Sydney WATER

Assessment of the Poolactif Technology

January 2003

1. Executive Summary

Poolactif International Pty Ltd approached Sydney Water to test its Poolactif process claiming that it could improve drinking water quality. This process involves the addition of a small amount of ozone in conjunction with chlorine. Currently the process is used in a number of swimming pools where the water is continually recirculated. The process is claimed to be able to reduce the chlorine demand and chlorine odour in swimming pool water. To date this process has not been used for the drinking water treatment in Australia.

Field sampling of several swimming pool installations and controlled laboratory experiments were carried out to study the effect of the Poolactif process on swimming pool water and drinking water quality. The findings of this project are summarised as follows:

Effect of Poolactif - process recirculation in reservoir

- The Poolactif process did appear to have a significant effect on the quality of both the tap water from Prospect WFP and filtered water from North Richmond WFP in the **recirculation** experiment after a long period of time (say more than ten hours of continuous operation). The effects were usually shown in the indicators (eg. TOC, DOC, UV254, fluorescence, THMs, etc) associated with the levels of organic compounds in the water. After a relatively long time.

- It appears fairly clear that the ozone is steadily oxidising the organic compounds present over time as ozone is continually added in the recirculation loop. The key implication of this is that it would appear that the impact of the Poolactif process on the water quality is stoichiometric and thus would follow conventional thinking regarding the chemistry and use of ozone for oxidation.

Key Conclusions

- It is concluded that the use of Poolactif in its current form (ie low continuous dose) is unlikely to be useful for 'open/single pass' water treatment applications such as WFPs where the water is a single pass system. The Poolactif system is really likely to be useful/effective for 'closed loop' systems where the water is continuously recirculated such as swimming pools, cooling towers, water reservoirs and etc.

Objectives

- To firstly evaluate the effectiveness of the Poolactif process on the quality of swimming pool water in relation to its claims to reduce chlorine demand, taste and odour, and THM formation.

Tasks

The tasks in this project included:

- Field trips to collect and assess data from a few selected swimming pools currently using the Poolactif process. The pools selected are located in the New South Wale University, the Fairfield City Leisure Centre and the Swiss Grand Hotel at Bondi Beach.

- An assessment of the effect of the Poolactif process on the swimming pool water quality before and after the installation of this process. The Swiss Grand Hotel was chosen for this exercise as the equipment was just about to be installed.

2. Methods and Materials

Inspection of swimming pools

Swimming pools in the University of New South Wales, the Fairfield City Leisure Centre and the Swiss Grand Hotel at Bondi Beach, and Coogee Rankwick RSL club were inspected by the project team to identify the possible problems associated with swimming pool water quality. A list of questions was prepared to obtain information on the perception of swimming pool water quality.

Water

Swimming pool water samples were collected from the University of New South Wales, the Fairfield City Leisure Centre and the Swiss Grand Hotel at Bondi Beach, for water quality analysis.

Water quality analysis

Water samples from the swimming pools and from the experiments were analysed for selected parameters. These parameters (see Table 2) were used to evaluate changes, if any, in water quality.

Table 2. Water quality parameters analysed in this project

Parameter	Abbreviation
Chlorite (mg/L)	ClO_2^-
Chlorate (mg/L)	ClO_3^-
Ammonia-nitrogen(mg/L)	NH_3-N
Nitrate (mg/L)	NO_3^-
Nitrite (mg/L)	NO_2^-
Total nitrogen (mg/L)	TN
Alkalinity (mg/L as $CaCO_3$)	ALK
True colour (colour unit at 400nm)	TC
Turbidity (NTU)	Turbidity
PH	PH
Odour rating (1 – 5, 1 lowest)	Odour
UV254nm	UV
Total organic carbon (mg/L)	TOC
Dissolved organic carbon (mg/L)	DOC
Acetaldehyde (µg/L)	Acetald
Acetone (µg/L)	Acetone
Total aldehyde (µg/L)	Aldehyd
Formaldehyde (µg/L)	Formald
Gluteraldehyde (µg/L)	Glutald
Methylethyl ketone (µg/L)	MEK
Prionaldehyde (µg/L)	Propion
Chloroform (µg/L)	Chlorof
Bromodichloromethane (µg/L)	Bdchmet
Chlorodibromomethane (µg/L)	Dbrchme
Bromoform (µg/L)	Bromfor
Trihalomethanes (µg/L)	THM
Chloroacetic acid (µg/L)	CAA
Bronoacetic acid (µg/L)	BAA
Dichloroacetic acid (µg/L)	DCAA
Trichloroacetic acid (µg/L)	TCAA
Bromochloroacetic acid (µg/L)	BCAA
Bromodichloroacetic acid (µg/L)	BDCAA
Chlorine decay rate	

