行政院國家科學委員會專題研究計畫 成果報告

飲用水加氯消毒對消毒副產物生成及微生物再生之效應研究
研究成果報告(精簡版)

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報告附件：出席國際會議研究心得報告及發表論文
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中華民國96年10月31日
Effects of Chlorine Disinfection on DBPs Formation and Microbial Regrowth

Abstract

This study elucidated the characteristics of DBP formation in drinking water. The study was separated into three parts: 1) effects of prechlorination on algae cells and its impacts on DBP formation; 2) chlorination of selected model compounds and DBP formation; 3) degradation of DBPs in distribution system. The third part of this study is still in progress, and this report covers the first and the second parts. The first part (chlorination of algal cells and impacts on DBP formation) has been presented in 2007 ACS National Meeting, and the second part has been submitted to 2008 World Water Congress for possible presentation.

The effect of pre-chlorination on the trihalomethanes (THMs) and haloacetic acids (HAAs) formation from Microcystis aeruginosa was investigated. M. aeruginosa was cultivated under both batch and chemostat modes and harvested at different growth phases, and the formation of disinfection byproducts (DBPs) from the algal suspensions and extracellular organic matter (EOM) in the water treatment processes with and without pre-chlorination were measured. The results showed that pretreatment with 4 mg/L of chlorine increased chloroform formation potential by 62–113 μg/L and 12–23 μg/L from M. aeruginosa cultivated in batch culture and in chemostat, respectively. After conventional treatment processes, the pre-chlorination results in 10–50% decrease in overall DBPs precursor removal. When 0.5 mg/L of bromide was spiked into the algal suspension, the DBPs formation shifted from chlorinated to brominated species. Furthermore, the results of THM formation potential (THMFP) tests showed that the algae cultivated at the lower temperature water released less intracellular organic matter and less amounts of THMs precursors after pre-chlorination than that cultivated at the higher temperature water. Chlorine reactivities with model compounds are also studied. The results demonstrated that aromatic precursors favor the chlorine-DBPs formation; however, a major portion of bromine-DBPs was observed when the aromatic precursors were oxidized by chlorine.

Keywords: Disinfection byproducts, prechlorination, eutrophication, organic precursors.

INTRODUCTION

Chlorine is widely used as the primary disinfectant in water treatment process for protection of public health. In addition, chlorine may also be used as a pre-oxidant for the oxidation of many reduced inorganic species and organic pollutants in raw water. When eutrophicated water is used as the raw water, algae cells and their excreted metabolic products may be present in the water
and contribute to the formation of DBPs. In general, factors affecting DBP formation include algae species, algal growth phase, and reaction condition such as pH, chlorine dose, and contact time. It has been reported that algae cells and biomass play the major role in THM production while the extracellular products (ECP) produces only a small fraction of DBPs. The ECP of algae may not be effectively removed by the traditional water treatment processes while algae cells can be removed in the coagulation and filtration units.

In this study, the effects of prechlorination on DBPs formation from *M. aeruginosa* were assessed. The specific objectives were (i) to determine the effects of incubation modes on algal growth; (ii) to determine DBPs formation from algal suspensions and EOM; (iii) to determine the effects of prechlorination on DBPs formation from algal suspensions after water treatment processes. In addition, the structure of the organic precursors also affects the THMs species distribution. In general, aromatic precursors favor chlorine reactions and aliphatic precursors favor bromine reactions. The chlorine reactivity with different model compounds were also evaluated.

**EXPERIMENTAL**

**Algal Culturing**

Axenic culture of *M. aeruginosa* (cyanobacterium, strain 4044) obtained from Academic Sinica in Taiwan was cultured and investigated in batch mode and chemostat. In batch culture, *M. aeruginosa* was grown in a 22-L custom-made cultivation tank containing 15 L of the synthetic sterilized algal growth media that was modified from M-11. Cultures received 1500~2000 Lux of light on a 14-h light/10-h dark cycle and the water temperatures were maintained at 24±1°C. For chemostat mode, *M. aeruginosa* was cultured in a continuously mixed, 15-L custom-made cultivation tank. The chemostat reactor was supplied with a constant inflow of synthetic sterilized algal growth media, and was cultivated at a dilution rate of 0.3/day at 24±1°C, supplied with filtered air, and provided with 1500~2000 Lux of illumination on a 14-h light/10-h dark cycle.

