OZONE USE IN HOSPITAL LAUNDRY:
CAPE TOWN 2004/5

(REPORT ON THE TRIAL CONDUCTED AT TYGERBERG HOSPITAL LAUNDRY TO DETERMINE THE EFFICACY OF THE USE OF OZONE IN THE LAUNDRY PROCESS)

Authors:
Prof. Shaheen Mehtar
Ndumiso Dlamini
Graham Alan Kluk

JULY 2005

Table of Contents

Executive Summary

When a decision was made to prove the efficacy of the use of Ozone in laundry systems; a trial run was organized in the laundry at Tygerberg Hospital Laundry in Cape Town. The main objective was to verify the commonly published advantages of Ozone laundry, with a particular focus on its ability to reduce a given bio-burden to acceptable levels, while reducing or eliminating the use of heat. The trial also aimed, under controlled conditions, to establish the use of an Ozone system in the laundry process as a primary and **superior sanitation method** to the traditional use of hot water, and to ascertain and quantify the potential **economic benefits** of such a system *inter alia* the consumption of energy, water, and detergents in the laundry process. The impact of the use of Ozone on fabric tensile strength, and thus on the life expectancy of the textiles, would also be examined.

A protocol was drawn up with the University of Stellenbosch Medical School and the Tygerberg Laundry on the way the trial would be undertaken.

The trial proved conclusively that the introduction of Ozone into the laundry process at a minimum temperature of 38°C achieved a **greater rate of bacteriological disinfection** than a standard laundry process conducted at a minimum temperature of 80°C. It was also concluded that **significant economic benefits were measured** and attained during the trial.

Introduction

The history of Ozone

A Dutch chemist named Van Marum was probably the first person to detect Ozone gas sensorily. In the description of his experiments, he mentions noticing a characteristic smell around his electrifier.[1,3] However, the discovery of Ozone was only mentioned by name decades later, in Schönbein's 1840 report to the University of Munchen. Schönbein had noticed the same characteristic smell during his experiments. He called this gas 'Ozone', derived from *ozein*, the Greek word for scent. Generally, the discovery of Ozone is ascribed to Schönbein. Moreover, Schönbein is mentioned as the first person to research the reaction mechanisms of Ozone and organic matter.

After 1840, many studies on the disinfection mechanism of Ozone followed. The first Ozone generator was manufactured in Berlin by Von Siemens,[1,3,6] who also wrote a book about Ozone application in water. This prompted a number of pilot projects researching the disinfection mechanism of Ozone.

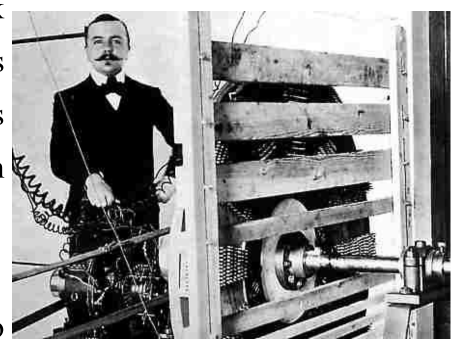

Figure 1: Marius Paul Otto

The French chemist Marius Paul Otto (Figure 1) received a doctorate from the French University for his essay on Ozone. He was the first person to start a specialized company for the manufacture of Ozone installations, 'Compagnie des Eaux et de l'Ozone'.[5]

The first technical-scale application of Ozone took place in Oudshoorn, Netherlands, in 1893.[3,5] This Ozone installation was studied thoroughly by French scientists, and another unit was installed in Nice in 1906. Ozone was applied continuously in Nice, occasioning the title, 'the place of birth of Ozone for drinking water treatment'.

In the years prior to World War I, there was an increase in the use of Ozone installations in various countries. Around 1916, forty nine Ozone installations were in use throughout Europe, of which 26 were located in France.[3] The increase, however, soon faltered as a result of research into toxic gases, which led to the development of chlorine. This disinfectant seemed a suitable alternative to Ozone – without the shortcomings in management, such as low applicative guarantee and low yield of Ozone generation. Ozone production did not reach its prior level until after World War II. While the number of Ozone installations worldwide in 1940 had only grown to 119, by 1977 this number had increased to 1043. More than half of the installations were located in France.[1,3] Around 1985, the number of applied Ozone installations was estimated at more than 2,000.[2]

Today, chlorine is still preferred over Ozone for water disinfection. However, the last decade has seen another increase in the application of Ozone applications, due to the discovery of trihalomethanes.

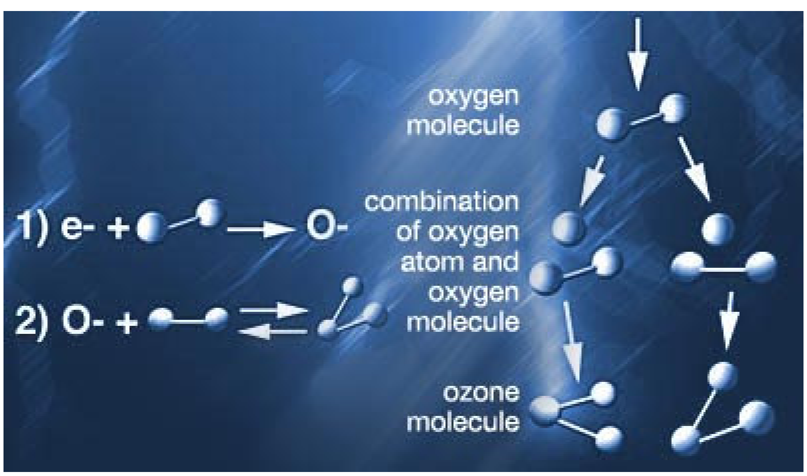

Figure 2: Formation of an Ozone Molecule

What is Ozone?