Water samples were collected, preserved and transferred as per the Standard Methods. Chlorite and chlorate were analysed by Levay & Co. Environmental Services, Ian Wark Research Institute, University of South Australia. Other parameters were analysed by Analytical Services, Environment & Innovation, Sydney Water Corp.

Fluorescence scan

The fluorescence intensity was measured on an Aminco-Bowman AB2 spectrometer by using 1 cm cells. The samples were irradiated at 350nm and the fluorescent signal at 90 deg was scanned from 350-800 nm. The intensity at around 431 nm is normally used to indicate natural organic matter (NOM) concentration in water.

3. Results and Discussions

3.1 Investigation of pool installation

Four swimming pools were visited to obtain information on the perception of the impact of the Poolactif process on pool water quality by various pool staff. These swimming pools are

located in the University of NSW, the Fairfield City Leisure Centre, the Coogee Randwick RSL Club and the Swiss Grand Hotel.

Water samples were taken for water quality analysis from the swimming pools at the University of NSW, the Fairfield City Leisure Centre and the Swiss Grand Hotel at Bondi Beach during the visits.

The Poolactif processes had been installed, prior to this study, at the University of NSW and the Fairfield City Leisure Centre, so the water samples from these sites represented the water quality after the Poolactif process treatment. Water samples at the Swiss Grand Hotel were taken both before and after the installation of the Poolactif process. Therefore, the water quality parameters in these water samples were indicative of the effects of Poolactif process on swimming pool water quality.

Change in the perception of water quality after installation of Poolactif process

Table 3 summarises the perception of pool operators on the changes in swimming pool water quality and chemical consumption after the installation of the Poolactif process.

Table 3. Perception of the Poolactif performance on water quality

Swimming Pool	Before the Poolactif process	After the Poolactif process
Coogee Randwick RSL club		• Use less acid to adjust pH • Water is a lot better • Odour is improved • less chlorine usage but no figures
Swiss Grand Hotel	• Pool looked slightly milky • Chlorine smell • Sore eyes • Cracking dry skin	• Chlorine smell reduced • Water is clear • No sore eyes
Fairfield City Leisure Centre	• No detailed complaints • Water was cloudy	• Water is clear • Seems less odours in air • Chlorine usage seems slightly reduced but there is no detailed figures

It should be noted that the above observations were made from the perception of the pool operators.

Analytical results for the Swiss Grand Hotel swimming pool water quality before and after installation of Poolactif

The University of NSW and the Fairfield City Leisure centre had installed the Poolactif processes a few years ago and there was no data to compare the change in water quality from these pools. The impacts of the Poolactif process on swimming pool water quality could only be studied by comparing the changes in water quality before and after the installation of the Poolactif process at the Swiss Grand Hotel at Bondi Beach.

The analytical results of pool water at Swiss Grand Hotel are summarised in the Table 4. Table 4 summarises **only** the changes in water quality.

Table 4. Change of pool water quality at Swiss Grand Hotel due to the Poolactif process (71 days after installation)

Parameter	Unit	Before Poolactif	After Poolactif
TOC	mg/L	19.6	18
DOC	mg/L	19.4	17.5
Acetaldehyde	ug/L	716	<100
Acetone	ug/L	275	<100
Formaldehyde	ug/L	587	114
Total aldehyde	ug/L	1940	114
MEK	ug/L	357	<100
THM	ug/L	589	277
DCAA	ug/L	891	221
TCAA	ug/L	1320	315
BCAA	ug/L	16	13
BDCAA	ug/L	9	12

This table shows that the Poolactif process did have an impact on the swimming pool water quality. The most profound improvements of water quality were in organic matter such as aldehyde, haloacetic acid and THMs.