**Simulation of Water Treatment Processes**

For pre-chlorination treatment, 4 mg/L chlorine (prepared with NaOCl) was added into 1500 mL of the incubated algal suspensions (denoted as the raw water), stirred evenly and kept still for thirty minutes. For coagulation, reagent grade aluminum sulfate (Nacalai Tesque, Kyoto, Japan) was used as coagulant in jar-test experiments. Prior to addition of the coagulants, the pH of the samples was adjusted to 5 with H2SO4 and/or NaOH. Following the addition of the 20 mg/L of alum, the jars were rapidly mixed at 100 rpm for 1 minute, flocculation occurred while stirring at 20 rpm for 30 minutes and quiescent settling for thirty minutes. The supernatant was withdrawn and filtered with 1 μm membrane filter (denoted as the filtered water) for further analysis. In order to differentiate the EOM contribution to DBP precursors, the algal suspensions were filtered with 0.45 μm filters to remove the algal cells.

**Chlorine Reactivity with Model Compounds**

Four model organic precursors are used in this study to represent the THMs precursors with different structures: resorcinol, phloroglucinol, hydroquinone and 1,7-heptanediol. Although with similar structure, the preliminary tests showed that the three aromatic precursors have different THMs formation potentials. The THMFP measurement follows the procedures described in section 5710B of the Standard Methods. Four THMs were quantified by a GC/MS (Agilent 6890GC/5973MSD) using a fused silica capillary column. Bromide was spiked at 0 and 0.5 mg/L in THMFP tests for comparisons.

**RESULTS**

**Effect of Pre-chlorination on Algal Suspensions and EOM**

Table 1 shows the effect of pre-chlorination on the NPDOC concentration of the bulk algal suspensions. For *M. aeruginosa* growing in batch culture and collected at the 10th, 20th, and 45th day, the treatment processes resulted in a NPDOC removal from 1.96, 2.31, and 4.10 mg/L to 0.83, 1.57, and 3.44 mg/L, respectively, when pre-chlorination was not applied. On the other hand, the pre-chlorination increased the NPDOC of raw water to 3.53, 4.82 and 7.64 mg/L, respectively, at different growth phase; and the NPDOC was 2.95, 3.51, and 5.48 mg/L, respectively, after treatments. After pre-chlorination, the NPDOC of raw water almost doubled for *M. aeruginosa* growing in batch mode, and similar results were observed for chemostat mode. From the data in Table 2, it appeared that the increase of NPDOC in raw water resulted from the liberation of the intracellular organic matter from algal cells. The lysing of algal cells due to chlorine oxidation will contribute to the NPDOC and hence the DBP precursors in the chlorinated raw water, in particular for algae in batch culture.

**THMs Formation from Algal Suspensions**

THMFP from *M. aeruginosa* suspension in batch culture with and without pre-chlorination is shown in Figure 1. Without pre-chlorination, it is observed that 498, 1397 and 2623 μg/L of chloroform formation were obtained from water samples taken on the 10th, 20th and 45th day of cultivation in batch mode. A significant increase of THM precursors accompanying the algal growth was observed. After the coagulation and sedimentation processes, a 70–90% reduction of chloroform precursors was obtained. However, the
filtration process only exhibited a limited ability to remove more THM precursors. When 4 mg/L of pre-chlorine was applied in the raw water, the chloroform formation was about the same as obtained without pre-chlorination. However, a slight increase of chloroform yield was noticed, especially in the filtered water (discussed later).

Figure 2 shows the chloroform formation from the algal suspensions in chemostat mode that was collected on the 10th, 20th and 30th day of cultivation. Without pre-chlorination, the three raw water samples produced 80, 123, and 115 μg/L of chloroform, respectively. Unlike that in the batch culture, the algae cultivated in chemostat did not produce more chloroform precursors with the increasing growth time. The coagulation and sedimentation treatments reduces 53–77% of the chloroform precursors for samples taken from the chemostate. For filtered water, however, additional 10% of THM precursors removal was obtained. On the other hand, when the samples were pretreated with 4 mg/L of chlorine, the chloroform formation was about the same as obtained without pre-chlorination in the raw and settled water. But no additional THM precursor removal was obtained after filtration when pre-chlorination was applied.