Ozone (O_3), or trioxygen, is a molecule composed of three oxygen atoms, temporarily existing in a very unstable and reactive state. Ozone is so reactive that a suitable container for storage has not been discovered, and probably does not exist. Unlike the O_2 molecule (described below), this triatomic oxygen defies man's attempts to store or liquefy it. Compared to O_2, O_3 is an extremely active molecule – probably 1,000 times more active than oxygen – and is sometimes referred to as activated oxygen.

Oxygen (O_2) is normally thought of as the fraction of air which is utilized in breathing. It is very necessary and has many common and obvious uses. This regular oxygen or dioxygen is a relatively stable molecule, composed of two oxygen atoms held together with a fairly firm double bond. This diatomic oxygen is stable enough to compress, liquefy and store, yet it is still quite reactive.

Ozone can be visualized as a regular O_2 molecule with a very nervous, active, reactive, excitable, energetic, corrosive, and lively O_1 atom as a sidekick. This monatomic O_1 atom does not like to be alone, but, near the earth's surface, it refuses to stay with the fairly stable O_2 double bond. It is active and reactive, with energy that needs to be channeled in some useful direction. It will combine with virtually anything on contact, or at least it will try. This active O_1 will not stabilize until it can break away from the O_2 and form a stable molecule with something else, virtually any other molecule that is available. If no other molecule is available, it will eventually unite with another O_1 atom in the same situation, and restabilize as O_2.

Ozone is a very strong disinfectant and oxidizer. Any pathogen or contaminant that can be disinfected, altered or removed via an oxidation process will be affected by Ozone. Ozone is the strongest of all molecules available for disinfection in water treatment, and is second only to elemental fluorine in oxidizing power. Compared to chlorine – the most common water disinfection chemical – Ozone is more than 50% stronger and oxidizes over 3,000 times faster. Both chlorine and fluorine are highly toxic chemicals.

On this planet, Ozone is a major work horse. From the highest reaches of the atmosphere to the bottom of the deepest ocean, Ozone is a very efficient protector, provider and recycler. It constantly tries to get rid of one oxygen atom, O_3 □ O_2+O_1, which allows it to react with almost anything it encounters.[1]

How does Ozone work?

Ozone will initiate a series of reactions in water that are very complex and quite specific to the water being treated. Unlike the very regular and uniformly shaped O_2 molecule, O_3 is a lopsided dogleg shape. Being of dipolar structure with extreme forms of resonance, it is very versatile, while still quite selective in its direct reactions. Ozone can attack as a dipole, as a molecule, electrophilicly or as a nucleophilic agent.

Ozone reacts in water, or any aqueous solution, in two ways:

DIRECTLY as molecular Ozone via three mechanisms:

(Slow and very selective), forming aldehydes, ketones and carboxylic acids,

cyclo addition (+ & -); on unsaturated bonds, as a dipole.

ozonide > carbonyl > hydroxy-hydro peroxide >
carbonyl & hydrogen peroxide

electrophilic (+); on molecular sites with strong electronic density.

aromatics (phenol & aniline)

nucleophilic (-); on molecular sites with an electronic deficit, usually on carbons carrying electron withdrawing groups.

INDIRECTLY via radicals formed as it decomposes in water;

A few such radicals are as follows:

hydroxyl radical, OH^- , a main reactive ingredient
hydroperoxide radical, HO_2
superoxide radical ion, $O_2^{\sim}$
ozonide radical ion, $O_3^{\sim}$

The indirect reactions produced by molecular Ozone are limited only by the various radicals it produces, which vary with the initial water quality. The worse the water quality, the more potential Ozone has to perform. Even if the Ozone is used up quickly, the radicals produced by its interaction will continue reacting.

For example, the contact of Ozone molecules with water ($O_3+H_2O \rightarrow O_2+OH^-+OH^-$) produces hydroxide ions, which assist in cleaning the water over and above the work of the Ozone itself.

Ozone oxidizes many materials into insoluble oxides that can precipitate or settle out (normally all are filterable); occasionally some are foamy (so can be skimmed). Some combinations of soluble organics and polyvalent cations produce insoluble materials with Ozonation. Ozonation causes surface charges to change from positive to negative. Colloidal particles are usually held in suspension by their surface charges. Thus, Ozone can induce some flocculation in turbid waters, depending on the water composition.

By imparting a negative charge to molecules, Ozone encourages hydrogen bonding, which in turn encourages coagulation and flocculation. With hydrogen bonding of oxidized material occurring, conglomerates form which can be precipitated, filtered out or skimmed off.

The effect of Ozone as an anti-bacterial agent has been reported in several studies, ensuring the use of Ozone as an almost standard disinfecting medium with many applications, including drinking water, bottle washing, food applications, and effluent treatment.[2,3,4]

Ozone in laundries

Over the past few decades, Ozone has been tested and implemented for laundry purposes in a number of countries, most notably in the USA. The US Army Environmental Centre, for example, recommends the use of Ozone for the cleaning of oily rags.[5] At the Clean Show in Las Vegas in 2005, a variety of Ozone laundry units were on display. Most of these were targeted at the coin-operated laundry industry.

We were interested in whether Ozone had been applied to hospital-based laundry systems. As we could find no empirical data or information regarding the use of Ozone in hospital or clinical laundry application, we decided to set up a trial. The trial was to apply Ozone to hospital laundry ware, monitoring specific disinfection criteria. The test was carried out at the Tygerberg hospital laundry in the Cape Town metropolitan area, between October 2004 and June 2005.