Conclusions

- There were measurable reduction in the disinfection by-products present in the swimming pool water during commissioning of Poolactif at one pool (ie in recirculation mode).

3.2 Laboratory Investigation for drinking water application

Laboratory experiments were carried out to study the effects of this process on drinking water quality. Unlike the study on swimming pool water, the water used in the laboratory investigations was treated according to the drinking water standards at the North Richmond WFP or at the Prospect WFP. Unlike the swimming pool water, the drinking water was very clean and had a low level of organic matter.

A number of experiments were carried out under different operational modes.

3.2.1 West Ryde tap water: using circulation mode (Exp1)

Aim: To study the effect of Poolactif process on the quality of chloraminated tap water in circulation mode.

Run 1: (01/08/2002)

Tap water taken from the Pilot Plant Room was used in this study to fill the water tank. This water was treated by the Prospect WFP. A submersible pump in the water tank was used to recirculate water through the Poolactif system while O_3 was continuously injected through the venturi. The pump had a maximum flow rate of 13700 L/h, however the actual circulation flow rate was thought to be less than this and is unknown.

In this run, the experiment lasted for 5.75 hours. The total O_3 injection time was the same. The water tank volume was 2700 L. An accumulative total O_3 dose into the tap water in this run was 0.64 mg O_3/L.
After comparing the quality of the water samples taken before and at the end of the experiment, the results for the parameters listed in Table 5 were found to be different.

Table 5. Change in the water sample quality before and after the experiment.

Parameter	**Before experiment**	**End of experiment**
NO_2 (mg/L)	0.004	0.001
True colour (400nm)	2	<2
pH	7.88	7.79
Odour (odour level)	1	2
Acetaldehyde (µg/L)	512	444
Formaldehyde (µg/L)	346	<100
Total aldehyde (µg/L)	858	444
THM (µg/L)	52	45
TCAA (µg/L)	5	<1

The total aldehyde level in the water appeared abnormally high in this experiment. It may have been caused by a contamination from the water tank or submersible pump. The results in this table show that the Poolactif process appeared to have a measurable impact on the volatile organic compounds in the water.

3.2.4 North Richmond WFP filtered water with free chlorine: using the circulation mode (Exp4)

Aim: To study the effect of Poolactif process on the quality of filtered water from the North Richmond WFP in a circulation mode (with free chlorine residual)

Run 1: (21/08/2002 to 26/08/2002)

After the flow through experiment using chlorinated water, the experiment was switched to circulation mode so that there was no discharge of the Poolactif process treated water into the drain. All the Poolactif treated water was returned back to the water tank. The circulation experiment started at 13:00 hrs on 21/08/2002 and finished at 17:00 hrs on 26/08/2002.

The Poolactif process was used to treat the filtered water during normal working hours only. The total duration of injection time is listed in Table 11 and was 25.5 hours. The total volume of treated water was 1250 L. Cumulative O_3 injected into the water was therefore:

25.5 h * 0.3 g/h / 1250 L = 0.00612 g/L = 6.12 mg/L based on the claimed O_3 generation rate

Table 11. Time of the Poolactif treatment

Date	Start time	Stop time	Total hours for the Poolactif process treatment
21/8/02	13:00	17:00	4
22/8/02	9:30	16:00	10.5
23/8/02	9:00	17:00	18.5
26/8/02	10:00	17:00	25.5

Table 12 clearly shows a decrease in the UV absorbance with the time of recirculation. The UV_{254} absorbance is caused by the presence of unsaturated organic compounds. Ozone is particularly reactive with unsaturated groups, cleaving the carbon-carbon double bond to produce aldehydes, ketones or acids depending on the constituents, amount of ozone and contact conditions applied. The UV absorbance in this experiment decreased gradually as the amount of ozone injected from Poolactif increased. Similarly, increments in the concentration of aldehyde were also observed. There had also been an upward trend in the concentration of haloacetic acids. The THM concentrations were reduced as the ozone dose was applied.