**THMs Formation from EOM**

Figure 3 shows the chloroform formation from EOM (ECP plus released intracellular products after pre-chlorination) in batch culture treated with the same processes as described in the previous section for algal suspensions. The chloroform formation in raw water were lower than that obtained from algal suspensions; however, the chloroform formation in filtered water were about the same as those obtained from algal suspensions (see Figure 1). For comparison, Figure 4 shows the chloroform formation from EOM in chemostat mode. The effects of pre-chlorination on chloroform formation are much more apparent in Figure 4. Without pre-chlorination, the EOM (ECP only) in chemostat mode produced a nearly constant quantity of chloroform throughout the treatment train. With 4 mg/L of pre-chlorine addition in the raw water, however, the chloroform formation was tripled for the raw water samples. The sedimentation unit removed about 50% of the chloroform formation potential, but no further removal was found in filtration unit.

Results in Figures 1 to 4 indicate that the primary source of chloroform precursors in the filtered water of the algal suspensions comes from the EOM (ECP only) of the algal cells, and the ECP can not be effectively removed by the conventional water treatment process. When raw water is treated with pre-chlorination, the algal cells was oxidized and released the intracellular organic matter into the water because of cell lysing. The cell lysing contributes to the DBP precursors and increase the THM formation potential in the treated water.

Table 2 summarizes the percentage removal of THM precursors for algal suspension and EOM samples after treatment processes (filtered water THMFP vs. raw water THMFP). For EOM in chemostat mode, the treatment processes remove 23% of the THM precursors when pre-chlorination was not applied; and the THM precursors percentage removal increased to 45–48% when samples were pre-chlorinated. It has been shown that the intracellular matters comprised high molecular weight organic compounds like humic acid while ECP were composed of low molecular weight organic matter (11). The high molecular weight intracellular organic matters that produced from cell lysing after pre-chlorination could be partially removed by coagulation and settling units when it is transferred into water. After pre-chlorination, however, it should be noted that the DBPFP is still higher than those without pre-chlorination. For batch mode, the EOM didn’t show this phenomenon since the 4 mg/L pre-chlorine dosage is not high enough to oxidize the algal cells in raw water. When the bulk algal suspensions were used for treatments, essentially all of the samples without pre-chlorination gave better percentage removal of THM precursors than that of the samples with pre-chlorination. **Chlorine Reactivity with Model Compounds**

As examples of THMFP tests, Figures 5 and 6 give the THMFP of resorcinol and 1,7-heptanediol. The aromatic resorcinol gives a very high THMFP – as high as 18,000 μg/L of THMFP when the concentration of resorcinol is 8 mg/L as dissolved organic carbon (DOC). For comparison, the THMFP of 1,7-heptanediol is quite low – only 50 μg/L of chloroform when bromide is not spiked. When bromide is spiked at 0.5 mg/L, a higher THMFP was obtained for 1,7-heptanediol (no apparent increase on total THMFP for resorcinol was observed when bromide was spiked). For chlorogluconol and hydroquinone, the THMFP tests give similar trends as shown in Figure 1; however, a lower total THMFP were obtained. The chlorine dosages in THMFP tests are very high (100 mg/L) so that suitable chlorine residuals after THMFP tests can be obtained. When chlorine dosages are not enough, the THMFP tests may give different results. As shown in Figure 3, the total THMFP decreases with increasing resorcinol concentrations; and no bromine-THMs are formed when bromide was spiked in the solution. The result in Figure 7 is consistent with general concept for DBP characteristic of aromatic precursors – the aromatic precursors favor chlorine reactions to form chloroform. However, the addition of higher chlorine dosages will change the resorcinol structure. Figure 8 showed that resorcinol was degraded to some products when chlorine was added, and higher chlorine dosage formed more degradation products. The chlorine may break the aromatic ring so that the degradation products can react
with chlorine/bromine to form bromine-THMs when bromide is spiked, as shown in Figures 5 and 7.