The main objective was to verify the commonly published advantages of Ozone laundry, with a particular focus on its ability to reduce a given bio-burden to acceptable levels by reducing or eliminating the use of heat. The reduction in temperature would result in saving energy. This was of particular significance as our ultimate aim was sanitation of laundry in rural areas. Savings on chemicals in the wash process can also be achieved through Ozone laundry, and are widely acknowledged,[5,6] but were not sufficiently explored within the focused scope of this trial report. Ndumiso Dlamini, a final year MSc (Energy and Development - UCT) student with a BSc Mechanical Engineering, conducted the trials under the supervision of independent monitors Professor Shaheen Mehtar (Head of Unit for Infection Control, Department of Community Health – University of Stellenbosch) and Dr Elizabeth Wasserman (NHLS Tygerberg Laboratories).

Tygerberg Hospital Laundry was chosen to conduct the trial for the following reasons:

- It is the largest hospital laundry in the Western Cape.
- The hospital is attached to the University of Stellenbosch, whose Medical School is home to the world-renowned Department of Community and Infectious Disease.
- The Western Cape Government Laundry Group is regarded as one of the better run facility in South Africa.
- Tygerberg, in particular, is run by Ian Strelensky, who has over 30 years experience in laundry and washing.

In this regard we agreed to set up a protocol with the University and the laundry on the way the trial would be undertaken. Two identical machines would be set aside. One would be connected to the Ozone system; the other would be serve as the control using the standard SABS method.

Tygerberg Laundry has three large tunnel washing machines and accompanying drying machines – at least four to each tunnel dryer. It also has a number of smaller machines for laundry processing such as washing, drying, and ironing. The facility has a constant supply of hospital laundry ware.

Purpose of Trial

The trial was set up to investigate the disinfection properties of Ozone in a laundry washing hospital linen. Economic and other aspects – such as energy consumption, water usage, time taken, and textile degradation – were also considered to form a holistic picture of the uses of Ozone. The tests were commissioned by Umoyamanzi, who sourced the Ozone generator and patented contact system from Chem-Free Aqua, a Durban-based company providing Ozone services.

The trial set out to compare the effect of washing hospital laundry ware using Ozone (at a water temperature of 38°C) with that of conventional hot water laundry washing (at a water temperature of 80°C) on a known bio-burden introduced into each washing load.
It was hoped to show the benefits of the Ozone system relative to the conventional methods, and prove that Ozone has significantly superior disinfection properties.

Potential benefits

Some of the potential benefits of ozone laundering include:

Hard savings:

Water savings: 30-45 % reduction of water consumption through reduced wash formulas.
Heating fuel: 70-80% reduction of wash temperatures on all formulas due to Ozone keeping chemicals active throughout the formula.
Production time: 20-25% reduction based on reduced wash formula programmes.
Chemical savings: 25-30% reduction due to regeneration of chemistry.

Linen strength: Up to 90% savings on linen replacement due to increased strength of fabric.

Soft savings:

Linen savings: replacement of linen greatly reduced. Some linen life extended by a factor of 2-3 based on reduced wash time, reduced chemical activity and the Ozone working as an anti-chlor in the wash cycles after the bleach bath.

Reduced dryer fuel: Ozone makes the water slicker through chemical action on contaminants, allowing the water to extract off the linen faster.

Maintenance savings: maintenance time reduced due to reduced running of the equipment. Motors, shafts, bearings, and such break down less often.

Maintenance savings: lint developed through the wash process is greatly reduced. Lint collectors fill up less frequently, providing improved dry time and reduced maintenance.

Equipment replacement: by reducing formulas by approximately 25%, the replacement cycle of the laundry machinery is extended, therefore reducing costs.

Operating environment improved: through the reduction of the use of hot water for the wash cycle, the work environment is improved by lower room temperatures and reduced moisture levels in the air.

Softer linen: by reducing the use of chemicals, we eliminate residual inactive chemistry in the fabric. With this process we have basically eliminated bed sores on patients in nursing facilities.

Odour elimination: Ozone is valuable in odour removal from the air or from fabrics. This provides a more pleasant fabric for guest comfort.

Improved ironing / finishing: because the residual chemistry is eliminated, there is better affinity for starch when used on table linen. Use of starch is reduced. Use of softeners is reduced because the fabric returns to its natural softness.

Waste water: improved waste water conditions reduce or remove alkali, as in wash chemical or chlorine bleach. This improves discharge through oxygen (Ozone) for improved BOD, COD, and FOG contamination reduction.

Waste water: reduces or eliminates waste water odour.

Waste water: improves operation of most waste water treatment systems through pre-flocking of solids for quicker, more efficient removal.

Waste Water: reduces chemical levels required for waste treatment operation for DAF (Dissolved Air Flotation) or Membrane systems.

Methodology

For the trial, two identical 125kg washing machines were utilized. One was connected to the Ozone system and the other was utilized as the control washing machine according to standard testing methods.