Table 12. Effect of the Poolactif process on the filtered water quality from North Richmond WFP

Analyte	Before circulation (dose=0 mg O_3/L)	10.5 hr after circulation (dose=2.47 mg O_3/L)	25.5 hr after circulation (dose=6 mg O_3/L)
Turbidity (NTU)	0.24	0.19	0.36
UV254 (abs/10mm)	0.027	0.018	0.016
TOC (mg/L)	2.7	2.3	1.9
DOC (mg/L)	2.5	2.2	1.8
THM (µg/L)	41	34	13
DCAA (µg/L)	7	11	9
TCAA (µg/L)	6	7	9
BCAA (µg/L)	5	8	6
BDCAA (µg/L)	4	3	5

The changes in selected water quality parameters after the Poolactif process treatment are summarised in Table 17. Chlorate and nitrate increased slightly, and, ammonia-nitrogen and total nitrogen decreased in the experiment. The calculated total O_3 dosage was 4.8 mg/L based on the design O_3 generation rate.

Table 17. Changes in selected water quality parameters after Poolactif process in mono-chloramine environment

	Date	Total treatment time (hr)	Chlorite (mg/L)	Chlorate (mg/L)	NH_3 (mg/L as N)	NO_3 (mg/L as N)	NO_2 (mg/L as N)	TN (mg/L as N)
Start	18/9/02	0	<0.01	4.76	0.73	0.8	0.001	1.69
	18/9/02	7	<0.01	4.93	0.67	0.84	0.002	1.72
	19/9/02	15	<0.01	4.79	0.57	0.91	0.002	1.64
End	20/9/02	23	<0.01	4.88	0.52	0.96	0.001	1.62

Conclusions

- Ammoniacal nitrogen decreased while the level of nitrate increased. Overall the total nitrogen decreased slightly

- In contrast to experiment 1 the Poolactif process have an effect on ammoniacal nitrogen/total nitrogen levels under recirculating conditions.

4. Summary discussion of the analytical results

4.1 TOC/DOC, UV254, Fluorescence

TOC/DOC, UV254 absorption, and Fluorescence are all indicators of various organic compounds present in water. TOC/DOC is a gross measure, while UV absorption and fluorescence are indicators of particular types of compounds.

The effect or impact of the Poolactif process on TOC/DOC could only be observed in the recirculation mode experiment using North Richmond WFP filtered water, and then only after a long (10 hours approx.) experiment time. Table 18 summarises the results.

Table 18. Effect of the Poolactif process on TOC/DOC in North Richmond WFP filtered water in circulation mode

Analyte	**Before circulation (dose=0 mg O_3/L)**	**10.5 hr after circulation (dose=2.47 mg O_3/L)**	**25.5 hr after circulation (dose=6 mg O_3/L)**
TOC (mg/L)	2.7	2.3	1.9
DOC (mg/L)	2.5	2.2	1.8

Thus it can be concluded that the ozone is slowly oxidising organic compounds present.

A similar conclusion can be drawn from the UV254 absorption results. In the flow through mode experiment, the effect of the Poolactif process on the UV_{254nm} absorbance of North Richmond WFP filtered water appeared to be very small. In the recirculation mode experiment however, **there was a significant reduction (41%)** in UV_{254nm} absorbance in North Richmond WFP filtered water after 26 hours continuous treatment by the Poolactif process.

Fluorescence typically detects organics with the double bonds. Higher absorbance represents a higher level of double bonds or organic matter in the water. After an initial measurement indicated significant change in fluorescence a test was conducted in the first load of North Richmond filtered water to further examine this change involving both flow through and recirculation modes.

The impact of the Poolactif on fluorescence intensity of this water is shown in Figure 5. The fluorescence intensities of the various samples in decreasing order are:

- Nth Richmond dual media filtered water
- Ozonated Nth Richmond dual media filtered water – single pass
- chlorinated Nth Richmond dual media filtered water – single pass
- Ozonated + chlorinated Nth Richmond dual media filtered water – single pass
- Ozonated + chlorinated Nth Richmond dual media filtered water – 12hr recirculated
- Ozonated + chlorinated Nth Richmond dual media filtered water – 27hr recirculated

- Milli Q water (as a background).

That is the figure shows that fluorescence intensity decreased as treatment time increased. The aromatic compounds in the water were oxidised gradually when more oxidants (chlorine and O_3) were added into the water.

Changes of fluorescence intensity of treated water at selected wavelength were summarised in Table 19. At each wavelength, fluorescence intensity decreased when the water was treated by more ozone.

Table 19. Effect of the Poolactif on fluorescence intensity of water

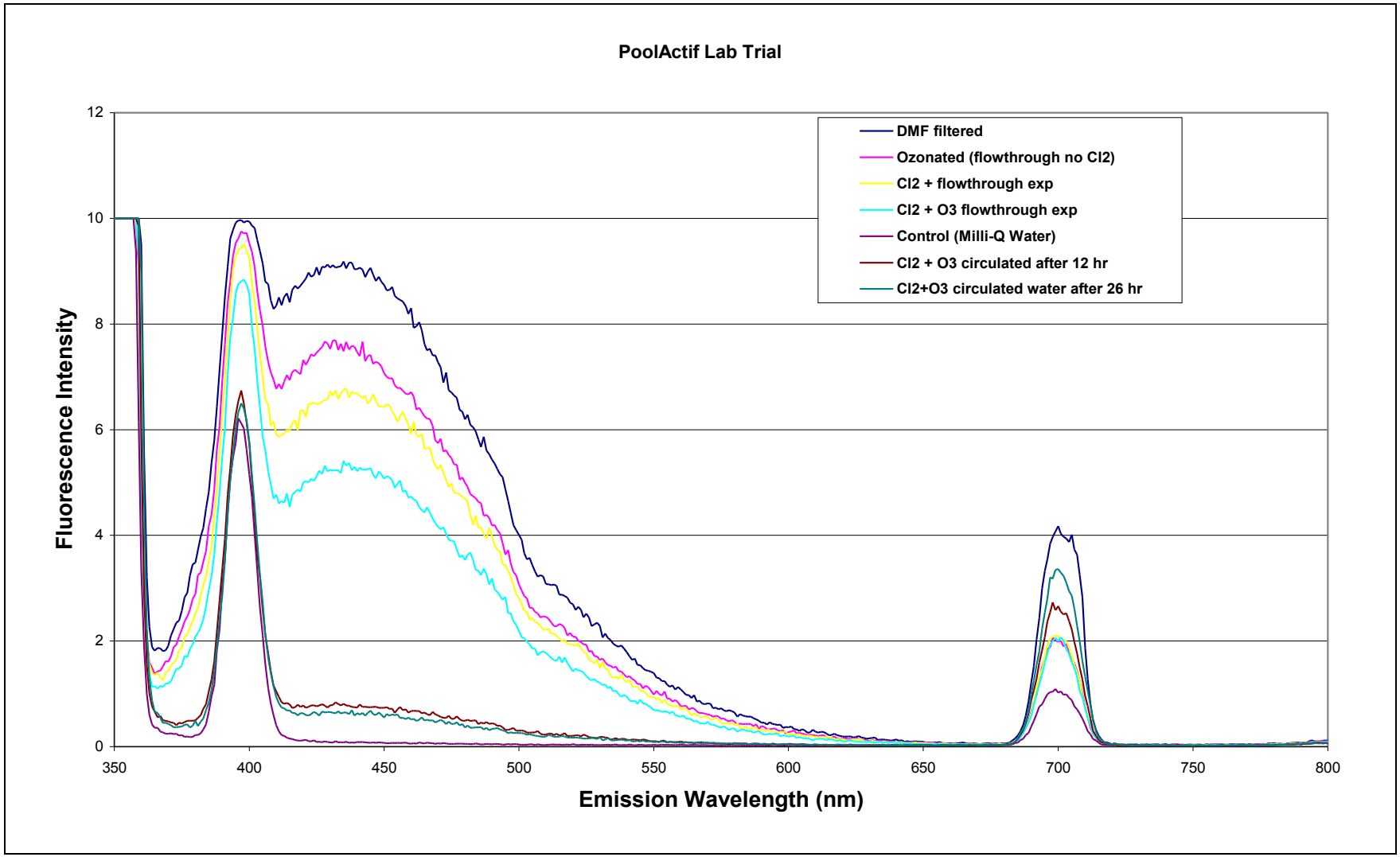
Wave length	**430nm**	**431nm**
Sample	**Absorbance**	**Absorbance**
DMF filtered	9.06799	9.11285
Ozonated (flowthrough no Cl_2)	7.52747	7.68433
End of flowthrough + chlorination	6.72729	6.64001
Cl_2 + O_3 flowthrough experiment	5.23773	5.224
Cl_2 + O_3 circulated after 12 hr	0.782166	0.784302
Cl_2+O_3 circulated water on 27/08/02	0.652161	0.64209
Milli Q Water	0.081787	0.076599

Thus it is very clear that the ozone is steadily oxidising the organic compounds present over time as ozone is continually added. One key implication of this is that it would appear that the impact of the Poolactif process on the water quality is stoichiometric and thus follows conventional thinking regarding the chemistry and use of O_3 for oxidation.

4.2 Total trihalomethanes (THMs)

THM formation is related to the organic compounds present and the breakdown products that occur through oxidation/halogenation of them. Thus it could be expected that the flow through experiments would show no impact (small ozone dose & short reaction time) where as after a long period of treatment by the Poolactif process under a recirculation mode there would be an impact. This prediction is matched by the results. Poolactif had no effect on THMs formation in the flowthrough mode. **In the circulation mode a sixty-eight percent reduction in the THM level** of the North Richmond filtered water was found after 26 hours of continuous treatment of the Poolactif process.

Figure 5. Effect of the Poolactif process on the fluorescence intensity of filtered water from the North Richmond WFP



4.3 Other disinfection by-products (haloacetic acid)

A similar prediction to the THM performance might also be expected for HAAs. The results however, appeared to show that the Poolactif process had no effect on the haloacetic acid level in the North Richmond filtered water over the recirculation times tested. It may be that a longer treatment time may lead to a reduction in the HAAs as well. HAAs are not particularly volatile and thus this no effect on HAAs could also indicate that the drop in THMs was not due to the ozone addition but rather due to their relatively high volatility. That is they were driven off to the atmosphere during recirculation.

4.7 Nitrogen

Despite the no impact observed in experiment no 1 it would appear that the Poolactif process may have an effect on ammoniacal nitrogen/total nitrogen levels over a long treatment period of time (10 hours approx.) under recirculating conditions.

5. Conclusions and recommendations

Effect of the Poolactif process on drinking water

- The Poolactif process did appear to have a significant effect on the quality of both the tap water from Prospect WFP and filtered water from North Richmond WFP in the **recirculation** experiment after a long period of time (say more than ten hours of continuous operation). The effects were usually shown in the indicators (eg. TOC, DOC, UV254, fluorescence, THMs, etc) associated with the levels of organic compounds in the water. After a relatively long time (ie. 10 hours and more), these indicators generally decreased (with the exception of haloacetic acids.

- It appears fairly clear that the ozone is steadily oxidising the organic compounds present over time as ozone is continually added in the recirculation loop. The key implication of this is that it would appear that the impact of the Poolactif process on the water quality is stoichiometric and thus would follow conventional thinking regarding the chemistry and use of ozone for oxidation.

- It is concluded that the use of Poolactif in its current form (ie low continuous dose) is unlikely to be useful for open water treatment applications such as WFPs where the water is a single pass system. The Poolactif system is really likely to be useful/effective for closed loop systems where the water is continuously recirculated such as swimming pools, cooling towers, water reservoirs etc.

Reference

APHA, AWWA, WEF (1992) Standard Methods for the Examination of Water and Wastewater, 18th edition.