**References**

### TABLE 1. NPDOC of algal suspensions with and without pre-chlorination

<table>
<thead>
<tr>
<th>Cultivation time</th>
<th>Without pre-chlorination</th>
<th>With pre-chlorination</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raw Filtered</td>
<td>Raw Filtered</td>
</tr>
<tr>
<td>Batch culture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10\textsuperscript{th} day</td>
<td>1.96 0.83</td>
<td>3.53 2.95</td>
</tr>
<tr>
<td>20\textsuperscript{th} day</td>
<td>2.31 1.57</td>
<td>4.82 3.51</td>
</tr>
<tr>
<td>45\textsuperscript{th} day</td>
<td>4.10 3.44</td>
<td>7.64 5.48</td>
</tr>
<tr>
<td>Chemostat (24±1 °C)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10\textsuperscript{th} day</td>
<td>1.13 0.92</td>
<td>1.82 1.45</td>
</tr>
<tr>
<td>20\textsuperscript{th} day</td>
<td>1.38 1.25</td>
<td>2.18 1.63</td>
</tr>
<tr>
<td>30\textsuperscript{th} day</td>
<td>1.57 1.36</td>
<td>2.27 1.75</td>
</tr>
</tbody>
</table>

**NOTE:** The unit of NPDOC is mg/L.

The filtered water has gone through coagulation/flocculation and sedimentation units.

### TABLE 2. THMFP percentage removal for algal suspensions after water treatment processes with and without pre-chlorination

<table>
<thead>
<tr>
<th>Cultivation time</th>
<th>EOM Algal suspensions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No pre-Cl\textsubscript{2}</td>
</tr>
<tr>
<td>Batch culture</td>
<td></td>
</tr>
<tr>
<td>10\textsuperscript{th} day</td>
<td>94.3 43.7</td>
</tr>
<tr>
<td>20\textsuperscript{th} day</td>
<td>68.6 69.3</td>
</tr>
<tr>
<td>45\textsuperscript{th} day</td>
<td>71.2 70.3</td>
</tr>
<tr>
<td>Chemostat (24±1 °C)</td>
<td></td>
</tr>
<tr>
<td>10\textsuperscript{th} day</td>
<td>0.0\textsuperscript{*}</td>
</tr>
<tr>
<td>20\textsuperscript{th} day</td>
<td>19.5 45.3</td>
</tr>
<tr>
<td>30\textsuperscript{th} day</td>
<td>22.7 47.7</td>
</tr>
</tbody>
</table>

\textsuperscript{*}No apparent THMFP removal was observed.
Figure 1  Effect of prechlorination on chloroform formation for algal suspensions (in batch culture).

Figure 2  Effect of pre-chlorination on chloroform formation for algal suspensions (in chemostat).

Figure 3  Effect of pre-chlorination on chloroform formation for EOM (in batch culture).

Figure 4  Effect of pre-chlorination on chloroform formation for EOM (in chemostat).
Figure 5  THMFP of resorcinol ([resorcinol] = 2, 5 and 8 mg/L as DOC, [Cl$_2$]$_0$ = 100 mg/l.)

Figure 6  THMFP of heptanediol ([heptanediol] = 2, 5 and 8 mg/L as DOC, [Cl$_2$]$_0$ = 100 mg/l.)

Figure 7  THMFP of resorcinol ([resorcinol] = 2, 5 and 8 mg/L as DOC, [Cl$_2$]$_0$ = 10 mg/l.)

Figure 8  HPLC chromatogram of resorcinol with and without addition of chlorine.

[Cl$_2$] = 0 mg/L  
[Cl$_2$] = 20 mg/L
參加美國化學會年會報告
American Chemical Society 233rd National Meeting