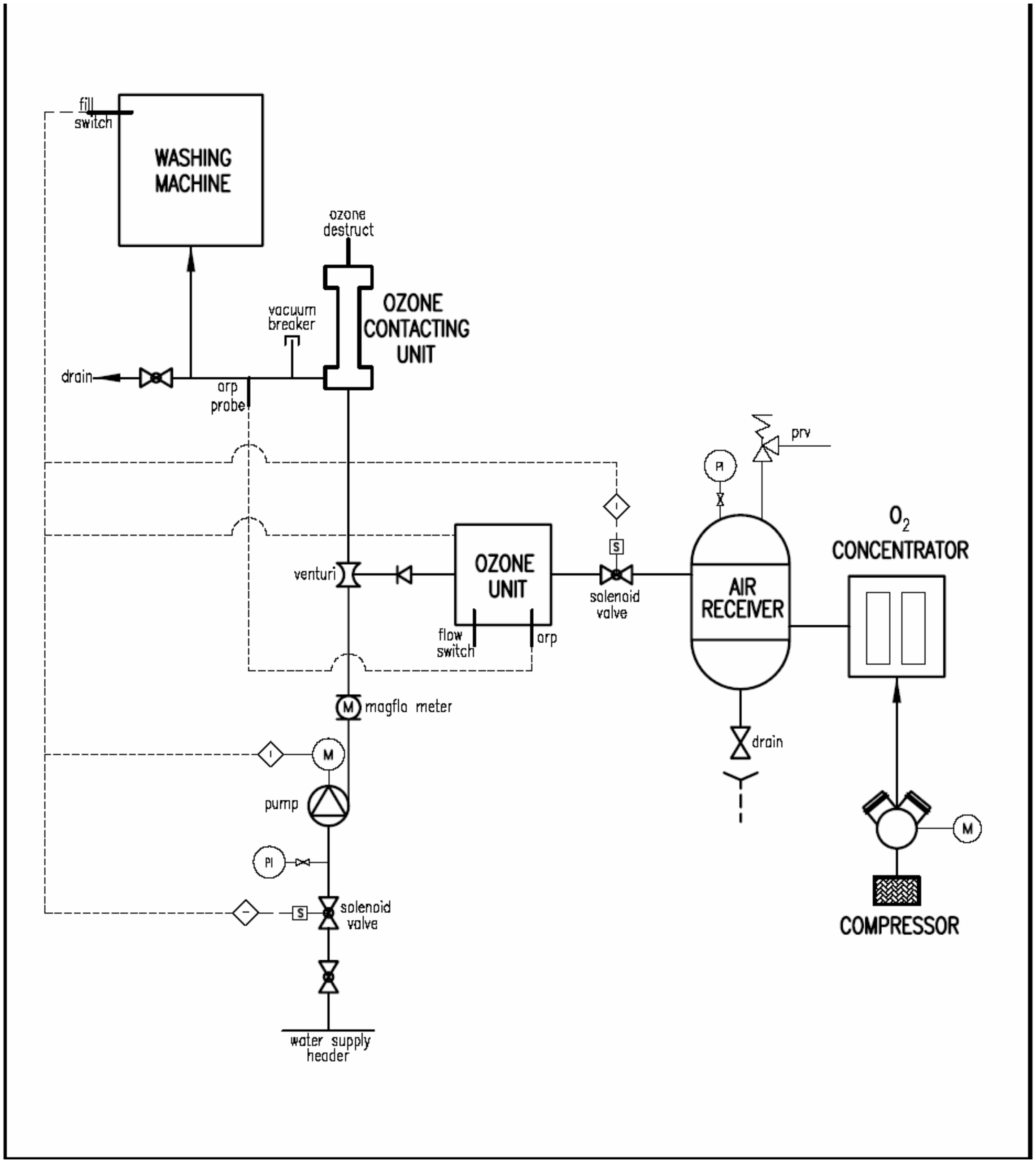

Figure 3 Structure of the Ozone Laundry System

In order to achieve a definitive result, The sample size was established at a minimum number of 50 cycles to be tested. Although 50 cycles were undertaken, only 32 of the washes (33 in the case of the normal wash process), included the swatches for the testing of microbial reduction. During those 50 cycles a control piece of fabric was placed in each washing machine to assess the degradation on the textile material (sheeting). These fabrics were sent to Berg River Textiles, an accredited laboratory, for strength testing according to ASTM method D2261.[8]

Thus 32 Ozone washes and 33 normal washes were carried out. The linen load in each of the two machines was the same size (100 kgs), both taken from the same batch of soiled hospital linen: bed sheets from the hospital wards, taken to the laundry as part of the normal wash procedure. The linen was divided between the two machines in such a way that the heavily soiled linen was evenly distributed between the two washing processes.

Both machines were started at the same time, enabling us to monitor the time differential between each method. Water was monitored by a Kent water meter. Each machine was loaded with the contaminated samples supplied by the National Health Services Laboratory as per the protocol set out by Professor Mehtar.

Bio-burden introduction method

The following contaminant species were mixed into a solution which yielded 105 cfu/ml. The temperatures on the right relate to their characteristics in relation to temperature.

Enterococcus faecalis	NCTC	Killed at 60 to 80°C
Klebsiella pneumoniae	NCTC	Killed at 60 to 80°C
B. subtilis spores	NCTC	Destroyed at 130°C

For each wash, and for each one of these species, a small cotton cloth was impregnated with 1 ml of this solution. Each cloth was then placed in a separate Petri dish, following which they were transported to the laundry – a few hundred metres from the laboratory. At the laundry, the cloths were removed from their respective Petri dishes and placed together (using sterile forceps) in one nylon mesh bag per cycle, and introduced into the machine just before the start of each wash cycle. The cotton cloths were each capable of withstanding at least two laundry cycles before disintegrating. At the end of each cycle, each cotton cloth was removed from the washing machine using the forceps, placed in a separate, clean Petri dish, and sent to the laboratory for testing for the bio-load. In this way, each wash cycle contained three of the cotton cloths – a total of six for the Ozone wash and the normal wash together – each time.

Determination of Savings Method

The effect of the use of Ozone in the washing cycle on the commercial aspects of laundries was determined using the following method:

Each of the Ozone wash cycles was compared to an equivalent non-Ozone cycle. The water levels were measured by a Kent water meter. Wash cycle times were taken on a stopwatch and energy was determined by the calculation of heat required to raise water to the temperatures observed, as measured by thermometers built into the machines.

