

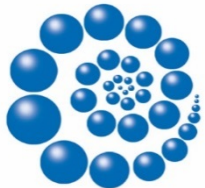
INFLUENCE OF PRE-OZONATION AND MEDIA TYPE ON BIOLOGICAL ACTIVATED CARBON (BAC) PERFORMANCE

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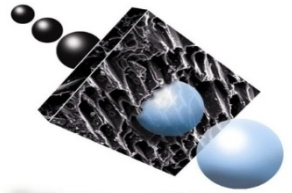
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Overview

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- * Methodology/ Process
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 - * Mineral Content
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- * Conclusions

Introduction/ Background - 2014

- * BAC Aging Profile in May 2014 at Kyneton WTP showed significantly higher Mn compared to 2013
- * Ozonators had been shut down for 8 days prior to the 2014 BAC sampling
- * Concern about leaching Mn when ozonators re-started lead to an investigation about what form the Mn was in – biological or chemical
- * Found elevated biology (plate counts and SEM) across the entire bed and highly distributed Mn
- * BAC Aging Profile in September 2014, when ozonation operating, found a reduction of Mn and biology at lower depths

Introduction/ Background - 2015

- * Following on from the full scale plant studies at Kyneton, four BAC pilot columns were commissioned at Castlemaine WTP from June – September 2015
 - * Two columns – Full scale BAC media (surface)
 - * Two columns – Sterilised BAC media (surface)
 - * Fed with ozonated water
 - * EBCT 30 minutes
- * Sterilised columns leached high amounts of Mn and DOC for 20 days
- * Took 50 days for the sterilised columns to match the DOC reduction of the non-sterilised columns
- * Note: experiments conducted during winter (cool water temp)

Introduction/ Background - 2016

- * Following on from the previous studies this pilot trial looked at the performance of two different virgin carbons
 - * Acticarb GA1000N
 - * Acticarb GS1300
- * Compare the performance of the carbons and how adsorbance and biological processes contribute to filtered water quality
- * Evaluate the impact of ozonation on feed water quality and BAC performance
- * Analyse the carbon after the trial and compare physical and biological parameters

Methodology/ Process

- * Five BAC pilot columns were commissioned at Castlemaine WTP from Nov 2015 – July 2016
 - * Column 1 – Established BAC media from the onsite filters
 - * Column 2 – Acticarb GA1000N 8x30 mesh - steam activated, coal based activated carbon
 - * Columns 3-5 – Acticarb GS1300 8x30 mesh - steam activated, coal based activated carbon
 - * Columns 1-4 - Ozonated feed water
 - * Column 5 – Non-ozonated (membrane filtered) water
 - * EBCT 12 minutes, backwashed weekly

Methodology/ Process

- * Column inlet, outlet, and full scale BAC effluent monitored for the following
 - * pH, DO, turbidity
 - * Organics – DOC, BDOC, UV254, Colour
 - * Minerals – Total and soluble aluminium, iron, manganese and calcium
 - * Biological – plate counts, ATP
 - * Nutrients and media analysis (plate counts, ATP, and DNA profiling) were conducted seasonally
- * After the trial the media was analysed for
 - * Adsorptive capacity
 - * Mineral content