會議時間：2007 March 25 ～ 29.
會議地點：美國伊利諾州芝加哥市
報告人：王根樹（國立台灣大學公共衛生學系）

1. 前言

美國化學會（American Chemical Society）所舉辦之年會及儀器展為化學界最盛大的國際研討會之一。ACS 年會每年春、秋兩季輪流於美國主要城市舉辦，本年度春季年會於 2007.3.25. 至 2007.3.29. 於芝加哥市舉行。ACS 年會已舉辦超過 100 年，規模龐大，為世界化學界之盛事；雖為美國之化學專業研討會，但吸引各國化學領域人員參加。由於 ACS 有數十個不同之 Division，每個 Division 有區隔成數個至十餘個 Sub division，因此全國會議舉行時均由各個 Division 分別進行論文蒐集、審查及發表工作。由於同時有數十個會場進行論文發表，一般會議中心無法提供如此多之會場，本次年會分別在芝加哥市最大之 McCormick Place（分成三個彼此相連卻又獨立運作之會議中心）以及市中心幾個大旅館之會議中心舉行會議。以筆者參與之 Environmental Chemistry Division 而言，筆者主要參與之消毒副產物論壇（DBPs Symposium）口頭發表會場位於芝加哥南區之 McCormick Place North 會場（亦為 Environmental Chemistry Division 各專業論壇之會場集中地）但壁報論文會場則位於芝加哥市中心之 Hyatt 旅館，兩地距離超過 30 分鐘車程。

本次 ACS 年會總參加人數達一萬二千人以上，發表論文近千篇，參與國際人士亦無法計數（僅國際委員會之歡迎茶會即有 400 人參加）。如同筆者往年常參與之 AWWA 年會，ACS 年會亦兼具學術與實務功能，除了專業學術論文發表外，亦針對化學領域實務操作及管理議題加以探討，此點與我國舉辦之學術會議參加人員幾全為學術界人事之現象有很大之差異。

2. 本次大會內容

本次 ACS 年會共分成 33 個 Division Meeting，涵蓋範圍自基礎之有機、無機、物理等基礎化學至應用領域之農業、毒理、環保、法規等應用化學。各不同 Division 再依其涵蓋範圍規劃不同之論文主題。以筆者所參與之環境化學 Division 爲例，即包含十個環境化學相關之主題（包括污染物質傳輸、空氣化學、水化學、能源、復育等），各個不同主題再細分其論文類別。筆者所參與之論文發表即屬於環境化學 Division 所涵蓋之「消毒副產物之生成、控制及健康效應論壇」（Occurrence, Formation, Health Effects
and Control of Disinfection By-Products in Drinking Water). This symposium covered all drinking water disinfection by-products research topics, with a total of 6 sessions, each featuring 8 oral papers, and an additional poster session, where research personnel from various research units and the United States participated. The symposium was organized by ACS Environment Division, four mid-generation scholars (aged 45-50), continuing the previous disinfection by-products symposium (the last was in the 1990s). The symposium was peer-reviewed and compiled into ACS Symposium Series, listed in SCI, and published in late 2007.

This symposium allowed participants to participate in ACS annual meetings. The main reason was because the author participated in AWWA annual conferences and published related DBP research papers, so he was invited to submit papers and became a member of ACS. The author's published papers have passed initial review and been submitted to ACS Symposium Series. This symposium also let the author know that THMs, HAA5, etc. research has gradually passed, and current DBP research is gradually shifting to new disinfection by-products (such as NDMA). In the future, new research topics must be developed to compete with other researchers.

3. The author's paper
The author's submitted poster paper was: Pre-chlorination Induced DOC and DBPs Formation from Microcystis aeruginosa in Treatment Processes. The water treatment plants in Taiwan have adopted pre-chlorination for pollution control. When raw water contains algae, especially from highly eutrophic sources, it may increase the concentration of disinfection by-products in drinking water, posing health risks.

The research conducted various laboratory experiments to simulate water treatment processes with or without pre-chlorination, algae cell and extracellular contributions, temperature effects, bromide and chloride competition, and THMs and HAAs generation. The results showed that pre-chlorination increased disinfection by-products in drinking water.
物質的含量，且這些前趨物質是由於藻類細胞破裂，釋出胞內物質而產生的；藻類細胞所產生的有機物大多為脂肪族的前趨物質，因此在形成消毒副產物時溴離子會增加其生成量1-2倍；而前加氯的氧化力對於低溫(17-20℃)環境培養下的藻類細胞作用較小。以往之研究多以水中溶解性有機物為對象，本研究則以藻體為目標物進行探討。有趣的是在會場聆聽中發現大陸哈爾濱工業大學亦正進行類似研究。

4. 心得與建議

本次參與 ACS 年會，注意到自來水研究已逐漸走向跨校合作及國際化，所執行之研究計畫常由跨國團隊共同進行，其品質遠非筆者這種「單打獨鬥」行的研究所能比擬。未來若不能加強科技整合並參與其他研究團隊共同研究，並進一步與國際研究人員合作，未來恐無法在學術研究領域立足。

此次研討會也讓筆者知道目前所進行之 THM、HAA 等研究已逐漸過時，目前之 DBP 研究已漸漸朝新興消毒副產物（以含氮之 DBP 爲主，如 NDMA）。未來必須開發新的研究題目方能與其他研究人員競爭。會後與美國亞歷山那州立大學（Arizona State University）之 Paul Westerhoff 教授聯絡，請教其所進行含氮 DBP 物種研究概況。Paul Westerhoff 教授為此次會議主辦人之一，筆者於 2006 年參與 AWWA 會議時與其認識。蒙 Paul Westerhoff 教授協助，提供其近年所進行研究相關資料，並應允未來將協助筆者進行 N-DBP 之研究，筆者已與研究室人員研商，預定暑假開始進行 N-DBP 之前置試驗，配合現有 C-DBP 之研究設備及成果，在現有研究架構及成果為基礎下轉移研究主題，以與世界研究主流接軌。

本次參與 ACS 年會有機會參與國際研究人員之聚會。由於過去參與國際研討會，能有機會認識到國外貴賓，此次前往 ACS 年會即互相聯絡，並能透過此機會參與一些聚會，對提升國際視野有很大的幫助，未來應多參與此類活動，以增加與國際研究人員接觸的機會。
參加美國化學會年會報告
American Chemical Society 233rd National Meeting

會議地點：美國伊利諾州芝加哥市
報告人：王根樹（國立台灣大學公共衛生學系）

1. 前言

美國化學會（American Chemical Society）所舉辦之年會及儀器展是化學界最盛大的國際研討會之一。ACS 年會每年春、秋兩季輪流於美國主要城市舉辦，本年度春季年會於 2007.3.25 至 2007.3.29 於芝加哥市舉行。ACS 年會已舉辦超過 100 年，規模龐大，為世界化學界之盛事；雖為美國之化學專業研討會，但吸引各國化學領域人員參加。由於 ACS 有數十個不同之 Division，每個 Division 有區隔成數個至十餘個 Sub division，因此全國會議舉行時均由各個 Division 進行論文蒐集、審查及發表工作。由於同時有數十個會場進行論文發表，一般會議中心無法提供如此多之會場，本次年會分別在芝加哥市最大之 McCormick Place（分成三個彼此相連卻又獨立運作之會議中心）以及市中心幾個大旅館之會議中心舉行會議。以筆者參與之 Environmental Chemistry Division 而言，筆者主要參與之消毒副產物論壇（DBPs Symposium）口頭發表會場位於芝加哥市之 McCormick Place North 會場（亦爲 Environmental Chemistry Division 各專業論壇之會場集中地）但壁報論文會場則位於芝加哥市中心之 Hyatt 旅館，兩地距離超過 30 分鐘車程。

本次 ACS 年會總參加人數達一萬二千人以上，發表論文近千篇，參加國際人士亦無法計數（僅國際委員會之歡迎茶會即有 400 人參加）。如同筆者往年常參與之 AWWA 年會，ACS 年會亦兼具學術與實務功能，除了專業學術論文發表外，亦針對化學領域實務操作及管理議題加以探討，此點與我國舉辦之學術會議參加人員幾全為學術界人事之現象有很大之差異。

2. 本次大會內容

本次 ACS 年會共分成 33 個 Division Meeting，涵蓋範圍自基礎之有機、無機、物化等基礎化學至應用領域之農業、毒理、環境、法規等應用化學。各不同 Division 再依其涵蓋範圍規劃不同之論文主題。以筆者所參與之環境化學 Division 爲例，即包含十個環境化學相關之主題（包括污染物質傳輸、空氣化學、水化學、能源、復育等），各個主題再細分其論文類別。筆者所參與之論文發表即屬於環境化學 Division 所涵蓋之「消毒副產物之生成、控制及健康效應論壇」（Occurrence, Formation, Health Effects
and Control of Disinfection By-Products in Drinking Water). This forum covers all drinking water disinfection by-products research themes, with 6 sessions arranged. Each session has 8 oral papers, and there is another poster session, where university and consultant company researchers present their latest research results. These sessions are usually full of researchers from various research units, and it is also a good opportunity to meet senior researchers from various parts of the United States.

This disinfection by-products forum is led by ACS Environmental Chemistry Division four mid-career academics (with ages around 45-50), and continues the previous two disinfection by-products forums (at the same time in the early 1990s). This forum has been approved by ACS and will collect the papers presented at the forum, after peer review, and compile them into ACS Symposium Series (SCI journals), scheduled for publication in 2007.

The author of this paper participated in the ACS conference's disinfection by-products forum, mainly because the author has been participating in AWWA conferences and publishing DBP-related papers, and the author has received invitations to submit papers and become a member of ACS. The author's paper has already been peer reviewed and has been submitted to ACS Symposium Series.

A significant point that can be derived from this conference is that THMs and HAAs are no longer the main focus of research. Currently, research is gradually shifting towards new disinfection by-products, such as NDMA, and new research topics must be developed to compete with other researchers.

3. The author's paper

The author's published oral presentation was: Pre-chlorination Induced DOC and DBPs Formation from Microcystis aeruginosa in Treatment Processes. Water treatment plants, during the treatment process, adopt advanced oxidation techniques to oxidize contaminants and other organic matter, and reduce the burden of subsequent coagulation, sedimentation, and filtration units, and reduce operation costs. However, chlorination can increase the occurrence of disinfection by-products, especially when the source water contains algae cells or comes from highly eutrophic sources. This study simulates the water treatment process using laboratory-bred algal water and discusses the differences between chlorination and non-chlorination, algae cells and extracellular material, temperature effects, chlorination and bromination competition, and the formation of THMs and HAAs. The results show that chlorination can increase the occurrence of disinfection by-products.
物前趨物質的含量，且這部份前趨物質是因為藻類細胞破裂，釋出胞內物質而產生的；藻類細胞所產生的有機物大都為脂肪族的前趨物質，因此在形成消毒副產物時溴離子會增加其生成量 1~2 倍；而前加氯的氧化力對於低溫(17~20℃)環境培養下的藻類細胞作用較小。以往之研究多以水中溶解性有機物為對象，本研究則以藻體為目標物進行探討。有趣的是在會場聆聽中發現大陸哈爾濱工業大學亦正進行類似研究。

4. 心得與建議

本次參與 ACS 年會，注意到自來水研究已逐漸走向跨校合作及國際化，所執行之研究計畫常由跨國團隊共同進行，其品質遠非筆者這種「單打獨鬥」行的研究所能比擬。未來若不能加強科技整合並參與其他研究團隊共同研究，並進一步與國際研究人員合作，未來恐無法在學術研究領域立足。

此次研討會也讓筆者知道目前所進行之 THM、HAA 等研究已逐漸過時，目前之 DBP 研究已漸漸朝新興消毒副產物（以含氮之 DBP 爲主，如 NDMA）；未來必須開發新的研究題目方能與其他研究人員競爭。會後與美國亞歷山那州立大學（Arizona State University）之 Paul Westerhoff 教授聯絡，請教其所進行含氮 DBP 物種研究概況。Paul Westerhoff 教授為此次會議主辦人之一，筆者於 2006 年參與 AWWA 會議時與其認識。蒙 Paul Westerhoff 教授協助，提供其近年所進行研究相關資料，並應允未來將協助筆者進行 N-DBP 之研究，筆者已與研究室人員研商，預定暑假開始進行 N-DBP 之前置試驗，配合現有 C-DBP 之研究設備及成果，在現有研究架構及成果為基礎下轉移研究主題，以與世界研究主流接軌。

本次參與 ACS 年會有機會參與國際研究人員之聚會。由於過去參與國際研討會，能有機會認識到國外貴賓，此次前往 ACS 年會即互相聯絡，並能透過此機會參與一些聚會，對提升國際視野有很大的幫助，未來應多參與此類活動，以增加與國際研究人員接觸的機會。