<u>Results of the Trial</u>

Disinfection

Figure 4 below summarizes the rates of disinfection ascertained from the laboratory tests conducted on the pre- and post-wash swatches on both Ozone and regular laundry washes. Overall, while both Ozone and hot water removed vegetative forms of bacteria, the log reduction with Ozone was quicker than with water alone. As expected, while log reduction occurred with *B. subtilis* with both test and control system, the difference in reduction was not statistically significant. The mean reduction of colony forming units of all test organisms was 1.1 log with Ozone and 1.4 log reduction with a water cycle alone ($p= 0.05$) and are shown in Table 1, below. It is noteworthy that in results both with and without *B. subtilis* test spores the mean log reduction was greater with Ozone than with an ordinary wash cycle and was statistically significant ($p=0.05$).

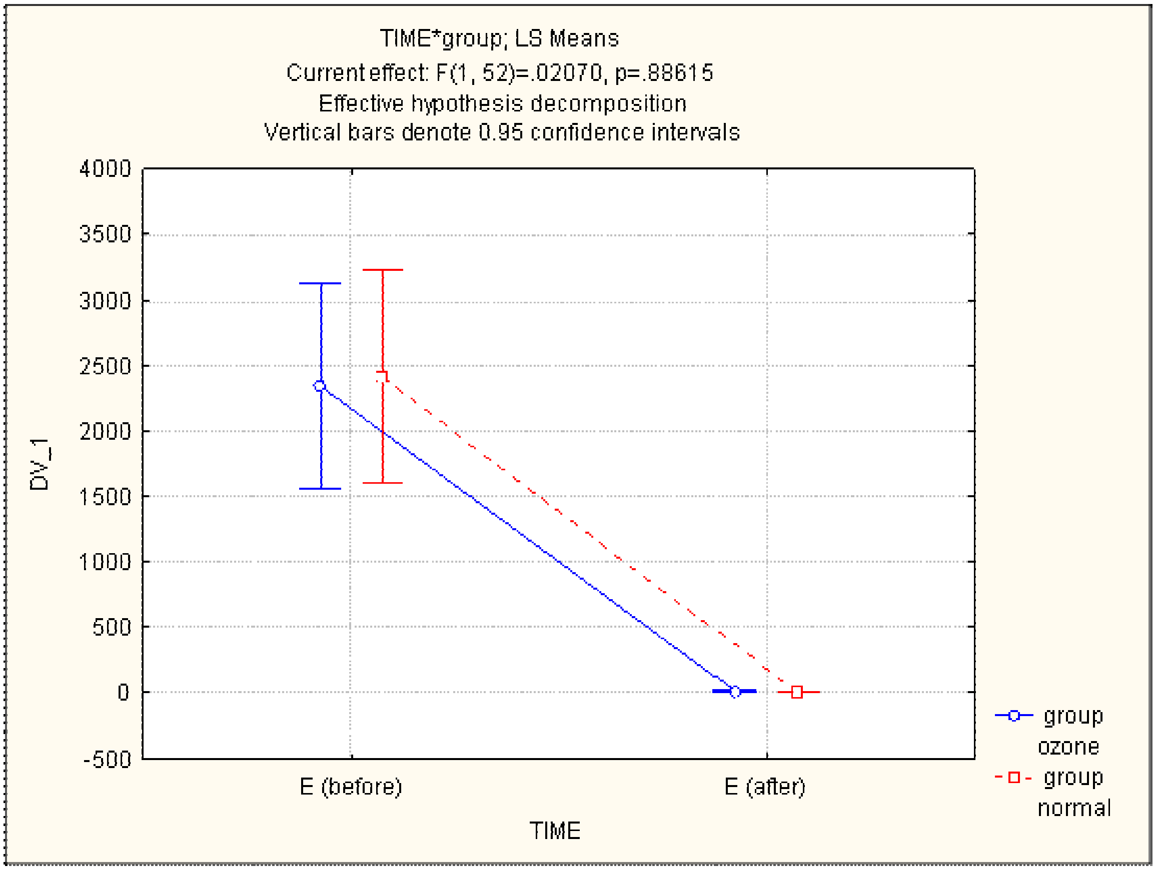

Figure 4 Disinfection rates on pre- and post-wash swatches.

	Mean log reduction	Mean log reduction	P value
Test organisms	Ozone	Normal	
All	1.1	1.4	0.03
All less B. subtilis	2.3	2.6	0.03
E. coli and Klebsiella	2.6	3.6	<0.001
B. subtilis alone	0.5	0.9	0.05

Table 1 Log reduction with B. subtilis in test and control systems.

Results on other characteristics of the Ozone wash

The results on the other characteristics of Ozone washing which were monitored can be found in Annexures 4 to 8 of this document. They indicate a number of benefits of using Ozone in laundry, including savings in energy, water, and time, and increased life of the textile material. These findings are consistent with the expected benefits expressed by a number of sources.[2,7,10,11]

Discussion of Results

This study illustrates that Ozone reduces the bioburden quicker than washing alone. It effectively reduces vegetative forms of bacteria more rapidly than routine washing cycles used in the laundry services. While a reduction in spore forming organisms was noted with Ozone, not surprisingly it was similar to the ordinary wash cycle.

Conclusions

The trial proved conclusively that the introduction of Ozone into the laundry process at a minimum temperature of 38°C achieved a greater rate of bacteriological disinfection than a standard laundry process conducted at a minimum temperature of 80°C.

In addition, from the results of the trial as described above, we also concluded that the following average estimated savings were measured and attained during the trial:

Water and sewage consumption(26 % for make up water)	45% saving
Energy	42% saving
Rewash rate	less than 2%
Productivity (time only)	9% saving
Chemical usage	27% saving
Linen life	18% saving

It should be noted that certain other potential savings have been identified but were not measured during the trial. These include:

Maintenance: the washing machines are running cooler and there is less lint build up.
Environmental savings due to lower chemical and water usage.
Fuel savings and boiler benefits.