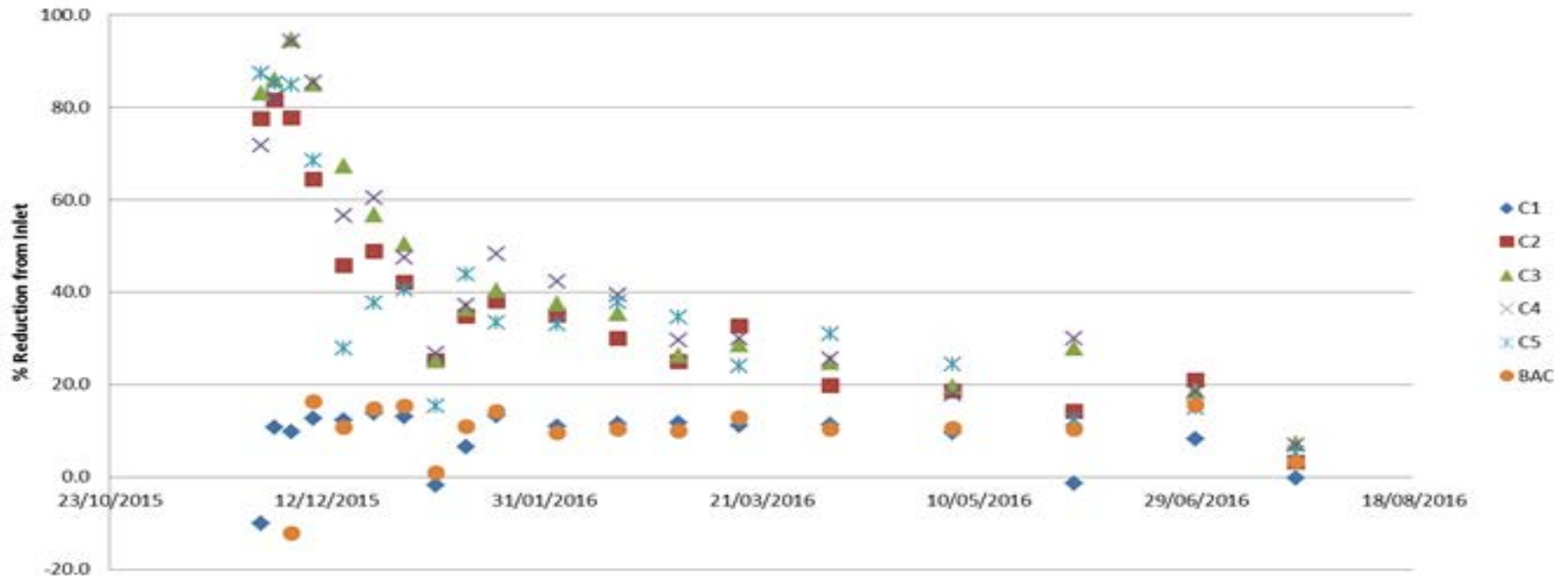
Feed Water Quality

* Full data in the paper, key points

Parameter	<i>n</i>	Ozonated Feed (Columns 1-4)			CMF Feed (Column 5)		
		<i>Mean</i>	<i>Min</i>	<i>Max</i>	<i>Mean</i>	<i>Min</i>	<i>Max</i>
Temp (°C)	34	16.8	8.9	21.8	16.8	8.9	21.8
Ozone Residual (mg/L)	34	0.33	0.17	0.48	NA	NA	NA
Colour (CPU)	19	1.1	0.1	1.6	2.6	0.5	4.8
UV254 (Abs/cm)	19	0.046	0.063	0.033	0.078	0.047	0.099
DOC (mg/L)	19	4.2	3.2	4.9	4.3	3.1	5.0
BDOC (mg/L)	16	1.1	0.5	1.7	0.7	<0.1	1.6
Soluble Manganese (mg/L)	17	0.007	<0.001	0.049	0.005	<0.001	0.041
Total Phosphorus (mg/L)	2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Organics Reduction

Castlemaine Pilot Plant Trial - DOC Reduction



Organics Reduction

- * Initially the virgin carbons showed strong DOC removal:
 - * Acticarb GS1300 (Columns 3 and 4) – 95 and 94% reduction
 - * Acticarb GS1300 (Column 5 (non ozonated feed) – 87%
 - * Acticarb GA1000N (Column 2) – 82%
- * Column 1 (BAC from the full scale plant) showed similar DOC reduction to the full scale plant (BAC) – 8% and 12% respec.
- * Ozonation significantly reduced Inlet water colour and UV254 (59 and 41% respectively).
- * Ozonation increased the [BDOC] of the feed water by 65%.
- * Column 5 showed slightly lower BDOC concentration (average 0.4 mg BDOC/L) than the columns fed with ozonated water.

Organics Reduction

- * In ozonated feed water, Acticarb GS1300 had consistently better organics reduction throughout the trial

	GS1300 (Columns 3/4)	GA1000N (Column 2)	GS1300 no ozone (Column 5)
Av. DOC Reduction (%)	47	40	41
Av. BDOC Reduction (%)	52	47	38
Av. UV ₂₅₄ Reduction (%)	53	45	56
Av. Colour Reduction (%)	67	49	79

Organics Reduction

- * After the initial adsorptive period the average DOC reduction was between 25 and 30% for the virgin carbons and 8% for Column 1.
- * As the water temperature dropped the % average DOC reduction also dropped with Columns 3/4 showing the best DOC reduction at 18%.
- * Column 5 (non-ozonated) showed similar DOC reduction at 14%.
- * BDOC concentrations in the effluent leaving the ozonated columns were very similar (0.5-0.6mg/L) even when the water temperature dropped

