Microbiological Status of Microfibre Mops & Cloths Report on the Bacteriological Testing of Microfiber Cloths and Mops Utilising the OTEX System", April 2005. [Effects of ozone laundering on microfiber materials following ozone laundering] Report No MLL3

MICROSEARCH LABORATORIES LTD., Mytholmroyd, Halifax, UK, (2005d) "Viral Testing With

OTEX”, July 8, 2005. [Effects of ozone laundering on virus inactivation] Report No RRP92 LD02

MICROSEARCH LABORATORIES LTD., Mytholmroyd, Halifax, UK, “Hot Water Testing”, Report 2004 [Effects of thermal laundering on microorganisms] Report No MLL1

Reid, T., Wilson, A.W., and Galloway, D.B., (2007), “A Comparative Study on the Disinfection of Hospital Laundry Using Ozone: A 2-part Single Blind Study Using Standard Hospital Laundry Cleaning Techniques versus the OTEX Validated Ozone Disinfection System, Final Study Report, Protocol No. Ozone/01-2007/120207/Hospital Laundry Study, Version 6, 22 June 2007. (Side-by-side comparison of ozone vs conventional laundering] Reprt No RRP913

Rice, R.G., Cardis, D., Tapp, C., and Gerace, S., (2007), “Eradication of MRSA and *C. difficile* in Hospital Mops and Wiping Cloths by Ozone Cold Water Laundering. Comparisons with Standard Thermal Laundering and Cost Benefits in the United Kingdom”, presented at July, 2007 Annual Meeting of the Association for Professionals in Infection Control and Epidemiology, Palo Alto, CA, USA. [Comparison of ozone vs conventional thermal laundering on survivability of MRSA and *C. difficile* microorganisms]

Rice, R.G., DeBrum, M., Hook, J., Cardis, D. and Tapp, C., (2009a), “The Ozone Laundry Handbook: A Comprehensive Guide for the Proper Application of Ozone in the Commercial Laundry Industry”, Ozone: Science &

Rice, R.G., DeBrum, M., Hook, J., Cardis, D. and Tapp, C., (2009b), “Economic and Environmental Benefits of Ozone in Ozone Laundering Systems”, Ozone: Science & Engineering, 31(5):348-356.

Robinson, J., and Hook, J, (2009), “Microfibre Efficacy Following Ozone Disinfection Laundering – A Clinical Study”, JLA Report issued Aug. 2009. [Detailed study of repeated ozone laundering on properties of microfiber cloths] Report No RRP MED7

WRc-NSF Ltd., Medmenham, Marlow, Bucks, UK, (2005), “The OTEX Validated Ozone Disinfection Washing System” May 22, 2005. [Third party validation of OTEX ozone laundering system]

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Biographical Sketches

Dr. Rip G. Rice is President/CEO of Rice International Consulting Enterprises, located in Sandy Spring, Maryland, USA, and specializing in ozone technologies, particularly with respect to Agri-Foods as well as water and wastewater treatment and ozone laundry systems. Dr. Rice co-founded the International Ozone Institute (now the IOA) in 1973, was its President during 1982-1983, Editor-in-Chief of *Ozone: Science & Technology*, the Journal of the IOA and Editor-in-Chief of *Ozone News*, the newsletter of the IOA. He has authored more than 120 papers on various aspects of ozone technology, including ten dealing with Ozone Laundering, and is Editor-in-Chief of the Ozone Laundry Handbook (to be published in 2011). He also has edited or coedited 21 books, proceedings or monographs in ozone technology. In 1995, Dr. Rice received the Morton J. Klein Memorial Award for outstanding service to the IOA. He has chaired the IOA-Pan American Group Agri-Food Task Force since its formation in 2003. In 1999, Dr. Rice co-founded the International Ultraviolet Association, and served as Editor-in-Chief of *IUVA News*, IUVA’s newsletter, for its first several years.

Dick Cardis is Research and New Product Development Director at JLA Ltd, Ripponden, West Yorkshire, UK. He has worked in the commercial and industrial laundry market for over 30 years, developing a substantial knowledge of the commercial laundry industry from both the equipment and end users perspectives, He has acted as Director of Technitex; the UK’s Technical Textiles and Advanced Materials Sector, focusing on research, design and development of new technologies and applications for the technical textile industry. He is also an active member of the UK’s Textile Services Association (TSA) Healthcare group. TSA is the trade association for the laundry, dry cleaning and textile rental industries in the United Kingdom, with membership ranging from large multi-site public companies to smaller family businesses. TSA acts to lead the industry - to represent the sector effectively and with authority to Governments both in the UK and EU, to regulatory bodies and to the media. As part of the senior management team at JLA he has been at the forefront of novel technologies developed by JLA. Successfully developing the Aquatex system providing a “green” alternative to environmentally harmful chemicals previously used within the dry cleaning industry and in response to the Montreal Protocol.

More recently as Research and New Product Development Director at JLA Ltd he headed up the development of the OTEX ozone laundry system and he has been invited to join a UK government steering group developing new laundry policies to meet the needs of the UK's Department of Health and National Health Service laundry requirements for disinfection policy.

Jacqueline Hook is a Chartered Chemist, Member of the British Institute of Cleaning Science, British Occupational Hygiene Society and Hospital Infection Society. She has spent 25 years in Research & Development for the UK Railway Industry in a range of scientific disciplines from laboratory analysis, cleaning science technology, environmental and occupational hygiene. She was an active member of a professional forum introducing new technologies into the railway environment. She joined JLA Ltd. In 2004 and is active in laboratory and site testing, and compilation of training and health/safety procedural documentation, coordinating and liaising with leading health and safety authorities. Her responsibilities also include investigating and assisting in new developments relating to laundry and ozone technologies. Working closely with microbiologists and health care professionals, Jacqueline has contributed to the introduction of ozone laundry systems into the UK National Health Service. Project managing has included wash program development at a number of field trials including Welwyn Garden City and Woodend Laundry, Aberdeen ozone laundry hospital studies. Culmination of 6 years of work involving *in vitro* and clinical studies leading to ozone laundry disinfection recognition by the UK's Department of Health in September 2009. Jacqueline is also active in promoting training within the laundry industry and is a member of a focus group formed in 2010 in conjunction with the British Institute of Cleaning Science.