We therefore conclude that the use of Ozone in laundry washing cycles is significantly more efficient in the bacteria disinfection process than conventional washing methods, and simultaneously provides substantive commercial savings on all key indicators measured.

Acknowledgements

Sincere and grateful thanks to the following who made the trial possible:

- Professor Shaheen Mehtar, Head of Unit for Infection Control, Department of Community Health – University of Stellenbosch
- Dr Elizabeth Wasserman and her staff at NHLS Tygerberg Laboratories
- Mr Quinton Escreet, Head of Laundry Services, Directorate: Engineering & Technical Support, Western Cape Provincial Administration
- Mr Ian Strelensky and his staff at Tygerberg Hospital Laundry
- Graham Alan Kluk, M D Chem-free-aqua, technical advisor on ozone usage
- Albert van Eeden, Textile Care Manager of DynaChem (Pty) Limited.

Annexure 1: Professor Mehtar's report on trial results

My initial observations, as discussed in this study, illustrate that Ozone reduces the bioburden quicker than washing alone. It effectively reduces vegetative forms of bacteria more rapidly than routine washing cycles used in the laundry services. While a reduction in spore forming organisms was noted with Ozone, not surprisingly it was similar to the ordinary wash cycle. The energy savings, though, need to be considered. I am in the process of expanding my observations and we will be submitting a paper on the topic to the Society of Infectious Diseases.

Annexure 2: Overview of Ozone in laundry

Annexure 2.1: Technical Background

Ozone is an unstable compound generated by a corona discharge. The weak bond holding Ozone's third atom is what causes the molecule to be unstable and to be one of the best known oxidants. Because of this instability, an oxidation reaction occurs upon any collision between an Ozone molecule and a molecule of an oxidisable substance such as certain forms of Iron (Fe) and Manganese (Mn) or organic molecules (bacteria, viruses and some plastics and rubbers).

The process works on the basic chemistry of surfactants and their manufacture. In general, cleaning surfactants contain a hydrophobic end and a hydrophilic end. The hydrophilic end usually contains oxygen, and sometimes nitrogen, fluorine, or other electrophilic species. Mild oxidation of oily contaminates with oxygen containing compounds, and free radical reaction with oxygen containing free radicals produces surfactants containing hydrophilic functional groups such as alcohols, esters, carbonyl, and carboxylic acids attached to hydrophobic hydrocarbon chains.

Ozone reacts directly with organics by attacking unsaturated carbon to carbon double bonds. Some reaction products of Ozonation include organic peroxides, hydrogen peroxide, and superoxide anion. These organic peroxides can react non-selectively with other saturated or unsaturated compounds in the recycled cleaner through a free radical reaction mechanism, thus forming new compounds through a coupling process that is similar to polymerization. This results in the creation of a wide variety of surface-active compounds in the recycled cleaner/Ozone process.

After repeated exposure of recycled cleaning solutions to limited amounts of Ozone, new surfactants begin to form that are amphoteric with alcohol, glycol, and carboxylic acid functional groups, all on the backbone of the hydrocarbon. These surfactants exhibit high solubility in water, the ability to chelate and sequester metal ions, and can increase the cleaner's ability and capacity to emulsify and solubilize hydrophobic contaminants.

According to the EPA and FDA in the USA, Ozone is capable of reducing pathogenic bacteria on fabrics by 99.9992%. These tests were also performed by the SABS in South Africa and a higher effectiveness was found (Ref: 1777233/3151/V13924 and other tests). The structure of the organic molecule is changed by oxidation, which often causes the whole molecule to come apart. Bacteria and virus cells are literally split apart by Ozone.

Annexure 2.2: How Ozone operates

Ozone is highly unstable, and this property also makes it a very powerful oxidizing, cleaning and bleaching agent, with special application in laundry washing. Ozone works best in cold water. It attacks all organic soils and kills bacteria 3,000 times faster than chlorine bleach. Ozone is totally biodegradable and when it completes its function, it reverts rapidly back to Oxygen (O^2), leaving no chemical residue behind.

The installation used for this test comprised an Ozone Generator, which was integrated with the existing laundry equipment. Compressed air was forced through a high voltage electrical arc, which resulted in the conversion of oxygen molecules (O^2) into Ozone gas (O^3). The Ozone was then dissolved in cold laundry wash water, where it exerted its powerful cleaning action. Because it is so reactive, Ozone readily attaches itself to fatty and other soils that bind dirt to clothing, destroying these impediments rapidly.

As one of the strongest known oxidizing agents, Ozone is capable of breaking down virtually any organic soil into innocuous compounds such as carbon dioxide and water. Being a gas in solution, Ozone penetrates and opens individual garment fibres, allowing faster cleaning and bleaching of garments with the use of fewer chemicals. The overall effect means considerable reductions in the washing and drying cycle times, and whiter, cleaner, softer garments.

Annexure 2.3: Ozone generation and how the system works

- Ozone is generated on site utilizing a corona discharge Ozone generator connected to a patented contact unit. The Ozone system is integrated with existing equipment in the laundry.

- Dry air is sucked through the corona discharge Ozone generator via a specialised inductor unit. This causes a reaction with the oxygen atoms, which then collide with other oxygen molecules to create Ozone.
- The Ozone is then injected into the water stream utilizing a patented contacting chamber. The chamber breaks down the Ozone gas bubbles, which allows them to mix more efficiently with the water to produce a better Ozone solution. The Ozonated water then enters the laundry chamber for further Ozone absorption.
- The Ozone concentration in water is measured by an oxidation-reduction potential (ORP) monitor, which measures the effective biocide activity of dissolved Ozone in water in millivolts, which is then converted to mg/l (ppm).
- A rota meter, which is normally adjustable, is installed to control the oxygen flow into the generator and therefore the production of Ozone molecules.
- This method of dissolving the Ozone in the water ensures that this is the safest method of Ozone application, both for equipment and personnel.