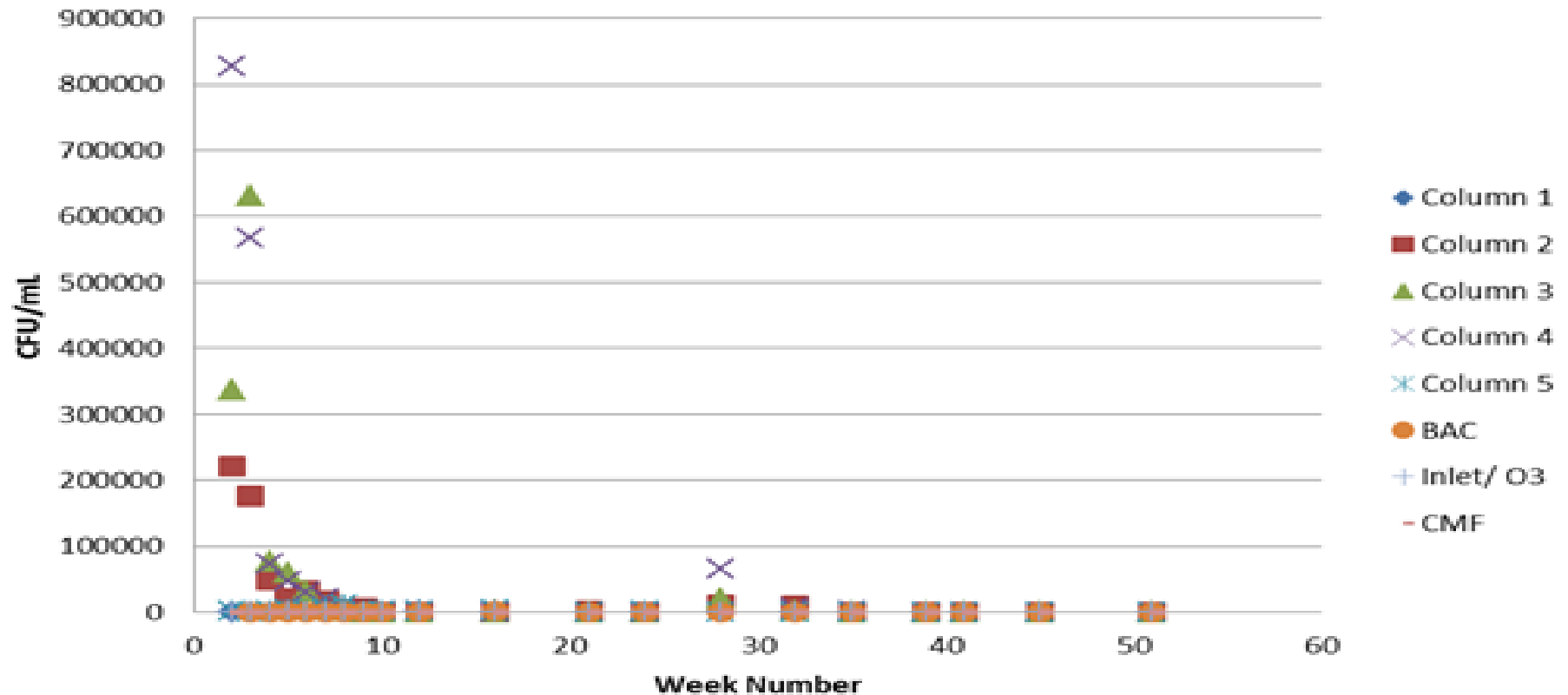
Mineral Content

- * Aluminium, iron and manganese levels throughout the trial were relatively low.
- * Mn concentration in the feed water increased in May and June
- * Best performing was the full scale plant, closely followed by Column 5 (the non-ozonated column) and Column 1 (the old media)
- * This suggests that the mechanism for manganese reduction is biological rather than adsorptive

Biological Indicators

- * Dissolved oxygen, plate counts and ATP concentrations of the column effluents were used as indicators of biological stability
- * DO levels showed a consistent decrease from the feed water (average all columns = 2ppm)
- * In addition to analysis of the water, samples of the media were analysed for plate counts, ATP, SEM and DNA profiling

