

行政院及所屬各機關出國報告提要

出國報告名稱：

因應發電廠空污防治措施強化後之廢水處理改善技術及策略之規畫

頁數 29 含附件：是 否

出國計畫主辦機關/聯絡人/電話

台灣電力股份有限公司人力資源處/陳德隆/02-23667685

出國人員姓名/服務機關/單位/職稱/電話

沈宗華/台灣電力股份有限公司/環境保護處/資深專業工程師/02-23668657

出國類別：1 考察 2 進修 3 研究 4 實習 5 開會 6 其他

出國期間：107 年 11 月 1 日至 107 年 11 月 10 日

派赴國家/地區：美國

報告日期：108 年 1 月 2 日

關鍵詞：燃煤/燃氣火力發電廠(coal/gas-fired power plant)、煙氣脫硫

(FGD)、零排放(ZLD)、廢水處理(waste water treatment)

內容摘要：(二百至三百字)

歐美等先進國家火力發電已採取更高端之廢水處理技術，並提升用水回收比例，其中零排放(ZLD, Zero Liquid Discharge)技術之應用已逐漸提升，本公司亦應研究採用該技術完全回收廢水不再排放。尤其新設電廠之規畫，電廠營運長達 40 年，為因應未來發展，應該將廢汙水零排放(ZLD)之觀念納入設計，於整廠規畫時預留相關設施之空間，依相關技術之發展逐步建置廢水零排放(ZLD)設施，如此即無超標遭罰之虞，亦可提升公司綠色企業形象，值得參採引進。

本文電子檔已傳至公務出國報告資訊網 (<https://report.nat.gov.tw/reportwork>)

出國報告（出國類別：考察）

因應發電廠空污防治措施強化後之廢 水處理改善技術及策略之規畫

服務機關：台灣電力公司

職 稱：13 等資深專業工程師

姓 名：沈宗華

派赴國家：美國

出國期間：107 年 11 月 01 日

報告日期：107 年 11 月 10 日

因應發電廠空污防治措施強化後之廢水處理改善技術及策略之規畫考察報告目錄

一、考察緣起及目的	1
二、考察行程規劃	1
三、考察內容及過程	2
1. 參訪美國德州拉馬爾大學(Lamar University)的水及空氣 品質發展中心.....	2
2. 參加2018年國際水會議(International Water Conference)	5
3. 參訪南加州Magnolia Power Plant (MPP)	25
四、考察心得及建議	28

因應發電廠空污防治措施強化後之廢水處理改善技術及策略之規畫考察報告

一、考察緣起及目的

近年國內秋冬季節受大氣擴散作用不良及境外污染物影響，空氣污染情況嚴重引發各界關注，火力發電機組除配合降載外並提升防制設備效能，由於環保署近期將參照美國聯邦環保署汽力機組放流水加嚴標準修訂我國法規，重點在汞、砷、硒及氮系化合物等，一旦發布後可能僅有 3~6 年之緩衝期限，必須及時完成改善，符合新管制標準，造成後續之廢水處理系統極大壓力。

歐美等先進國家之火力發電已採取更高端之廢水處理技術，並提升用水回收比例，其中零排放(ZLD, Zero Liquid Discharge)技術已逐漸被採用，本公司亦應研究採用該技術之可行性，若能完全回收廢水不再排放，如此即無超標遭罰之虞，亦可提升公司綠色企業形象，值得參採引進。

二、考察行程規劃

為能了解研究單位、專業顧問機構以及發電廠對於廢水處理方面的研究趨勢，規劃方向及實際應用情況，本次考察可分 3 個階段進行，分別 1、參訪美國德州 Lamar University 的 The Center for Advances in Water and Air Quality (CAWAQ)中心；2、赴亞利桑那州參加 2018 國際水會議 International Water

Conference (IWC)；3、參訪美國加州 Magnolia 發電廠廢水零排放(Zero Liquid Discharge，ZLD)系統。

由這 3 個領域中蒐集各項資料，作為未來電廠各項廢水處理規畫設計之參考。

三、考察經過及內容

(一)、參訪美國德州拉馬爾大學(Lamar University)的水及空氣品質發展中心(The Center for Advances in Water and Air Quality，CAWAQ)中心。

1. 該中心主管 C. Jerry Lin 博士在拉馬爾大學的水研究實驗室專注於傳統和先進處理系統的研發規劃和設計實施，以及工業用水的優化和管理。CAWAQ 中心研究項目涵蓋各項環境議題，包括管理石油、天然氣及能源行業的放流水和空氣排放品質，空氣和水中各種污染物的傳輸和產生之影響，淡水供應的質量以及沿海地區環境（包括港口和水道）的水和空氣之品質，還包括有關水和空氣對社會經濟影響，及維護水和空氣品質環境之因應政策擬訂等。

COLLEGE OF ENGINEERING
LAMAR UNIVERSITY
 Center for Advances in Water & Air Quality

C. Jerry Lin, Ph.D. P.E.
 Director, Center for Advances in Water & Air Quality
 Professor, Environmental Engineering
 Jerry.Lin@lamar.edu; (409) 330-3483

Center for Advances in Water & Air Quality
 Promotes understanding of critical environmental issues and develops solutions for mitigating challenges in water and air quality faced by industries and global community through research, educational programs, and community outreach.

Focus Areas

- Water-energy-food nexus
- Management of water discharge & air emission in oil, gas & energy industries
- Water & air quality in coastal environment
- Fresh water availability & quality in Texas
- Fate & transport of pollutants in air and water

Programs

- Research**
 - Flaring operation and process optimization for air emission reduction and cost saving
 - Industrial research collaboration grants
 - Development of long-term research programs in Center's focus areas
- Outreach**
 - Industrial partnership for water reuse, recycle and regeneration
 - Community engagement in water conservation and rainwater harvesting
 - Texas water availability and sustainability
 - Public seminars
- Education**
 - Undergraduate & graduate research in air and water
 - STEM programs for K-12 teachers and students
 - Master of Science programs in environmental science and engineering
 - Workshops on air quality and water technology

Working together for a sustainable future

2. 該中心對於環境中水和空氣的相互關係的數值模式也有研究，模式經由參數化和對複雜的相互作用進行科學分析計算，並經過嚴格的模式驗證和評估後，可作為污染事件的預測工具。提供決策單位制定管理水和空氣品質法規提供了寶貴的參考數據。在環境評估工作中，模式的一項重要功能是可以預測評估排放源對環境影響相對貢獻量及驗證並研擬因應對策。

COLLEGE OF ENGINEERING
LAMAR UNIVERSITY
 Center for Advances in Water & Air Quality

C. Jerry Lin, Ph.D. P.E.
 Professor, Environmental Engineering
 Jerry.Lin@lamar.edu; (409) 330-3483

Fate & Transport of Pollutants in the Environment

Introduction
 Air emission and water discharge introduce anthropogenic pollutants into the environment. The physical, chemical and biological transformations of pollutants in atmospheric and aquatic environments play a critical role in their toxicity and environmental profiles that make health, social and ecological effects. Sophisticated analytical and modeling tools are required to understand the complex interactions between the released pollutants and natural constituents. This understanding forms the basis for policy making and environmental protection programs to water and air quality.

Dr. Lin's Environmental Modeling & Assessment Laboratory develops, evaluates and applies first-principle and statistical models to determine the cause of pollution events, to delineate pollution source-receptor relationship, and to understand the global biogeochemical cycling of persistent pollutants.

Model Development & Evaluation
 Atmospheric & aquatic models are mathematical representations of occurring processes in the natural environment. The parameterization and formulation allow scientific analysis of complicated interactions and serve as predictive tools for pollution events that require detailed simulation and evaluation.

Intercontinental Transport of Pollutants
 Long-lived air pollutants (e.g., mercury & toxic organics) are persistent in the environment and subject to long-range transport on regional and global scales. Under favorable meteorological conditions, transport of air pollutants from East Asia to North America take 7-10 days. Such events can be simulated using atmospheric circulation models coupled with chemistry modules describing deposition & chemical transformation.

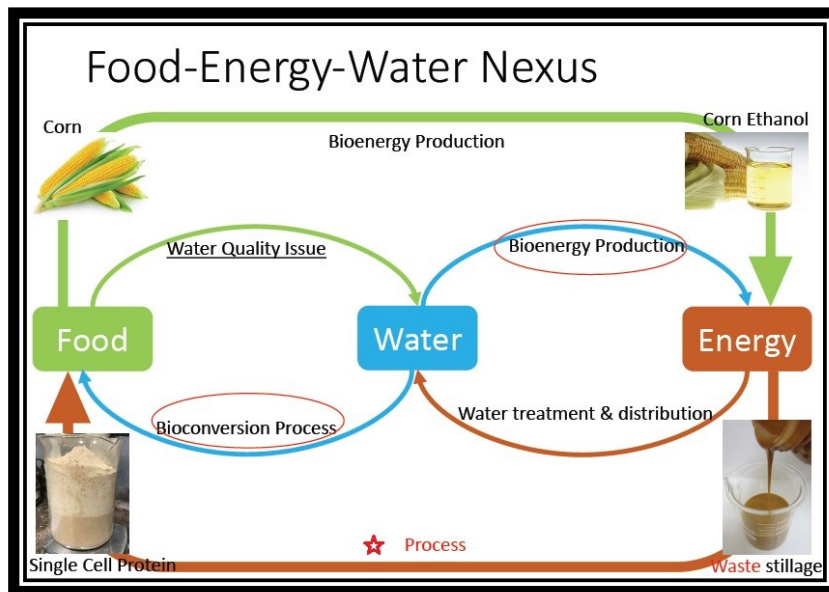
Biogeochemical Cycling
 Pollutants undergo regional to global cycling via biogeochemical processes that distribute the pollutant in different environmental compartments (soil, air, water, biomass, etc.). Using process model coupled with stable isotope tracing techniques, the transformation and degradation of pollutants can be confidently determined.

Source Apportionment of Pollutants
 An important task in environmental assessment is to identify the emission sources and determine their relative contributions to the pollution. Such apportionments provide valuable data for policy makers to formulate strategies for water and air quality management. Using first-principle models, the emissions from a specific source can be isolated and the source contribution to a pollution incident can be calculated based on the source strength, the regional degree of emissions reduction to attain air/water quality goals and their estimated.

Relative strength of contributing emission source comparison

Students: F. Prognoskova (DI, 2007); I. Shah (MS, 2010); J. Collins (MS, 2010); S. Shetty (Ph.D., 2011); F. Singhank (DI, 2013); L. Cai (Ph.D., 2014); W. Zhu (Ph.D., 2015). **Funding:** US Environmental Protection Agency; Exxon Commission on Environmental Quality; National Science Foundation of China.

3. 該中心最新研究的議題是，生質能源製造過程廢水處理之後水的回收及汙泥之應用，CAWAQ 中心接受業界委託，將汙泥經過特種微生物分解後產生單細胞蛋白(Single Cell Protein)的產品並應用於海產養殖之飼料使用，不但減少廢棄物數量，並創造廢棄物資源再利用及提升附加價值之效應，其成果應可作為參考。



參觀實驗室及先導型操作設施



先導型設施所生產的高價值附產品-單細胞蛋白質

(二)、 參加 2018 年國際水會議(International Water Conference IWC)

1. 國際水會議 IWC 之緣起

該會議歷史悠久自 1940 起每年舉辦，內容涵括各項有關水資源相關議題及最新技術發展情況之研討，除獎勵在水領域特殊貢獻及優秀的研發人員外，並辦理相關技術的教育訓練課程，使得在校相關科系的學生及年輕工程師有深入學習最新技術及交換經驗的機會。

今年度 2018 年國際水會議是第 79 屆，該研討會於 107 年 11 月 4 至 8 日在美國亞利桑那州 鳳凰城 Scottsdale 的 Talking Stick Resort 舉行，本次考察行程期間特別請美國 Stantec 顧問公司安排順道前往參與盛會，在會場並見到本公司退休同仁前綜合研究所水處理專家陳茂景組長，陳組長除了在水處理技術方面非常專業外，還經常赴先進國家及中國大陸參訪電廠水處理設施

及最新技術發展應用情況，陳組長長期關注國際水會議 IWC 的發展及歷年的研究成果，對於國際間水處理之技術發展及趨勢有深刻之瞭解。

國際水會議之會場同時還舉辦了各顧問機構及水處理相關設施研發製造廠家參與展覽。



IWC 國際水會議展場



與美國 Stantec 顧問公司技術人員及陳組長會談



參訪水處理設施廠商 Duraflow 公司



研討會現場

2. 會議相關內容

IWC 國際水會議除辦理各項水處理技術之發展及應用成果發表會之外，為表彰獎勵工業用水技術領域的傑出人員，每年 IWC 國際水會議都會由前一屆（2017 年第 78 屆）IWC 國際水會議所發表論文及常年參與會務工作績效優異者，經評選程序後頒發水處理相關三類獎項：

A. 年度優異獎 Annual Merit Award

IWC 國際水會議今年的優異獎獲得者是 Peter Meyers。他目前在 ResinTech 公司工作，並經常在 IWC 國際水會議擔任主持人，並參加 IWC 諮詢委員會，歷年來對會務貢獻良多。

B.保羅科恩獎—Paul Cohen Award

此獎是為紀念保羅科恩 Paul Cohen 對電力行業的貢獻而設，今年由 Mr. Akash Trivedi 獲得此獎，在去年(2017)第 78 屆 IWC 國際水會議上，提出的電力系統水技術領域最精確和最具創新性著作：Case Study: On-Line Chloride and Sulfate Measurement by Microfluidic Capillary Electrophoresis.。

C.首次論文發表者和整體最佳論文獎—First Time Presenter and Overall Best Paper Award

本獎項每年頒發給首次在前一屆（2017 年第 78 屆）IWC 國際水會議發表論文作者中經評選最佳者，以及參與 IWC 國際水會議論文中總體表現，最能清楚地說明對水資源利用、水化學的新理解或傳達最佳新知識信息，並能提供對工業用水或其他有益於維護人類生存環境用途的論文作者。

首次發表者獎(First Time Presenter)得主，是來自雅各布斯的 Chad Roby，論文：Closing the Bottom Ash Loop – Pilot Testing Treatment and Reuse for FGD Makeup。

最佳整體論文獎得主是來自 HDR 公司的 Dan Sampson 撰寫的：A Rock and a Hard Place – Managing use of Ammonia-laden Recycled Water.

3. 水技術及應用研討會各領域重點內容

本次研討會之內容簡述如下：

將因應環境需求冷卻水化學處理創新技術

Cooling Water Chemistry Innovations Support Environmental Needs: New Green

Chemicals, New Non-P Treatment, and Innovative Yellow Metal Treatment Technology in

Contaminated Water Reuse

IWC 18-01: State of Art of Natural Inhibitors of Calcium Carbonate Scaling: Last
Developments

IWC 18-02: New No P Scale Inhibitor for Inhibiting Scale under Highly Demanding
Conditions Such as Sea Water cooling and Thermal Desalination

IWC 18-03: Corrosion Inhibition with Azoles in a Cooling Water System with
Chloramine Contamination
水處理計畫

Water Projects: Delivering a Success

IWC 18-04: Project Considerations for Successful Execution of Water and Wastewater
Treatment Facilities

IWC 18-05: Utilizing Progressive Design-Build to Efficiently Complete Projects in the
Upstream Oil & Gas Sector

IWC 18-06: With the Chemistry Set, What' s Next? A Case Study to Deliver a Fast-
Tracked EPC Industrial Wastewater Project
逆滲透應用

Reverse Osmosis: The Application of a Very Important Tool

IWC 18-07: Reverse Osmosis vs Nanofiltration: Using Membrane Selectivity for Process

Advantage

IWC 18-08: The Practical Application of Ion Association Speciation Models to Mineral

Scale Formation and Control in High Ionic Strength Membrane Systems

IWC 18-09: A Case Study of Industrial Water Reuse and ZLD – 4 Years of Operation

and Lessons Learned

FGD 廢水處理

Nitty Gritty Details of FGD Wastewater Treatment

IWC 18-10: Plant-Scale Mass Balance to Determine the Effect of Flue Gas Additives on

Trace Metals in FGD Wastewater and Solids

IWC 18-11: Investigation of Constituent Volatility in Thermal Treatment of Flue Gas

Desulfurization Wastewater

IWC 18-12: Unforeseen Consequences of Cycling-Up Flue Gas Desulfurization (FGD)

Scrubber Water

鍋爐水污染物對鍋爐系統的影響

Boiler Water Contaminants and Their Effect on Boiler System Operations

IWC 18-13: How Do the Users of Ultrapure Water differ and What Drives Treatment

Decisions?

IWC 18-14: Flow-Accelerated Corrosion- What Is It and What to Do About It

IWC 18-15: Case Study: Monitoring and Controlling Corrosion Using On-Line Chloride
and Sulfate Measurement

IWC 18-16: Boiler Silica Excursion Results in Production Loss & Potential Plant
Shutdowns at an Ammonia Production Site

水處理設計的持續性發展 - 不僅僅是差異化因素，而是未來的競爭優勢

Sustainability in Water Treatment Design – Not Just a Differentiator, but the Future for
Gaining a Competitive Edge

IWC 18-17: Grey Water for Cooling Water Makeup: Mission Impossible

IWC 18-18: Sustainable Alternatives to Power Plant Make-up Water: Using Treated
Municipal Wastewater

IWC 18-19: Innovations in Water Treatments Employing Filming Amine Technology

IWC 18-20: Process Changes to Coal Fired Power Plant Gypsum Dewatering in a Postage
Stamp

污染物追蹤：檢測，清除和回收

Trace Contaminants: Detection, Removal and Recovery

IWC 18-21: Radium Removal from Potable Water Supplies

IWC 18-22: Water Treatment Residuals Management for Uranium Removal Using Ion
Exchange Media Re-certification and Reuse in Potable Water Systems

IWC 18-23: Compliance with Selenium Aquatic Life Criterion and the Importance of Speciation for Treatment Selection and Monitoring

IWC 18-24: Real-time, Continuous & Accurate Selenium Data Ensures a Reliable Selenium Removal Treatment

回收與再利用

Recycle and Reuse – Emerging Tools and Case Studies from Industry to Public-Private Partnerships

IWC 18-25: Upcoming Tools to Help Industry with Making the Business Case for Water Conservation Projects

IWC 18-26: Municipal Recycle Water Use for High Purity Manufacturing Processes, Lessons Learned

IWC 18-27: The Devil is in the Details – A Recycled Water Treatment Plant Case Study

IWC 18-28: Pharmaceutical Wastewater Reuse – Testing and Validating a Combination of Physicochemical, Biological and Membrane Processes

複循環機組廢水處理

ASME Session: Water Treatment for Combined Cycle Plants

IWC 18-29: Living in Perpetual Drought – Operational Impact of Power Plant Design Features to Minimize Water

IWC 18-30: Evaporative Cooler Water Requirements – The Letter and the Intent of the
Law

IWC 18-31: Experience Using a Film-Forming Corrosion Inhibitor at RWE Generation
UK’s Staythorpe Power Station

IWC 18-32: Decreasing Filterable Iron Levels in an Aircooled Condenser at a Combined
Cycle Power Plant

下一個創新的水處理技術

Next Treatment Level – Innovative Water

IWC 18-33: Technology Advances and Economic Optimization of Advanced Membrane
Brine Concentration and Zero Liquid Discharge

IWC 18-34: Development of a Fiber-Based Ion Exchange Material for Treatment of FGD
and Other Wastewaters

IWC 18-35: Canadian Thermal Oil Industry Water Technology Development Center
– Purpose, Design and Vision

IWC 18-36: Groundwater Remediation System Pilot and Operating Data

礦井水處理膜系統

Membranes for Mining

IWC 18-37: A New Membrane Based System for Mine Water Discharge Treatment

IWC 18-38: Three Years of Full Scale Water Treatment Plant Operational Experience
from Rare Earth Mining

IWC 18-39: MaxH₂O DESALTER Technology Treats Calcium Sulfate Saturated
Wastewater, a Perfect Solution for Treating Acid Mine Drainage Wastewater

IWC 18-40: Learnings from Phased Installation of a Permeable Reactive Barrier for Mine
Water Treatment

FGD 廢污水 - 處理、濃縮和固化

FGD Blowdown - Treatment, Concentration, and Solidification - Oh My

IWC 18-41: Brine Encapsulation as an Integral Step in Power Plant Wastewater Treatment

IWC 18-42: Application of Ultrafiltration for FGD Waste and Water Polishing,
Comparisons Pilot to Full Scale

IWC 18-43: A Scale-Resistant, Membrane-Based Solution for the Treatment of FGD
Wastewater to Meet EPA Guidelines

IWC 18-44: Wastewater and Brine Management using Encapsulation: Laboratory and Pilot
Testing Results, New Findings, and Testing Recommendations

汽電共生電廠蒸氣腐蝕及雜質控制

ASME Session: Controlling Corrosion and Impurities in Steam and Process Condensate

Industrial Cogeneration Plants

IWC 18-45: Measuring pH in Utility and Industrial Boiler Steam and Water Cycles

IWC 18-46: Evaluating Condensate Recovery and Treatment in Industrial Facilities

IWC 18-47: Key Production Plant Steam and Condensate System Factors that Impact

HRSG Feedwater Quality

IWC 18-48: A Reality Check on Condensate Polishing: A Discussion on Misconceptions

海水淡化的發展基礎

Fundamentals of Sustainable Desalination

IWC 18-49: Reverse Osmosis: A History and Explanation of the Technology and How It

Became So Important for Desalination

IWC 18-50: Fundamentals of Sustainable Desalination: Managing Operating Risks in

Industrial Reverse Osmosis Systems

IWC 18-51: Reverse Osmosis Treatment of Well Water Commingled with Flue Gas

Desulfurization Wastewater at a Power Plant

IWC 18-52: Survey of Brine Reduction Treatment Options and Techniques

水的製造與管理

Produced Water Management: Overcoming Unique Challenges in a Demanding Industry

IWC 18-53: Case Study: Horizontal Falling-Film Evaporator for Produced Water

Treatment at Shengli Oil, China

IWC 18-54: Threshold Inhibition of Magnesium Silicate and Prevention of Organic

Fouling in Produced Water Evaporator Preheaters

IWC 18-55: The Retrofit of a Remote 160,000 Barrel Per Day Oil Field Produced Water Train

IWC 18-56: Closing the Cycle: Optimizing Produced Water Management Through Efficient Reuse Treatment

有關薄膜應用於各種工業

If I Only Had a Membrane! (A Potpourri of Industrial Wastewater Topics All Connected by Membranes)

IWC 18-57: Membrane Processes for Wastewater Treatment in the Food Industry

IWC 18-58: Ceramic Hollow Fiber Membrane Technology for Industrial Wastewater Treatment in Recycle/Reuse Applications

IWC 18-59: Overcoming Challenges in Biological Treatment of Selenium Containing Wastewaters by Advancements in Bioreactor Design

IWC 18-60: MBR Technology Utilized to Resolve an Increase in Flows and New Discharge Requirements When Upgrading a CPI Wastewater Treatment Plant at Eastman Chemical facility in Chestertown, Maryland

冷卻水-- 監測，化學和模式研究的最新進展

Cooling Water - Recent Advances in Monitoring, Chemistry, and Modeling

IWC 18-61: Monitoring and Prevention of Mineral Scale Formation in Open Cooling Systems with an Inline Fouling Monitor

IWC 18-62: A Novel, Better Performing Yellow Metal Corrosion Inhibitor with Lower Toxicity and its Use for Copper Alloy Condenser at a Power Plant

IWC 18-63: Cooling Water High Cycle Silica Treatment Program Implemented at a Southwest ZLD Power Plant

IWC 18-64: Scale Formation in Cooling Tower: Theoretical Approach to the Thermodynamics and Kinetics of the Water Chemistry in the Makeup and Cycled Water

發電廠水資源管理

Water Management in Power Plants

IWC 18-65: Arsenic Treatability and Pilot Testing at Little Blue Run CCR Impoundment

IWC 18-66: Closing the Loop in Bottom Ash Systems – Not as Easy as They Thought

IWC 18-67: Water Management in Closed-Loop Bottom Ash Systems

IWC 18-68: Outage Wash Wastewater Treatment Alternatives at Coal Fired Power Plants

膜技術和應用的發展

Evolving Membrane Technologies and Applications

IWC 18-69: Counterflow Reverse Osmosis – New Membrane Technology for Ultra-High

Salinity Desalination

IWC 18-70: Using Membranes to Produce River Water Cooling System for Large

Chemical Plant

IWC 18-71: The New Standard for Industrial Desalination Michael Boyd, Desalitech,
Newton, MA

IWC 18-72: Evaluation of Long-Term Membrane Performance with Continuous Use of
Hydro-Optic UV Dechlorination at Plant Bowen

從實驗室到實際應用 - 廢水處理系統的優化

From the Bench to Full-scale - Optimization of Wastewater Treatment Systems

IWC 18-73: The “Ins & Outs” and “Dos & Don’ ts” of Bench Scale Treatment
Studies

IWC 18-74: Zeta Potential for Optimizing Coagulation at Industrial Water Treatment
Plants

IWC 18-75: Tiny Bubbles Float Flocc — Optimizing Dissolved Air Flotation Operations

IWC 18-76: Hydrogen Peroxide for Supplemental Dissolved Oxygen for Petrochemical
Wastewater Treatment

其他有關於地下水及放射性之整治量測共 3 篇

供國內對核能與火力電廠地下水水質監測整治參考

IWC 18-21: Radium Removal from Potable Water Supplies

IWC 18-22: Water Treatment Residuals Management for Uranium Removal Using Ion
Exchange Media Re-certification and Reuse in Potable Water Systems

IWC 18-36: Groundwater Remediation System Pilot and Operating Data

綜合以上 21 項目 76 篇論文報告中，與電廠脫硫廢水有關的技術論文就有 23 篇，比重最高約佔 30%，發電廠用水與系統水處理有 20 篇居第二約佔 26%。

燃煤電廠脫硫廢水處理(FGD WasteWater Treatment)，因各國排放法規的不同，電廠所在位置環境的不同（海邊、內陸 水源等），煤質的不同 脫硫塔運轉與設計等很難有一設計是全體適用，尤其政府加嚴排放標準、增加管制項目、循環經濟概念以及民眾期望減少污染排放等種種的現況下，值得公司同仁深入研究 FGD 廢水的經濟可行的全量程序，及環保法規對於 FGD 運轉的影響等。

美國環保署 EPA 2015 年 9 月公布 Steam Electric Power Generating Effluent Guidelines - 2015 Final Rule 並提供 EPA-821-R-15-007 電廠廢水處理技術發展調查報告：Technical Development Document for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category 供發電業者參考。

其中 2015 年美國 EPA 公布運轉中的 139 個濕式脫硫 FGD 廢水管理/處理技術的分佈如下圖(圖 7-1)，顯示大多數煙氣脫硫廢水管理其所採用處理技術最多的是零排放 Zero Liquid Discharge (ZLD) 共 51 個廠佔約 37%，地表蓄水池有 39 個廠佔約 28%，化學沉澱系統有 33 個廠佔約 24%，生物處理 5 個廠佔約 3%，另外將蓄水池蒸發和人工濕地分組為“其他”技術，有 11 個廠佔約 11%。

調查報告中汽力電廠廢污水各式處理系統，EPA 將系統分為以下類別（如下圖所示）：

地表蓄水池Surface Impoundments 39個廠 約佔28%

包括一個或多個蓄水池的系統，其中蓄水池是唯一的處理單元。該組還包括添加化學物質以在排放前控制pH。它不包括在更先進的處理系統（例如化學沉澱，生物處理），也不包括FGD廢水零排放的系統。

化學沉澱Chemical Precipitation 33個廠 約佔24%

包括使用氫氧化物和/或有機硫化物沉澱劑作為處理機制的系統。該組還包括將上述地表蓄水池與和化學沉澱系統相結合的系統，以及用於BOD5去除的好氧生物處理或用於營養物去除的生物處理（即，不針對用於去除重金屬設計）。它不包括系統化學沉澱和缺氧/厭氧生物處理系統，也不包括FGD廢水零排放的系統。

生物處理Biological Treatment: 5個廠 約佔3%

包括使用缺氧/厭氧固定膜或懸浮生長生物處理系統的系統，旨在去除硫和其他污染物。該組包括與生物系統組合還包括地表蓄水池和/或化學沉澱處理單元的系統。它不包括FGD廢水零排放的系統。

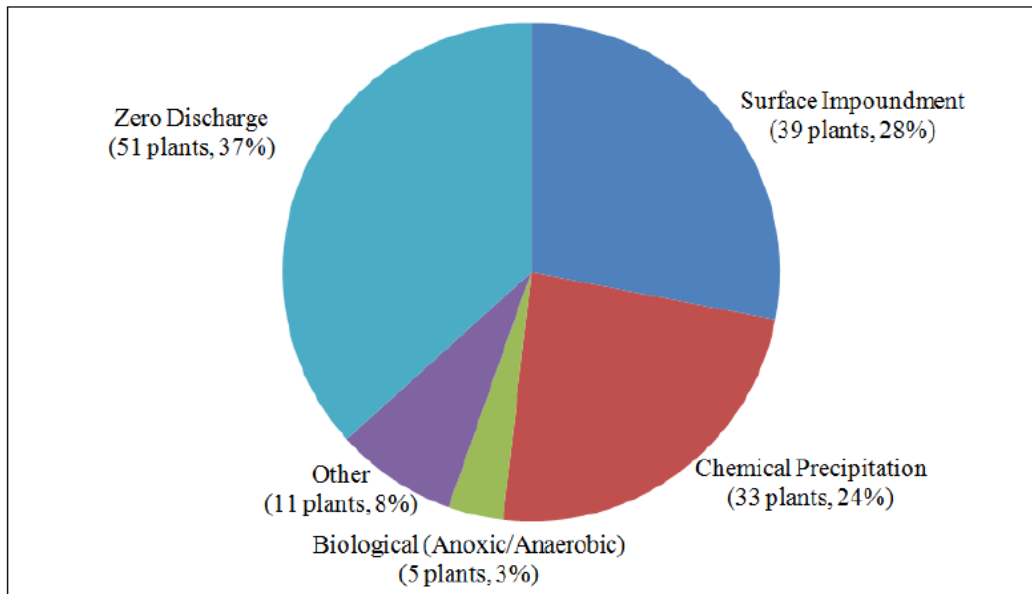
其他Other：11個廠 約佔8%

包括使用人工濕地或蒸發池處理單元的系統。該組還包括表面蓄水與人工濕地/蒸發系統以及多個沉降池系統的工廠，這些系統不被視為化學沉澱（例如，澄

清系統)。它也不包FGD零排放的系統。

零排放Zero Liquid Discharge：51個廠37%

零排放Zero Liquid Discharge (ZLD)系統基本架構主要是以回收再利用為主，經回收後所剩的濃縮液在經處理或固化後掩埋。包括所有將FGD廢水處理到可以回收使用的所有處理系統，例如，地表蓄水池，化學沉澱等。



Source: Steam Electric Survey [ERG, 2015a].

Note: This figure represents the EPA population used in analyses for the ELGs, which was developed using the Steam Electric Survey, industry profile changes (see Section 4.5), and additional industry-provided information.

Note: This figure represents the highest level of treatment; for instance, some plants categorized as “Other” or “Biological (Anoxic/Anaerobic)” may also operate a chemical precipitation system as part of a more advanced treatment system.

Figure 7-1. Distribution of FGD Wastewater Treatment/Management Systems Among 139 Plants Generating FGD Wastewater in the EPA Population

Table 1: 2015 ELG discharge limits established by the USEPA for FGD

FGD Wastewater 2015 Effluent Limitation Guidelines (US EPA)				
BAT Chemical Precipitation + Biological Treatment			BADCT Evaporation	
	Daily Max	30 Day Avg	Daily Max	30 Day Avg
Arsenic	11 ug/L	8 ug/L	4 ug/L	-
Mercury	788 ng/L	356 ng/L	39 ng/L	24 ng/L
Selenium	23 ug/L	12 ug/L	5 ug/L	-
NOx	17.0 mg/L	4.4 mg/L	-	-

上表 EPA 2015 年公布的的排放準則水質比較：化學沉澱 Chemical Precipitation +生物處理 Biological Treatment= Best Available Technology (BAT)與 Best Available Demonstrated Control Technology (BADCT) 蒸發法的排放水質，明顯(BADCT) 蒸發法較能符合更嚴的排放水質。

再由2014 IWC 國際水會議一篇有關煙氣脫流(Flue Gas Desulfurization)論文:

Technological and Operational Impact to Purge Water Treatment Systems Due to

Environmental Regulations (2014 IWC KENNETH CHEN Fluor Enterprises, Inc.)

中資料顯示，於2013年(如下圖)統計了145個燃煤電廠脫硫廢水處理法，相較於

2015 統計，脫硫廢水處理法僅兩年的時間內，採零排放處理就從28個廠(占

15%)，增加到51個廠(占37%)，而生物處理法卻無增加甚至減少 1個廠。相

較之下脫硫廢水採零排放ZLD已是目前的趨勢。

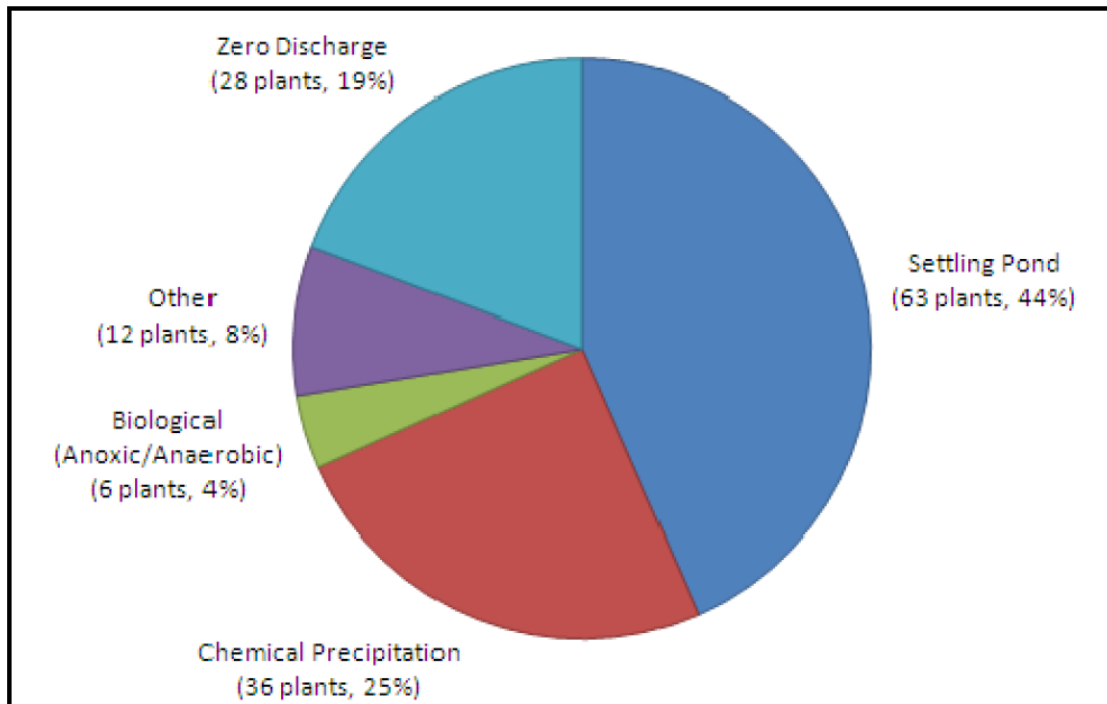


Figure 3 – Flow diagram for a Wet FGD purge water treatment system (Office of Water, 2013. Technical Development Document).

3. 順道參觀Arizon Falls

IWC 每兩年選在亞利桑那州的首府鳳凰城舉辦研討會主要該州臨近沙漠地區水資源長期需要保護與開發。會後也參觀 Arizona falls 水力發電設施與 G.R Herberger 運動公園及附近社區整合設施 其作法值得台電參考 讓社會大眾了解台電也很重視水（海洋 河川 湖泊等）環境與社區共榮共存。

<https://www.srpnet.com/water/canals/azfalls.aspx>

Arizon Falls 簡介

亞利桑那瀑布(Arizon Falls)沿著亞利桑那運河(源自於 Salt River)，在現在的 E Indian School Road 第 56 街和第 58 街附近形成 20 英尺的自然落差，也是鳳凰城第一座水力發電廠的所在地。發電廠建於 1902 年，於 1911 年由 SRP(Salt River

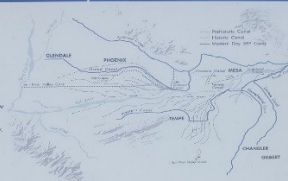
Project)水電公司重建並於 1913 年開始供電。亞利桑那瀑布(Arizon Falls)水力發電廠 750 千瓦的水力發電機所提供的清潔能源約足夠 150 個家庭用電。

AZ FALLS | SRP

WATER | POWER | COMMUNITY


WATER

The Hohokam Indians dug the first canals from the Salt River to grow food more than 2,000 years ago. After 1867, newcomers built upon these first canals and added new ones. These canals still play a vital role in sustaining life in the Salt River Valley today.





POWER

In the early 1900s, the federal government partnered with local water users to build Theodore Roosevelt Dam. SRP began using water behind dams and producing power to electrify the Valley. With a natural 24-foot drop in elevation, Arizona Falls was the perfect site for the Valley's first hydroelectric power plant.



COMMUNITY

The water and power provided by SRP supported farms growing citrus, cotton, wheat, barley and other crops. As the Valley's population increased, homes and businesses developed in place of farm fields. Arizona Falls continues to connect us with the flow of water, the generation of power and the history of our community.

Take the interactive tour of azfalls.com **1**

SRP
Delivering more than power.™

AZ FALLS | SRP

THE POWER OF WATER

The hydroelectric generator inside this building captures the tremendous power of water flowing through the canal with the help of gravity. This falling water moves a turbine that produces enough electricity to power about 150 homes! The water continues down the canal system completely unchanged, making the process both clean and renewable.

First constructed in 1902 and rebuilt by SRP in 1911, Arizona Falls was the first hydroelectric generating station in Phoenix. It now provides a working example of how SRP uses the power of water to generate electricity for Valley communities.

Solar panels on the roof capture sunlight and convert it into electricity, demonstrating one of the ways SRP harnesses renewable energy sources. SRP is pursuing innovative and effective renewable energy solutions for the future.





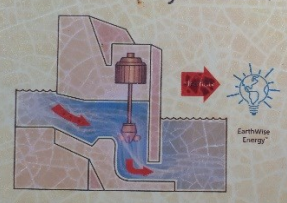


Take the interactive tour of azfalls.com **2**

SRP
Delivering more than power.™



What's going on behind these doors?
Earth-friendly energy.
Here's how hydroelectricity works:



SRP
EarthWrite Energy

(三)、參訪南加州 Magnolia Power Plant (MPP)

經由南加州 Stantec 公司及 Eric Wu, Ph.D., P.E. Chief of Groundwater Permitting Unit Regional Water Quality Control Board, Los Angeles Region 的協助之下，前往位於 The City of Burbank，Los Angeles County 的 Magnolia Power Plant 參訪。

Magnolia Power Plant 屬於南加州公共電力事業 (The Southern California Public Power Authority) 系統 之下的電廠，由 Burbank Water and Power 公司(BWP)經營管理。

BWP公司成立於1913年，是一家社區所擁有的公用事業公司，主要是為伯班克Burbank城市的居民和企業提供電力和水務服務。參與BWP公司Magnolia發電廠投資的社區包括:阿納海姆（Anaheim 38%），伯班克（Burbank 31%），喜瑞都（Cerritos 4%），科爾頓（Colton 4%），格倫代爾（Glendale 17%），帕薩迪納（Pasadena 6%）等6 個城鎮。BWP公司是以持續、可靠和安全的理念，提供社區優質的公用事業服務，並提供城市超過100,000名居民及在當地工作之數萬人充足的電與水。

Magnolia 發電廠新廠於 2003 年 7 月動工興建，於 2005 年 9 月 22 日商轉，取代兩個退役的 Magnolia 1 號和 2 號機組。Magnolia 新建電廠採用最先進的複循環機組發電技術。該設施包括氣鍋輪發電機，熱回收鍋爐之汽輪機發電機，冷卻塔，零液體排放系統(ZLD)。新機組為總裝置容量 31 萬瓩(310MW)，其效率提高了兩倍，排放量比舊廠減少了 90%。

Magnolia發電廠當時為了儘早取得電力開發許可證照，並趕在2005 年商轉供電，以提供並滿足Burbank等六個城市在2005年夏季電力需求高峰。因此在為了減少阻力及表達做好環境維護工作之誠意，在電廠水資源管理和放流水系統規劃方面，在製程所需用水均取自都市的回收污水而非自來水，並率先採取先進的廢水零排放(Zero Liquid Discharge, ZLD)全回收之處理程序，。

該電廠水零排放(Zero Liquid Discharge, ZLD)系統，除設置高效能之污染防治設施外，並配合廠區綠美化及節能等環境友善措施，例如將舊鐵道的架構造改為庭園，新設路線改為透水之地下管道，建置綠屋頂(green roof)之植栽截水設計可吸收70%雨水，對南加州乾旱缺水狀況之緩解頗有助益，由於廠方積極建置環境友善的措施，因此在6個月內即獲得建造許可，同時也加快了當地的其他建設計畫。



綠屋頂-截取雨水及降低室內溫度



舊鐵道建物景觀規劃-取自網路照片



廠區景觀規劃之一-取自網路照片

電廠廢水零排放(ZLD)回收設施之設計處理水量 400GPM，電廠冷卻水全回收零排放，主要處理方式為逆滲透(RO)及蒸發結晶，設備供應廠家為 Aquatech 公司

廠、發電廠快速增加。再從已發國家的北美和歐洲，到新興經濟體印度和中國等都呈現迅速增長的態勢，同時設置廢水零排放(ZLD)系統的全球市場正快速成長。

3. 本公司各電力設施(包括核能設施)的廢水都是經處理至符合放流水標準後排放，惟在政府加嚴排放標準、增加管制項目、循環經濟概念以及民眾期望減少污染排放等種種的現況，本公司應思考逐步邁向廢水零排放(ZLD)之可能性。
4. 目前國內外很多工業或電力公司已逐步規劃設計廢汗水之回收再利用。可以先蒐集相關法規與技術發展等資料，再研議從較容易的部分進行，增加處理單元將符合放流水標準之廢水再處理後回收利用。
5. 尤其新設電廠之規劃，電廠營運長達 40 年，為因應未來發展，應該將廢汗水零排放(ZLD)之觀念納入設計，於整廠規劃時預留相關設施之空間，依相關技術之發展逐步建置廢汗水零排放(ZLD)設施。