Annexure 3: Bacteriological Test Procedure

Pre test: An impression of the cotton swab on blood agar was taken after it had been impregnated with the bio-burden solution, but **before** it was processed in either type of laundry cycle.

Post test: After the wash cycle was complete, the cotton swab was carefully removed and an imprint taken on blood agar.

Both plates were incubated at 37^{o}C aerobically for 18 hours. A colony count on the presence or absence of the test organisms was performed and a log reduction in counts recorded. A mean log reduction was calculated for the approximately 30 cycles per system at the end of the study.

The samples were developed under the auspices of Dr Wassermann and the National Health Laboratory service at Tygerberg Hospital.

Annexure 4: Energy Savings

The Ozone cycle operated at about 40°C (the minimum set point temperature was 38°C). The normal cycle usually operated at above 80°C. The difference between the two types of wash cycles was therefore a temperature reduction of at least 40°C in heated water. The volume of water in a normal cycle was 0.454 cubic metres, while that in the Ozone wash was 0.330 cubic metres, representing a reduction of 0.124 cubic metres heated water per wash. Ambient water temperature was assumed to be 20°C. Water was assumed to have a specific heat capacity of 4.2 kJ per kg per degree Celsius.

In the normal wash, the heat energy required to raise the temperature of the water from 20°C to 80°C was KJ, while in the Ozone wash the heat energy required to raise the temperature of the water from 20°C to 40°C was kJ.

From the above calculation, we thus derived an energy saving of 86,688 kJ per wash cycle, which is equivalent to 24 kWh of electricity saving per cycle. This reflects a saving of 76%.

Annexure 5: Linen/textile test results

Linen test pieces were included in the Ozone washes, but these test pieces were washed for a number of washes exceeding that of the Ozone trial. After 50 washes, the test pieces used in the Ozone and normal washes were compared to each other, and a reference test piece (unwashed). The laboratory test results from Berg River Textiles were as follows:

On the weft of the fabric, the average tensile strengths (breakpoints) after 50 washes were as follows:

Original test piece (no washes)	630 N	
Ozone wash test piece	617 N	3% strength loss
Normal wash test piece	505 N	20% strength loss

These textile tensile strength results imply significant monetary savings. As can be seen from the results, the test piece washed in the normal (high temperature) wash aged more than six times as fast as the one washed with Ozone. If we do not consider other degrading processes in the laundry and elsewhere in the life cycle of the linen, the hospital would, by using Ozone washing, therefore have to replace its at a rate that is one sixth of the present scenario, a saving of more than 80%.

Annexure 6: Water and Effluent

Over the period of the trial, average water usages per wash cycles in litres were as follows:

	Ozone	Normal
Main Wash	330	360
Rinse 1	360	360
Rinse 2	360	360
Rinse 3		360
Total	1 050 litres	1 440 litres

Table 2 Average water usage per wash cycle.

Notes: The washing machines have level indicators, which allow a comparison of the amount of water in each machine.

- The wash water level used for the normal cycle was level 45 cm, compared to level 33 cm for the Ozone wash.
- Normal cycle rinse was consistently rinsing at above water level 64 cm, as compared to rinse level 37 cm for the Ozone wash.
- Water consumption **saving of 26 %**

The water savings in the wash cycle also mean that there is a reduction in effluent discharge as a result of the use of Ozone in the wash cycle.

Annexure 7: Savings on Detergents

During the preliminary stages of the trial, an SABS 1044 detergent was used. It was discovered that the correct results on quality were not being attained due to the low temperature of 38°C and the primary nature of the work being the removal of blood. A change to an enzyme detergent was thus made and the alkali levels reduced as a ph of 10 and high temperatures would kill the enzymes. The level of peroxide in the water was also reduced. The laundry washes conducted using this detergent mix and Ozone thereafter produced a significant reduction in the amount of chemicals used. The actual level of chemical saving will, in all likelihood, differ from laundry to laundry, but it is estimated to be in the range of 15-30%.

Other advantages of utilizing this mix of detergents and rinse aids are:

- Very low or no foam generation.
- Good wetting and rapid drainage with no break in the water film.
- Rapid dispersion at low temperature.
- Low order of toxicity.
- No residual haze or film.
- No gel formation or increase in viscosity when added to water.
- Promoting rapid drying of articles washed.
- It is fully bio-degradable.

Annexure 8: Productivity and Time

The overall cycle time advantage of using Ozone was calculated to be on average four minutes and nine seconds time saving out of a total average wash time of 39 minutes and 43 seconds (a normal wash cycle): a time saving of 10.4%. This saving is largely attributed to the reduction in time required to heat the water.

Annexure 9: Overview of Hospital Linen Laundry Process

The laundry process for hospital linen is generally as follows:

- Linen is removed from hospital bed.
- Any solid soiling on the linen is removed in a room inside the hospital.
- The linen is placed in bags and then transported by truck to the hospital laundry.
- At the laundry, the bags are emptied into trolleys in preparation for loading into the washing machines.
- The linen is loaded into the washing machines. In the case of the tunnel washers, the linen is first placed in bags suitable for automatic loading of the tunnel washers.
- After washing, the linen is placed in tumble dryers.
- The linen is then ironed using ironing machines.
- The linen is then folded, packed and sent back to the hospital.
- Linen is re-used in the hospital.
- Certain garments (such as theatre greens) are sterilized in the hospital before re-use.