Colony Counts in Water

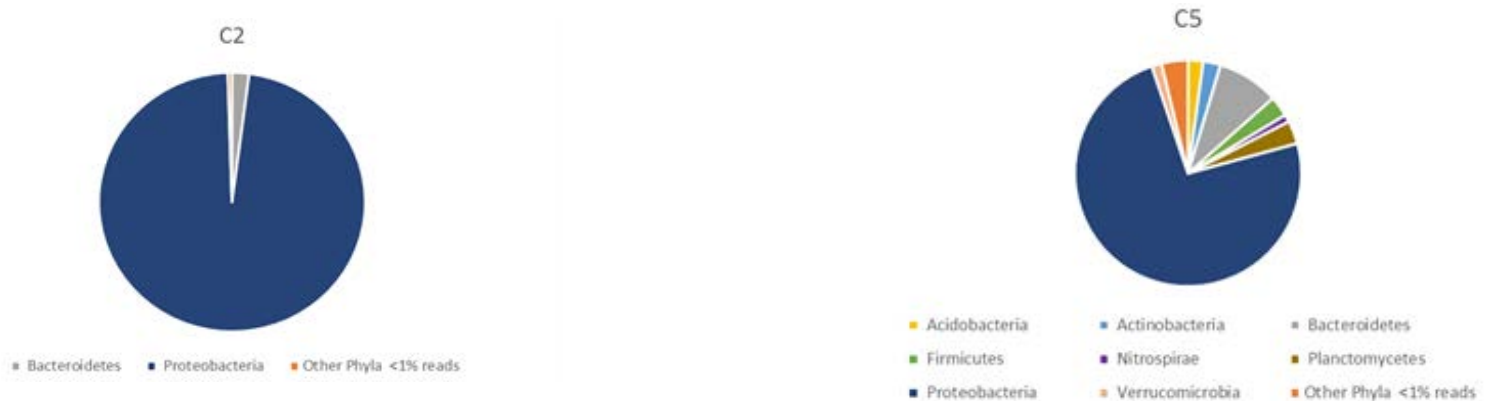


Biological Indicators - Media

- * Plate counts on the media were highest in December – this correlated strongly with the high plate counts of the water suggesting that the biological density was not yet stable (easily extracted from the carbon media)
- * September data showed lower ATP concentration in the media throughout all the columns most likely due to the cooler water temperatures.
- * In warmer weather the ATP concentration on the GS1300 (Columns 3 and 4) was significantly higher (up to 46%) than the GA1000N

Biological Indicators – DNA

DNA profiling of the May and November 2016 media samples showed greater biological diversity on non-ozonated C5 media



Biological Indicators – DNA

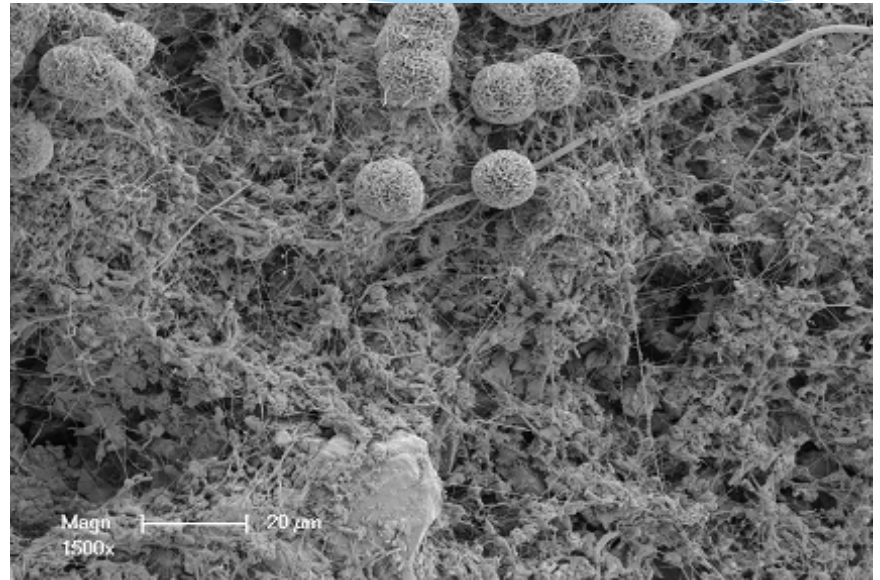
- * Ozonated feed columns with Acticarb GS1300 showed greater biological diversity than those with GA1000N
- * Protobacteria were the predominant species in all columns – include most common heterotrophs and Mn oxidising species
- * Bacteroidetes more abundant in November, capable of surviving in low nutrient environments

Biological Indicators – SEM

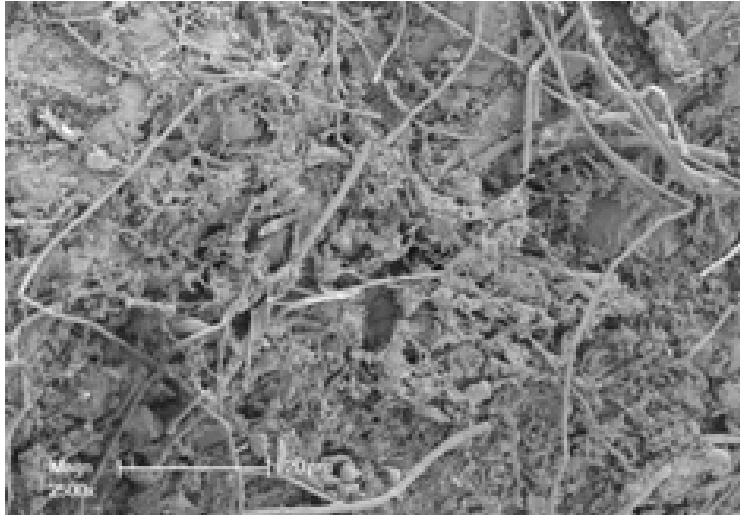
- * Evidence of biogenic structures in ozonated feed columns
- * Notably different biofilm distribution seen in non-ozonated column 5
- * Greater assortment of rod-shaped bacteria, and gallionella present for first time
- * Photos curtesy of Bio 21 University of Melbourne

Biological Indicators - SEM

- * Biogenic dome structures observed in Column 2
- * Thought to be related to Mn oxidation



Biological Indicators - SEM



- * Rod like bacteria, Column 5 (non-ozonated feed)
- * C5 had greatest biological diversity

Activated Carbon Analysis

Sample	Iodine Number	Total Ash Content (%)	Acid Soluble Ash Content (%)	Acid Soluble Ash Composition (mg/ g AC)						Volatile Content (%)
				Al	Ca	Fe	Mn	P	S	
GA1000N (virgin)	921	5.6	4.6	5.4	2.7	4.9	0.1	<0.5	2.7	
GS1300 (virgin)	1278	13.2	8.7	39.0	8.2	36.5	0.9	1.8	5.5	
BAC	302	18.1	11.8	31.3	101.7	8.9	26.3	1.4	16.8	28.6
Column 1	441	11.4	8.6	34.6	76.9	8.7	16.9	0.7	17.8	27.7
Column 2	681	4.8	1.9	4.8	10.0	4.4	0.9	<0.5	7.7	12.8
Column 3	671	17.9	5.1	21.4	16.6	25.9	2.6	1.0	12.4	14.7
Column 4	738	12.9	5.6	26.4	18.6	27.0	3.0	1.2	13.2	14.3
Column 5	719	10.7	6.2	24.9	24.4	25.5	2.4	0.8	16.0	18.6

Activated Carbon Analysis

- * Iodine number of GS1300 dropped to be similar to that of GA1000N by end of project
- * GS1300 carbon in ozonated and non-ozonated feed columns had similar iodine number and mineral levels
 - * Suggests that number of adsorptive sites available for biological regeneration similar for both conditions
- * Ca, Mn, P and S levels all increased but still significantly less than full scale BAC and “in use” carbon (C1)

CONCLUSIONS

- * Pre-ozonation and carbon type seen to influence treated water quality
- * Pre-ozonation provides significant reduction of UV254 and colour although BAC predominantly provides DOC reduction
- * Ozonation increases BDOC of feed water however all columns had similar DOC in the effluent
- * In ozonated feed water, Acticarb GS1300 had consistently better organics reduction throughout the trial
- * Plate counts and ATP levels of the media were higher in the warmer water temperatures which was consistent with higher DOC reduction
- * Ozonated feed columns with Acticarb GS1300 showed greater biological diversity than those with GA1000N however the most biological diversity was seen in the non-ozonated feed
- * At the conclusion of the trial both the carbons in ozonated and non-ozonated feed columns had similar iodine number and mineral levels which suggests that number of adsorptive sites available for biological regeneration were similar for both conditions

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