Annexure 10: Ozone Material Safety Data

Section 1- Product identification

Product Name: Ozone

Synonyms: Triatomic Oxygen, O3

Chemical Family: Oxidizer

Molecular Formula: O3

Molecular Weight: 48.0

Section 2 - Hazardous Ingredients

Components: Ozone Gas

Concentration: 0-20% by weight

Gas Registry Number: 10028-15-6

Section 3 - Physical Data

Boiling Point: -111.9 C

Melting Point: -192.7 C

Solubility in Water by weight at 20 C: 0.003 g/l (3 ppm)

Vapour Density (air =1)

Appearance and Odour: Ozone is colourless at all concentrations experienced in industry. It has a very pungent characteristic odour, usually associated with electrical sparks. Ozone odour is generally detectable at concentrations of 0.02-0.05 ppm.

Section 4 - Fire/Explosion Hazards Data

Ozone is a powerful oxidizing agent. Oxidation with Ozone evolves more heat and usually starts at a lower temperature than oxidation with oxygen. It reacts with non-saturated organic compounds to produce Ozonides, which are unstable and may decompose with explosive violence.

Ozone is an unstable gas which, at normal temperatures, decomposes to diatomic oxygen. At elevated temperatures and in the presence of certain catalysts such as hydrogen, iron, copper and chromium, this decomposition may be explosive.

Flash Point: Not Applicable
Auto-ignition: Not Applicable
Flammability: Non Flammable but vigorously supports combustion.
Extinguishing Media: Depends on source media.

Section 5 - Reactivity Data

Conditions contributing to instability: Ozone spontaneously decomposes under all ordinary conditions, so that it is not encountered except in the immediate vicinity of where it was formed. The decomposition is speeded by solid surfaces and by many chemical substances.

Incompatibilities: Ozone is a powerful oxidizing agent and reacts with all oxidizable materials, both organic and inorganic. Some reactions are highly explosive.

Hazardous Decomposition Products: None
Special Precautions: None

Section 6 - Health Hazard Data

Permissible Exposure Limit: The current standard for Ozone is 0.1 part of Ozone per million parts of air (ppm), averaged over an eight-hour work shift. This may also be expressed as 0.2 milligrams of Ozone per cubic meter of air (mg/m3). No criteria are set for the permissible concentration of Ozone in water.

Symptoms of Exposure: A sharp irritating odour is noticed after exposure to very low concentrations (=0.04 ppm) of Ozone for a very brief period of time. As the concentration of Ozone increases, the ability to smell it may decrease. Irritation to the eyes, dryness of the nose and throat, and a cough may be experienced. If the Ozone concentrations continue to rise, more severe symptoms may develop. These may include headache, upset stomach or vomiting, pain or tightness of the chest, shortness of breath, or tiredness, which may last for several days or weeks. Finally, with higher levels of exposure, the lungs may be damaged and death may occur.

Toxicological Properties: Ozone is extremely irritating to the upper and lower respiratory tract. The characteristic odour is readily detectable at low concentrations (0.02 ppm to

0.05 ppm). Ozone produces local irritation of the eyes and mucous membranes and may cause pulmonary edema at high exposure. Systematically, Ozone has been reported to mimic the effects of ionizing radiation, and may cause damage to chromosomal structures. A partial tolerance appears to develop with repeated exposures. Although most effects are acute, the possibility of chronic lung impairment should be considered, based upon animal experimentation.

Section 7- Preventive Measures

Leak Procedures: Persons not wearing protective equipment and clothing should be restricted from areas of leaks until cleanup has been completed. If Ozone is leaked, the following steps should be taken:

1. Ventilate area of leak to disperse gas.
2. Stop flow of gas.

Waste Disposal Method: Do not dispose of Ozone off gas to atmosphere without properly designed off gas destruct unit.

Engineering Controls:

1. *Respiratory Protection* - Positive pressure air line with mask or self-contained breathing apparatus should be available for emergency use.
2. *Ventilation* - All potential sources of Ozone off gas must be connected with a suitable collection system. All Ozone off gas must pass through a properly designed Ozone off gas destruct unit prior to release to atmosphere.
3. *Personal Protective Equipment*: Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations.
4. Appropriate respirators shall be provided and used when the use of respirators is the only means of controlling exposure for routine operations, or during an emergency. (Refer to Table 1 of ANSUI/ASTM E591-77 for appropriate respirator selection).

References:

DeMers LD, Renner RC. *Alternative Disinfection Technologies for Small Drinking Water Systems*. AWWA Research Foundation and American Water Works Association 1992.

Rice RG, Bollykly LJ, Lacy WJ. *Analytical Aspects of Ozone Treatment of Water and Wastewater*. Lewis Publishers 1987.
EPA/600/4-87/018, PB87-201372

Lide DR. *CRC Handbook of Chemistry and Physics*, 74th edn. CRC Press Inc. 1993.

Rice RG, Netzer A. *Handbook of Ozone Technology and Applications, Vol. 1*. Ann Arbor Science 1982.

Rice RG, Netzer A. *Handbook of Ozone Technology and Applications, Vol. 2*. Ann Arbor Science 1982.

Battino R, Ed. *IUAC Solubility Data Series, Vol. 7: Oxygen and Ozone*. Oxford, England: Pergamon Press 1981.

Microorganism removal for small water systems.1983;
EPA 570/9-83-012

American Water Works Association. *Ozone in water treatment: application and engineering*. Lewis Publishers, Inc. 1991.

Rice R, Browning ME. *Ozone Treatment of Industrial wastewater*. Noyes Data Corporation 1981.

SWTR Guidance Manual, Appendix "O", EP

List of Figures:

List of Tables: