經濟部

行政院所屬各機關因公出國人員出國報告書

（出國類別：其他）

台星雙邊水資源會議暨水資源再利用與淡化國際會議出國報告書

出國人：經濟部水利署署長黃金山

經濟部水利署簡任正工程司張廣智

經濟部水利署科長程桂興

出國地點：新加坡

出國期間：九十二年二月二十四日至三月一日

報告日期：九十二年三月

系統識別號：c09201216

公 務 出 國 報 告 提 要

頁數： 32 含附件：否

報告名稱：台星雙邊水資源會議暨水資源再利用與淡化國際會議報告書

主辦機關：經濟部水利署

聯絡人/電話： 楊尊華/（02）37073058

出國人員：經濟部水利署署長黃金山

經濟部水利署簡任正工程司張廣智

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報告日期：民國九十二年三月

分類號/目：G5/水利工程　G5/水利工程

關鍵詞：新生水（new water）、海水淡化（seawater desalination）、節約用水（water conservation）

內容摘要：

一、台星雙邊水資源會議是新加坡公共事務局（Public Utilities Board）依據2001年12月第八屆台星（新加坡）部長及經濟會議時，雙方同意就水資源管理經驗交流建立正式管道，並約定每二年召開一次水資源技術交流會議辦理。本次由新加坡負責籌畫召開第一次會，第二次技術交流會議輪由我國負責主辦。本次會議主要就水資源規劃利用、海水淡化及新生水（New Water）等替代水源課題進行技術經驗交流與討論。

二、水資源再利用與淡化國際會議（Water Reuse and Desalination Conference），會議主題包括世界各國目前對薄膜（membrane）科技在水處理發展趨勢、應用與實務經驗及對大眾健康衝擊影響等。黃署長在會議中以台灣在海水

淡化與廢水回收利用規劃（Planning for Sea Water Desalination and Waste Water Reuse in Taiwan）為題發表論文。

三、新加坡過去主要水來源為集水區的雨水收集與象馬來西亞簽訂購水契約。然而隨著新加坡人口的成長、工業用水需求增加以及向馬來西亞購水有政治風險的不確定性等因素干擾，因此以整體性用水思考模式，由水循環觀念增加海水淡化（sea water desalination）與生活污水回收利用（water reclamation）新生水做為供水來源。預計在 2012 年達成海水淡化與新生水站總供水 25% 目標；2061 年達成供水完全自給自足目標。

四、新加坡為了強化供水的整合力，進行水相關業務與組織功能再造。2001 年 4 月 1 日，新加坡公共事務局（Public Utilities Board）整合環境部（Ministry of Environment）的污水系統處理署（sewerage department）與排水系統處理署（drainage department）；同年 10 月，新成立水再生利用署（water reclamation department），負責海水淡化及使用過後的水處理回收再利用，供應工業用水與製造新生水（new water）。自此 PUB 遂成為新加坡專業水機構，下轄水務署（water department）以及上述等部門。

五、海水淡化是新加坡政府擴大長期供水來源策略之一，新加坡政府在三月初剛簽訂第一座海水水淡化廠合約，該海淡廠採 BOO 方式辦理，預定於 2005 年下半年開始，每天供水 13 萬 6000 噸，佔新加坡總用水量 10% 。該淡化海水價格每噸 0.78 新幣（約 0.44 美元）相當於新台幣 16 元。未來實際價格仍將依通貨膨脹率與能源價格波動做調整。

六、新生水是新加坡刻正積極推動的造水產業，新生水來源自生活與工業廢污水，經過前處理、MF（微過濾）、RO（逆滲透）以及 UV（紫外線殺菌）等高級處理程序後其水質已超過國際飲用水質標準，可以直接飲用。惟社會大眾對於以新生水作為生活用水仍存有相當大的疑慮，認為長期飲用對人體健康會有危害。因此，新加坡政府除在樟宜新生水水廠設立一座新生水多媒體展示館，除推廣水資源教育外，更將新生水整個生產過程做了詳實的介紹，以消除大眾的疑慮。目前生產出的新生水主要是提供作為工業用超純水水源，其餘新生水也不並直接送至水廠送家戶，而是將新生水直接輸送至水庫與雨水混合蓄存，而後再透過自來水處理程序，送至家戶飲用。

七、新加坡在推動節約用水一直不遺餘力，透過立法強制執行在各個公共場所、機關等均裝置省水水龍頭（每分鐘出水量不超過二公升）以及馬桶（4.5-6 公升）。新加坡家戶平均每人每日用水量 164 公升，自來水不可記數損失包括漏水等（unaccountable for water ）僅 4.8% ，均優於我國節約用水推動成效。目前新加坡為進一步減低家戶用水量，由 PUB 水務署配合世界水資源日活動挨家挨戶拜訪，並教導家戶 DIY 安裝水龍頭節水墊片。其相關做法均值得我國借鏡學習。

台星雙邊水資源會議暨水資源再利用與淡化國際會議出國報告書

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一、目　的

新加坡面積682平方公里，年平均降雨量2400公厘，人口總數400萬，每日需水量135萬立方公尺。過去新加坡主要供水來源靠集水區收集雨水（集水面積約新加坡一半的面積），以及半數以上用水來自馬來西亞輸入，由Johor河川配水至新加坡。

新加坡水源缺乏，由於人口成長、工商用水需求增加以及供水受制於馬來西亞，因此新加坡政府便不斷地朝節約用水以及非傳統替代水源開發等方向持續努力。在推動節約用水及減少自來水公水管線配水漏失率新加坡政府已展現驚人成效，根據新加坡公共事務局（PUB）統計，在2001年家戶中每人每日用水量已降至164公升，而自來水不可記數損失包括漏水等（unaccountable for water ），由1990年10.6% 降至2001年僅5.3% ；在非傳統替代水源開發方面，新加坡公共事務局在2001年10月成立水再生利用署（water reclamation department），負責海水淡化及新生水製造，預定在2012年以前，海淡水及新生水將佔總需水量25%。

新加坡政府在2003年3月初剛簽訂第一座海水水淡化廠合約，該海淡廠採BOO方式辦理，預定於2005年下半年開始營運，每天供水13萬6000噸，佔新加坡總用水量10% ；在新生水製造方面，預計要完成六個水再生利用廠（Water Reclamation Plant），目前已完成Bedok 和 Kranji 二個新生水工廠（WRP），總共日產72000噸/日。所產出之水供應晶元製造用水、商業大樓冷氣冷卻水供應及其他工業製程及冷卻水之用。

本次行程有二個主要目的，第一個是由本署黃署長與能邦科技顧問公司執行長朱文生博士出席參加水資源再利用與淡化國際會議（Water Reuse and Desalination Conference），會議主題包括世界各國目前對薄膜（membrane）科技在水處理發展趨勢、應用與實務經驗及對大眾健康衝擊影響等，黃署長在會議中以台灣在海水淡化與廢水回收利用規劃（Planning for Sea Water Desalination and Waste Water Reuse in Taiwan）為題發表論文；第二個目的是由黃署長率隊，出席參加台星雙邊水資源會議。

台星雙邊水資源會議是依據2001年12月第八屆台星（新加坡）部長

及經濟會議，雙方同意就水資源管理經驗交流建立正式管道，並約定每二年召開一次水資源技術交流會議辦理。經濟部水利署特與新加坡公用事業局(Public Utilities Board, Singapore)，合辦台星水資源雙邊會議(Technical Exchange Programme Between Taiwan Water Resources Agency and Public Utilities Board)，雙方就水資源規劃利用、海水淡化及新生水（New Water）等替代水源課題進行技術經驗交流與討論。希望藉由與同樣面臨水資源短缺之新加坡用水管理單位接觸下，將台灣在這種特殊的雨量豐沛卻水資源短缺條件下累積的管理經驗與新加坡當局分享；並進一步了解新加坡目前的用水狀況及規劃方向，作為我國水資源經營與管理思維上的參考。

除了雙方的交流會議之外，行程中尚包含新加坡目前為了因應水資源嚴重不足而大力推廣的"新生水"（NEWater）製造工廠，並拜訪此處理設備的承建廠商（Hyfiux），進一步了解整個污水回收系統的發展過程；除此之外，新加坡當局對於家庭用水節約推動不遺餘力，台灣方面特要求赴節水宣導現場參訪。

此次參與交流成員包括經濟部水利署黃署長、張廣智簡任正工程司、程桂興科長、工研院能資所溫子文經理、李東峰副研究員、文化大學土地資源系盧光輝教授、能邦科技顧問公司執行長朱文生博士以及金棠科技公司協理張振章博士等共 8 人，於 92 年 2 月 24 日啟程赴新加坡，於 3 月 1 日完成參訪行程返國。

註: 新加坡之配水漏失率含因水表不精確之漏失及管路漏水等，近年來 PUB 除致力於漏水檢修外，更大力汰換精度較高的電子式水表，以提升實質售水率

二、行 程

日 期	星期	時 間	內 容
92年 2月24日	一	07:45	中正機場搭機前往新加坡（黃署長金山、張簡任工程司廣智、程科長桂興）
		14:00	參訪 Vivendi Water Asia 公司
		18:30	台北駐新加坡代表處歐陽代表晚宴
2月25日	二	08:30- 11:40	參加水資源再利用與淡化會議 （Water Reuse & Desalination Conference）開幕
		14:30- 17:00	參訪 ONDEO 公司（海水淡化）
2月26日	三	08:30- 17:00	參加水資源再利用與淡化會議 （Water Reuse & Desalination Conference）
2月27日	四	09:00 09:05 09:10 09:35 10:30 11:00 12:00 12:30 14:00 16:00 19:30	到達會場 開幕致詞 題目： Overview of Singapore Water Supply 主講人：Mr. Koh Boon Aik, Deputy Director(Development), Water Department. 題目： Water Reclamation 主講人：Mr. Harry Seah, Deputy Director(Supply-1), Water Reclamation Department. 中場休息 題目： Wastewater Reclamation for Industrial Parks in Taiwan 主講人：Mr. Chang Chen Chang, Kintech Technology Co Ltd. 題目： Rainfall Harvesting in Taiwan 主講人：Professor Andrew Lo, President of IRCSA. 午餐 NEWater Visitor Center 參訪 Hyflux 淨水公司參訪 TWRA 代表團歡迎晚宴

		09:00	題目： Desalination – The Build-Own Operate(BOO) Approach 主講人：Mr Arasu Sivaraman, Sr Manager(Planning), Water Department.
		10:00	題目： Seawater Desalination and Water Reuse in Taiwan 主講人：Dr Chu Wen Sen, CEO, EITI.
			中場休息
		10:30 11:00	題目： Water Resources Development and Allocations in Taiwan 主講人：Mr Chen Kuei Chih, Section Chief, TWRA.
		11:30	題目：Governmental and Non-governmental Reactions and Efforts to 2002 Taiwan Drought 主講人：Mr Chang Kuang Chih, Senior Engineer, TWRA.
		12:00	題目： Drought Prevention and Emergency Measures for Hsin-Chu Science-Based Industrial Park in Taiwan 主講人：Mr Wen Tze Wen, Manager, Industrial Technology Research Institute.
2月28日	五		午餐
		12:30	參觀節水宣導會場
		13:00 14:00	題目： Ultrapure water from NEWater for use in Water Fabrication Plants 主講人：Dr Bruno Coniglio, Director, CAWT.
		15:00	題目： Water Demand Management 主講人：Mr Chong Hou Chun,Deputy Director (Transmission & Distribution), Water Department.
			中場休息
		16:00	結尾討論
		16:30	會議結束
		17:00	
3月1日	六	返程	新加坡搭機返回中正機場

三、參訪內容

（一）水資源再利用與淡化會議

水資源再利用與淡化國際會議（Water Reuse and Desalination Conference），會議2月25及26日在新達城國際會議暨展示中心(Suntec Singapore International Convention & Exhibition Centre）舉行，本項會議重點針對薄膜（membrane）技術在廢污水處理、水再生利用及海水淡化等領域應用進行交流與對談以及相關水處理設備展示。大會議題包括區域水處理實務經驗、薄膜在水處理研究發展與應用、薄膜水處理健康議題以及海水淡化等。黃署長及朱文生博士並於海水淡化議程中以台灣在海水淡化與廢水回收利用規劃（Planning for Sea Water Desalination and Waste Water Reuse in Taiwan）為題發表論文，並獲得熱烈回應。

綜觀而言，這次的會議中已透露，目前國際上均面臨水資源匱乏問題，而傳統水源開發方法近年來受到國際環境保育意識的興起，已難以推動；因此，把用過的水回收處理後再利用，不僅能兼顧生態環境、增加供水水源，維持水循環，已成為國際最重要的水議題之一。尤其在近幾年來，廢污水處理技術持續創新，膜應用處理已成為成熟的技術，水處理成本也因此大幅降低，整體環境已有利於推動廢污水回收再利用，值得我國正視此一領域的未來發展，及早扶植水產業（Water Industry）深根台灣，健全水循環。

會議中另一個值得我國重視的發展趨勢就是由美國廢水處理專家喬巴諾格拉斯教授(George Tchobanoglous)所提出的「非中央廢水處理系統(Decentralized Wastewater Management)」，將過去集中大型廢水處理系統改為在住戶、住宅大樓（廈）、社區或是市鎮地底下設置分散小型廢水處理。污水不必再集中到污水處理廠去，而是直接在當地系統處理後，然後重複使用。這些處理過的水並不用來飲用，而是作為澆灌、洗車及沖廁等用途。我國國內有很多具備獨立污水處理系統之工業區，這個概念可以應用於推動工業區內廢水回收再利用。

圖 3-1-1 水資源再利用與淡化會議會場

（二）台星水資源雙邊會議

1.新加坡用水環境介紹

(1)新加坡總面積 682km^2，總人口約 400 萬人，由新加坡島及附近 60 個小島組成，其中新加坡島占全國面積的 91.6%。地勢低平，平均海拔 15 米，最高海拔 166 米，海岸線長 193 公里。屬熱帶海洋性氣候，常年高溫潮濕多雨。年平均氣溫 24－27℃，日平均氣溫 26.8℃，年平均降水量 2344 毫米，年平均濕度 84.3%。

(2)供水概況

a.全國供水由公用事業局（Public Utilities Board）掌管。

b.新加坡每日需水量 135 萬噸，供水水源包括水庫、由馬來西亞進口水(Johor Water)、新生水(NEWater)及海水淡化水（2005 年運轉）等四類。水庫儲水佔總供水的一半左右，新生水佔 5.8%，其他不足的部分則由進口水來供應。新生水是指將處理後的生活污水再經高級處理至符合飲

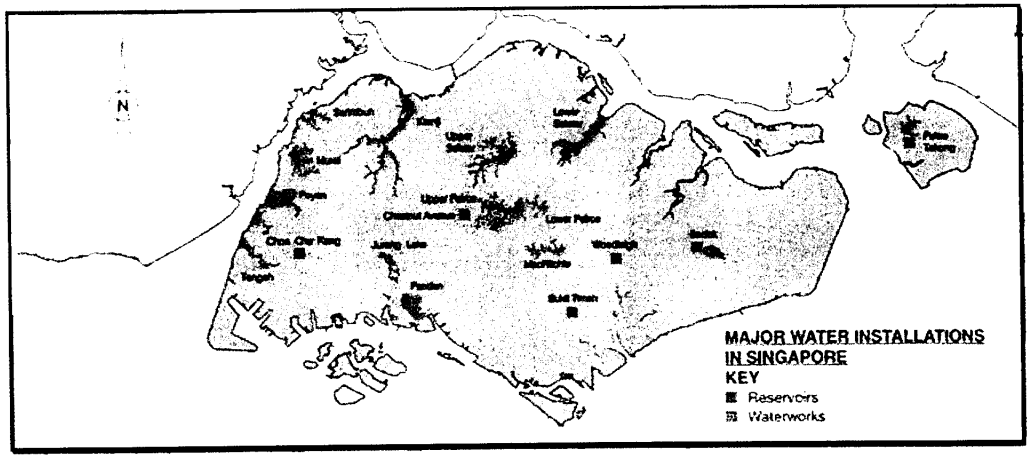
用水水質標準的再生水，目前每天可產 72,000CMD，其中工業用水約 63,000CMD，輸送至水庫為 9,000CMD。

c.目前馬來西亞與新加坡現有的供水合約共兩份，1961 年簽署為期五十年合約至 2011 年期滿及 1962 年簽署為期一百年合約，將於 2061 年到期。兩份合約規定大馬每日供給新加坡的生水總水量為 157.5 萬 CMD，售價是每 4.5 噸三分錢（以馬幣計）。馬來西亞希望能夠在 2002 年至 2007 年間，將水價提高到每 4.5 噸馬幣六角，並於 2007 年至 2011 年，再調高到每 4.5 噸馬幣三元。新加坡方面的想法是在第一項供水條約期滿後以每 4.5 噸四十五分的價格向馬來西亞購水；第二份合約期滿後則提高水價至每 4.5 噸六角，並每五年調整水價。由於雙方認知差異大，新加坡承受相當大的供水依賴壓力。

(3)水源及淨水場設施

a. 公用事業局轄下的水供應系統包括 19 個未淨化水水庫,9 個水處理廠,15 個存儲或服務水庫和大約 5150 公里管道的供水網路(如圖 3-2-1)。

圖 3-2-1 新加坡水庫及自來水廠分布圖

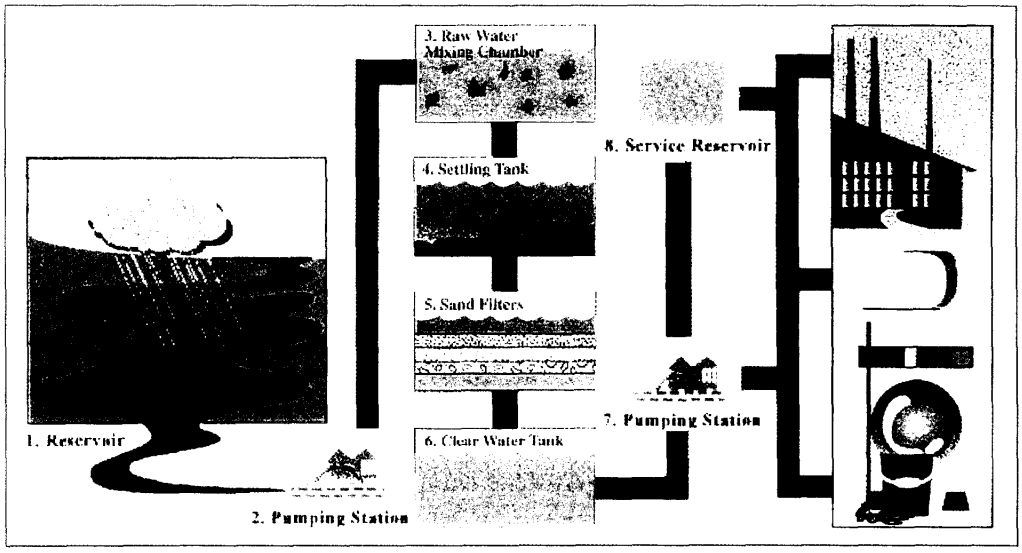


b.新加坡目前主要有六座淨水場，分述如下。

表 3-2-1　新加坡淨水場設施

淨 水 場	最大處理量(CMD)	完成年份
Bedok	136,000	1986 年完成
Choa Chu Kang	364,000	1975 年完成，1981 年擴建
Chestnut Avenue	273,000	1975 年完成
Woodleigh	227,000	1912 年年完成，1969 年擴建
Bukit Timah	73,000	1889 完成，1942 和 1950 年翻修
Pulau Tekong	6,800	1979 年完成
合　計	1,067,100	

圖 3-2-2 新加坡配水系統說明圖



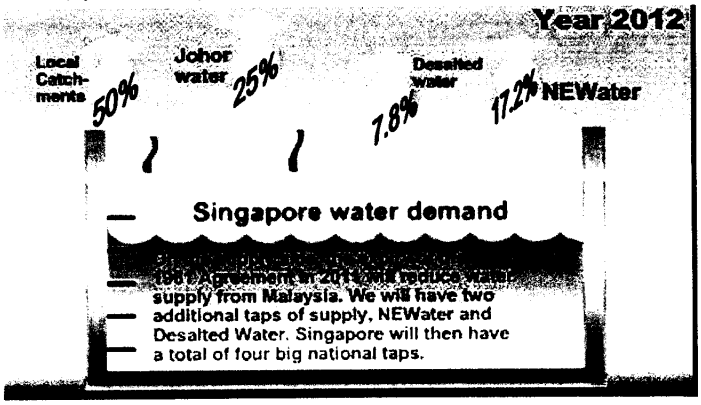
(4) 公用事業局目前預定之新水源開發方案

為了降低對鄰國的需水壓力，新加坡不斷的努力尋找水源，目前主要的方向如下圖 3-2-3，目標為在 2012 年將外購水量降至 25%左右，50%由降雨供應，25%則由新生水及海淡水來替代。

a.集水面積開發：目前全國有 1/2 左右的面積為集水區，目標於 2011 年擴充至全國面積的 2/3 為集水區。

b.非傳統水源開發：新加坡計畫於 2012 年將海水淡化及新生水的供水比例提升至總供水的 25%。其中，海水淡化供水目標為 135,000CMD，新生水為 295,000CMD。

圖 3-2-3 新加坡水資源 2012 年水源規劃圖



2.新生水系統介紹

(1)發展過程

於 1970 年代，新加坡政府即開始針對水回收科技進行研究，讓回收水的水質符合工業用水需求。其研究過程中發現，應用尖端的水處理流程（如除氮、離子交換、活性碳吸附等）可讓回收水質達飲用水標準；其中，RO 膜的處理方式確認相當有效，但費用門檻偏高。

在膜處理科技的進步下，將多種不同來源的水（如海水、處理後之污水）可靠的處理至符合飲用水水質標準已為可行，且所需之費用已降至可

接受範圍內。遂於 1998 年，新加坡政府開始兩年的研究，測試使用膜處理流程是否能將處理過之污水再淨化至符合飲用水標準。

(2)新生水處理評估廠介紹

a.開始操作時間：2000 年 5 月。

b.處理水量：10,000CMD。

c.建造時間：7 個月。

d.建造費用：6.5 百萬新加坡幣。

e.處理流程：微過濾（Microfiltration）＋逆滲透（Reverse Osmosis）＋紫外線殺菌（UV Disinfection）

f.評估結果：處理水水質完全符合飲用水水質要求（表 3-2-2）。

（3）新生水使用現況介紹

目前新加坡政府將新生水分為兩大用途，一是直接提供工業用水，另一則為補注水庫與雨水混合，再配送供民生用水；整個新生水的配送流程如圖 3-2-6 所示。

a.直接供應非飲用工業用水

目前有 Bedok 和 Kranj 兩座新生水廠（如圖 3-2-6），供應量 72,000CMD；主要供應工業及建築物冷卻水塔用水；預定於 2012 年達到 250,000CMD 的新生水供應量。

b.非直接供應民生用水

新生水供應民生用水方面，並非直接將新生水配送至家庭使用，而是將新生水送至水庫與雨水等其他水源混合；目的主要是提高民眾的使用意願，減少民眾使用新生水於生活及飲用的心理障礙。目前供應量為 9,000CMD，預定於 2012 年達到 45,000CMD；新生水供應系統說明如圖 3-2-6 所示。

圖 3-2-4 新生水廠處理流程圖

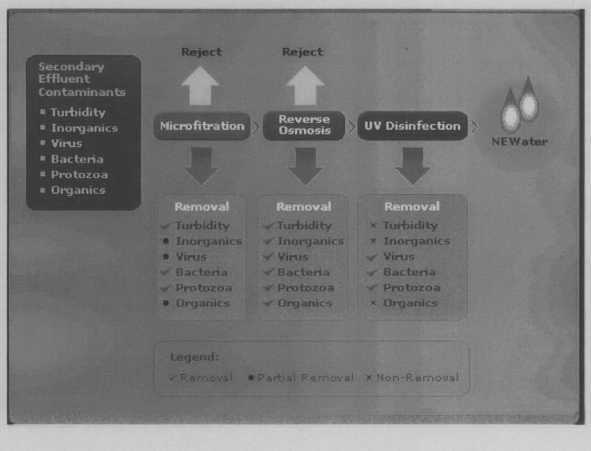


圖 3-2-5 兩座新生水廠位置圖

圖 3-2-6 新加坡新生水及海淡運用說明圖

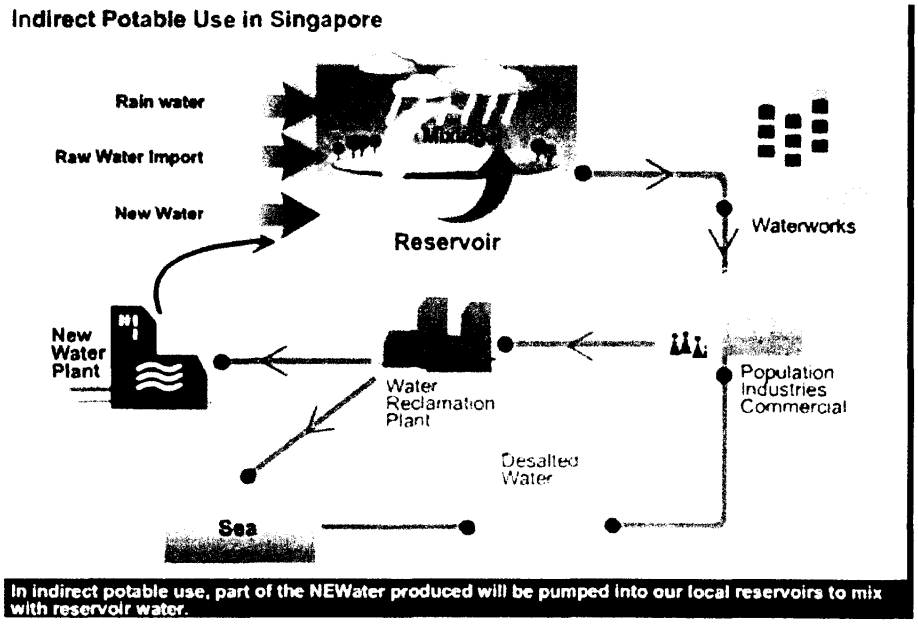


表 3-2-2 新生水水質及飲用水標準對照表

Water Quality Parameters	NEWater	USEPA /WHO Standards
	A) Physical	
Turbidity (NTU)	<5	5 / 5
Colour (Hazen units)	<5	15 / 15
Conductivity (μS/cm)	<250	Not Specified(- / -)
pH Value	7.0 - 8.5	6.5-8.5 / -
Total Dissolved Solids (mg/L)	<180	500 / 1000
Total Organic Carbon (mg/L)	1.0 - 2.0	- / -
Total Alkalinity (CaCO3) (mg/L)	5 - 16	- / -
Total Hardness (CaCO3) (mg/L)	<30	Not available
	B) Chemical (mg/l)	
Ammonia (as N)	<0.5	- / 1.5
Chloride (Cl)	<30	250 / 250
Fluoride (F)	<0.5	4 / 1.5
Phosphorus (as P)	<0.003 - 0.05	- / -
Silica (SiO2)	<5	- / -
Sulphate (SO4)	<5	250 / 250
Residual Chlorine (Cl, Free)	<0.01	Not available
Residual Chlorine (Cl, Total)	<2	- / 5

Cyanide (CN)	<0.05	0.2 / 0.7
	C) Metals (mg/l)	
Aluminium	<0.1	0.05-0.2 / 0.2
Antimony (Sb)	<0.02	0.006 / 0.005
Arsenic (As)	<0.0017	0.05 / 0.01
Barium (Ba)	<0.1	2 / 0.7
Beryllium (Be)	<0.004	0.004 / ND
Boron (B)	<0.5	- / 0.9
Cadmium (Cd)	0.0002	0.005 / 0.003
Calcium (Ca)	<30	- / -
Chromium (Cr)	<0.007	0.1 / 0.05
Copper (Cu)	<0.05	1.3 / 2
Iron (Fe)	<0.05	0.3 / 0.3
Lead (Pb)	<0.0005 - 0.002	0.01
Manganese (Mn)	<0.05	0.05 / 0.5
Mercury (Hg)	<0.00003	0.002 / 0.001
Molybdenum	<0.004 - 0.018	- / 0.07
Nickel (Ni)	<0.003 -0.013	- / 0.02
Potassium (K)	0.5-0.8	- / -
Selenium (Se)	<0.001	0.05 / 0.01
Sodium (Na)	<20	- / 200
Zinc (Zn)	<0.1	5 / 3
	D) Bacteriological	
Total Coliform Bacteria (Counts/100 ml)	Not detectable	Not detectable
Enterovirus	Not detectable	Not detectable

3.新加坡用水需求管理

為降低用水需求，新加坡由兩個方向下手，一是減少所謂的 UFW（Unaccountable For Water）（包含漏水、流量計讀數的誤差及其他造成配水與用水差異的水量），方法有：控制配水管線的漏水量、精確的流量計、正確的計算用水及嚴格的立法；另一個則是實質的降低用水量；如此一來，珍貴的水資源就能被有效使用。整個 UFW 的比率已從 1990 年的 10.6%降低到於 2002 年的 4.8%；各項管理重點如下：

a. 管線漏水控制：方法上包括使用品質較佳的管線、主要管線的定期汰換、主動偵測漏水點及對大眾回報立即處理。在管線的更新上，於 1995 年即開始汰換每年每公里有三個裂縫以上之主供水管線；於 2000 年開始汰換 50 年以上的老舊主供水管，這些行動使回報的漏水點數量由 1991 年的 7386

點降低至 2002 年的 3424 點。

b. 流量計精確度控制：為達到 100%的量測到所有的流量，水廠一律使用電子式流量計，而用戶的水表誤差控制於 3%以下，且需定期的更換（15mm 的水表為 10 年更換一次，大型水表為 7 年更換一次）。為了能夠提高非家庭用大型水表的量測範圍，在管線旁另加一較小管線及水表；且有專門的流量計工場進行流量計的測試服務工作。

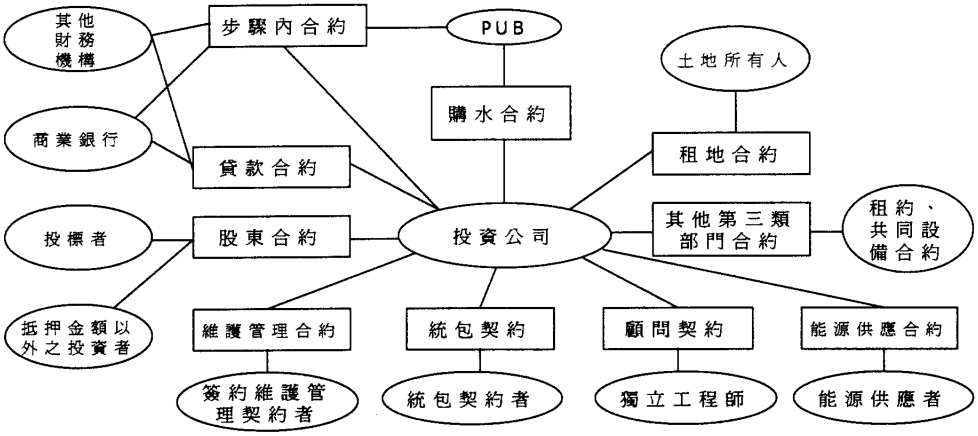
c. 降低實際用水量：這方面的工作包括使用省水器材及利用替代水源（如新生水、海水及工業廢水再用等），在省水器材上，推動使用 4.5L/次的省水馬桶（一般 9L/次），水龍頭則安裝省水片降低流量（已由一般 8~12L/min 左右降低至 6~9L/min，目前進行部份降低至 2L/min 的測試）；由於新加坡的民生用水佔總用水的 55%，省水器材推廣可有效的降低整體用水需求。其他如使用新生水於冷卻水塔、使用海水沖洗船身等也可有效減少自來水用水需求。

d. 教育宣導：除了各項工作的推行之外，要徹底高效率的使用水資源必須要全體國民的共同配合；所以到學校對學生進行宣導、節水宣傳品的製作、發放等都能有效促進節約水資源，減緩整體用水需求的成長。

4.以 BOO 方式興辦海水淡化

海水淡化是新加坡政府擴大長期供水來源策略之一，新加坡政府在 2003 年 1 月 17 日授與 Sing Spring 公司，3 月初簽訂第一座海水水淡化廠合約，該海淡廠採 BOO 方式辦理，期限結束無須轉移政府，採 20 年期限，自海淡運轉開始計算。預定於 2005 年下半年開始營運，每天供水 13 萬 6000 噸，佔新加坡總用水量 10% 。該淡化海水價格每噸 0.78 新幣（約 0.44 美元）相當於新台幣 16 元。未來實際價格仍將依通貨膨脹率與能源價格波動做調整。

a. BOO 可能之架構



b. BOO 特許公司對應各部門合約主要規範內容

合　　約	目　　的	合約內必須記載的主要問題
股東合約	定義得標公司之股東們的關係，包括權利與義務，以及描述計畫公司的目的和形式	■ 各個股東的延伸義務 ■ 不包括抵押部份出售之限制 ■ 投資公司從事一定活動或資產的能力
統包合約	藉由與有經驗廠商簽約 保證海淡廠在預算內及何時完成	■ 統包契約項目的固定價格 ■ 延遲完工與出水有缺點的處罰 ■ 配合在購水合約內訂定條款包括工廠之測試、委託營運、爭端之解決和法律變更

合　約	目　的	合約內必須註載的主要問題
維護運轉合約	保證海淡廠可藉由有經驗的操作者，做適當有效的運轉維護	■包括運轉維護的價格成本 ■執行不良的處罰 ■配合在購水條約內訂定條款，解決爭端與法律之變更
土地租賃合約	保證得標廠商可使用土地	■財務項目與租約期限 ■更新契約條件 ■評估檢討公司之權利 ■評估PUB之權利

合　約	目　的	合約內必須記載的主要問題
能源供應合約	設定技術與商業條件以控制對於海淡廠運轉需求之源供應與購買(電、熱、油)	■提供穩定質量的能源 ■價格與付款項目 ■供應不足的處罰

合　約	目　的	合約內必須記載的主要問題
借貸合約	提供計畫成本實質部份之財務計畫	■利率與償還時刻表 ■現金利用之先決條件 ■安全與後繼權

5.會議過程之討論焦點與關心議題

(1)新加坡方面：

a.台北市2002年旱災民生用水限水實施方法及成效

b.台灣水價現況及以缺水容忍度計算水價方式可行性

c.地下水利用情況及收費方式(有否利用人工補注地下水源)

d.台灣乾旱分階段配供水措施 (農業休耕→耗水工廠停工→民生用水限水)

e.台灣工業廢水回收再利用比率與研訂

f.台灣雨水利用比率及收集方式，儲存時間及雨水水質之確保

g.台灣雨水利用政府補助措施、及其對收集水量之影響

h.台灣海水淡化將來發展趨勢及可行性

i.台灣目前人口成長率及用水量成長之趨勢與應對措施

j.抗旱時期所提供之工業區節水服務之對應內容與節水服務團運作機制

k.台灣省水器材種類與節水規範與目前之執行成效

l.台灣整體水資源調整與應用，以及海水淡化所認定之優先次序

m.台灣之漏水防制措施，以及執行成效。

(2)台灣方面：

a.新生水用於補充飲用水水源的教育及宣導方式，民眾接受程度

b.新加坡水龍頭流量限制及各節水器材運用現況及推廣成效

c.淨水處理流程之評估方式及程序

d.新生水BOO案之評選、廠商營運方式

e.新生水水質監控方式及確保水質之管理方式

f.新生水原水來源及用途之評估方式

g.新加坡以海水沖廁之可能性及主要問題

h.新加坡採用二元供水系統之可能性

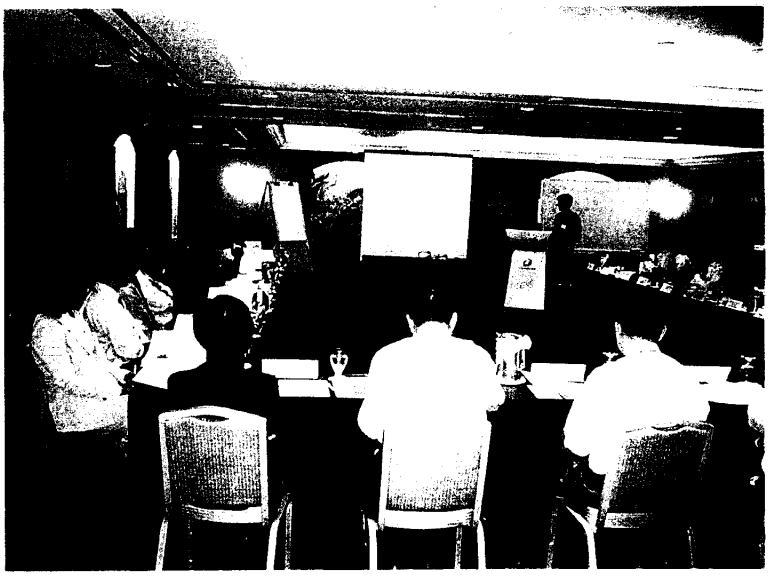
i.新加坡以較經濟之處理流程產生再生水用於次級用水之可行性

j.水價之研擬機制

k.新加坡將再生水應用在飲用水方面，在處理技術之突破與民眾心理方面之使用障礙克服方式及相關宣導配套措施

6.會議照片集錦

照片 3-2-1 新加坡代表報告實況



照片 3-2-2 台灣代表報告實況

照片 3-2-3 歡迎晚宴台新雙方互贈紀念品

(三)新生水系統參觀

1.新生水廠簡介

(1)本次參觀的為 Bedok 新生水廠，目前的處理流程為：微過濾（Micro filtration）＋逆滲透（Reverse Osmosis）＋紫外線殺菌（UV Disinfection）。其設計上為兩段式 RO 處理，可達 75%的回收率，RO 膜每 6 個月需清洗一次；目前本廠處理量為 32,000CMD，主要直接供應工業用水。

(2)本廠除了處理設施之外，主要設有一多媒體展示中心-新生水展覽館，本館包含六大部分：

1.入口處，說明水的重要

2.短片：說明如何用高科技造水

3.水的循環：用多媒體電腦教育民眾新生水的特性

4.國內外的淨化水：介紹其他國家的再生水用水現況

5.新生水製作過程：說明這些淨水科技的原理

6.新生水大挑戰：考考參觀者對於新生水是否真的了解？

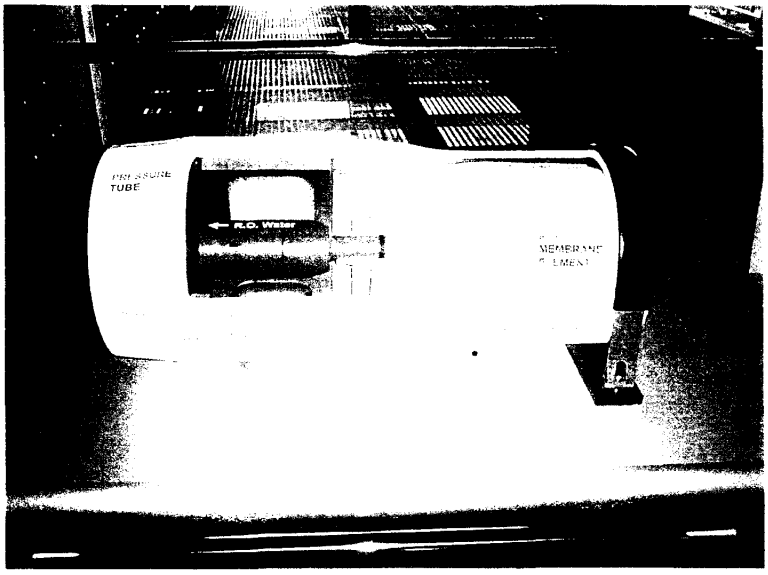
以上主要提供參觀者完整的新生水資料，包括設備種類、處理原理、處理後水質及監控方式等；這種宣導介面可以有效的提升民眾對於新生水使用上的疑慮，降低再生水使用心理上的障礙。

2.參訪照片集錦

照片 3-3-1 參觀新生水展示中心

照片 3-3-2 多媒體的新生水展示介面

照片 3-3-3 新生水 RO 膜處理設備說明模型



照片 3-3-4 Bedok 新生水廠參訪人員合影

照片 3-3-5 新生水試飲

(四)Hyflux 淨水公司參訪

1.Hyflux 公司簡介

(1)Hyflux 建立於 1989 年，目前員工超過 350 人，本身即具有膜生產能力；主要業務為給水處理、工業生產用途、廢水處理及水回收處理程序設計。目前新加坡的新生水廠即為此公司負責設計、施工建造。

(2)目前 Hyflux 主要將薄膜運用於各種不同的處理條件下，包括與生物處理結合開發生物薄膜反應器、與空氣中濕氣凝結機結合製作空氣造水飲水機等。雖然薄膜科技已確認可行，但是價格依然是應用上的一大障礙；藉由這些新興公司的努力，能夠有效的降低運用薄膜科技的價格，讓新科技更加快速的普及。

(3)Hyflux 公司代表性產品：超濾膜，此為完全是自主研發的產品（如圖 3-4-1），主要應用於工業及市政水處理，特別針對難以採用傳統處理方法的廢水、給水及其它工業流體。Hyflux 超濾膜元件採用中空纖維形式，膜的基本孔徑為 0.01 微米，膜材質為聚醚碸（Polyethersulfone ,PES），為親水性的材質。Hyflux 超濾膜採用雙皮層設計，能進行外壓式或內壓式操作，超濾膜的模組構造如圖 3-4-2 所示，這是一種採用低壓操作的膜過濾方式，用於截留進料液體中的細菌、病毒及其它高分子量的膠體顆粒和固體顆粒。在實際操作下，水經加壓，在壓力的作用下使乾淨而清潔的水通過膜過濾出來，而尺寸小於膜孔徑的膠體、細菌和其他物質被膜截留下來，從而完成整個過濾流程。超濾膜元件設計為中空纖維形式，能進行反沖洗操作，使膜表面的污垢脫落下來，維持膜表面的清潔。此超濾膜對於不同分子量的分離效率如圖 3-4-3 所示。

圖 3-4-1 Hyflux 超濾膜

圖 3-4-2 Hyflux 超濾膜模組構造及操作說明

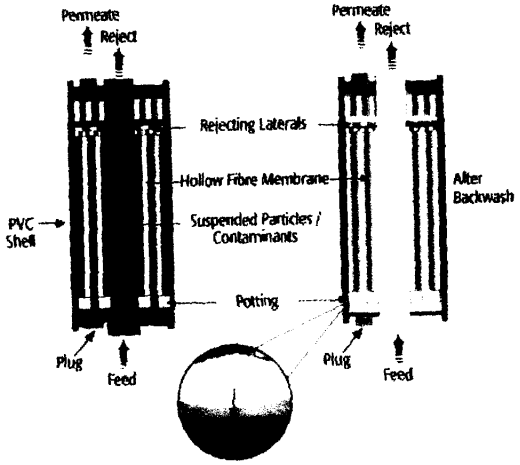
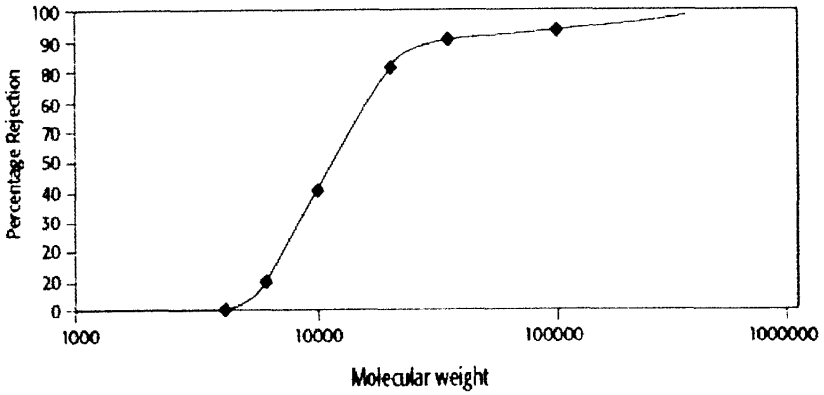


圖 3-4-3 Hyflux 超濾膜分子量截留效率曲線圖



2.參訪照片集錦

照片 3-4-1 Hyflux 公司 董事長 Miss Olivia Lum 親自接待台灣參訪團

照片 3-4-2 Hyflux 公司簡報

(五) 節水器材宣導現場參觀

1.節水宣導現場觀摩

(1) 公用事業局為再降低目前的 164 公升/人・日用水量，經常於各公開場所辦理節水宣導活動；本次特別到公用事業局其中一個節水宣導會場實際參觀，了解其宣導實況及民眾反應狀況。

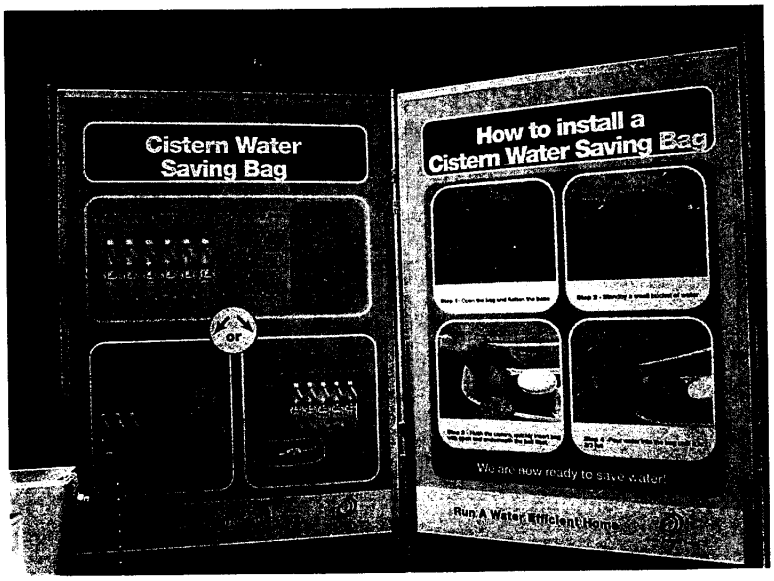
(2)節水宣導會場主要教育民眾如何減少生活中用水的需求量，現場並有實際的設備說明；而且教育民眾如何換裝省水設備，並發放水龍頭省水片及馬桶節水套件，讓民眾實際回家換裝。

2.參觀照片集錦

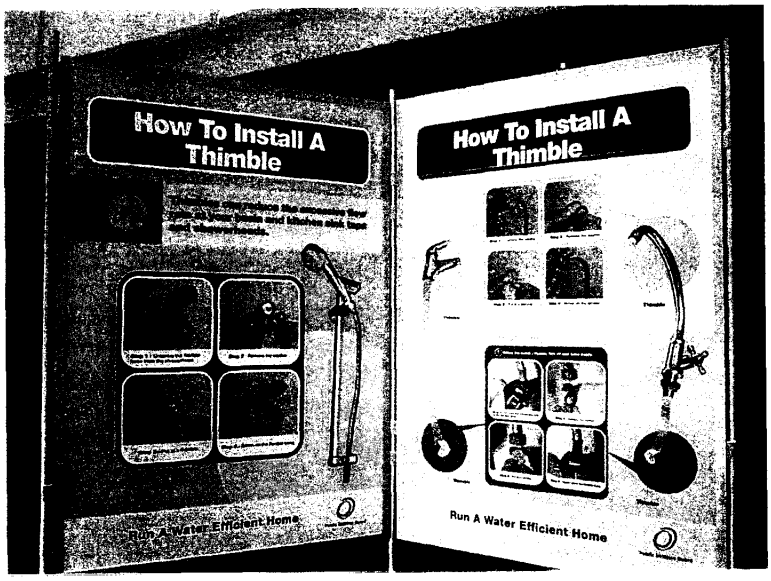
照片 3-5-1 參觀節水宣導會場

照片 3-5-2 節水器材安裝說明

照片 3-5-3 新加坡節水宣導看板-馬桶省水裝置說明



照片 3-5-4 新加坡節水宣導看板-龍頭及蓮蓬頭省水裝置說明



四、心得與建議

1.新加坡政府為了整合水利用，健全水循環，並推動海水淡化與新生水水源，特別進行水相關業務與組織功能再造。由新加坡公共事務局整合原屬環境部之污水系統處理署與排水系統處理署、新成立水再生利用署，統一水事權成為新加坡專業水機構。其政府組織再造的魄力與效率均值得我國借鏡。

2.新加坡本身缺乏水資源，在需進口用水的情況下，對於用水的節約及管理可說異常小心；不但民眾日用水量低，且極願意配合政府各項解決方案。相信在進一步與其交流下，必有更多的相關經驗可有效應用於我國。

3.用水問題的解決不外乎開源與節流；在開源上，新加坡應用了新科技產生了新生水及海水淡化此兩種新水源；而節流上，除了對民眾宣導節水方法，實際到各家庭中安裝節水器材，並徹底減少配水過程中的漏失。雖說原理簡單，但卻是最有效的解決方案。

4.雖說再生水用於飲用在處理技術上已非問題，價格上也漸趨可行，但是就民眾心理障礙上實非一朝一夕可以克服。新加坡政府為了減低民眾對新生水的疑慮，在做法上除了由新加坡總理親自試飲新生水證明水質安全可靠外，更進一部透過建立新生水展示館作實體導覽解說。

5.新加坡政府為了從事再生水技術研發，成立了先進水研究中心(Center for Advanced Water Technology，CAWT)，在淨水生產、轉換與處理等領域，創造新型科技平台，以使新加坡在水資源管理、費污水處理等研究領域與設計，能成為國際先進技術輸出者。國內在推動水產業深根時，成立台灣的 CAWT 有其必要。

6.國內水價偏低已造成日常節約用水推廣上的障礙，自來水配水管線的管理不善，漏水率偏高。新加坡在這方面所作的努力足堪為我國借鏡。

7.新加坡新生水雖已符合飲用水標準，但是為了確保沒有「萬一不安全」的發生機率，政府願意花費鉅資將生產出的新生水透過管線輸送到水

庫與雨水混合後再行配送供民眾使用，以降低民眾心理障礙，並提高使用上的安全性；再者，將新生水做為供應工業超純水與冷卻用水替代水源，其相關供水水源調度做法值得我國學習。。

8.新加坡地勢低平，配送水距離不長，所以用水的運送成本較低；台灣高低起伏大，配送至太遠的地區需耗費較大的管路與動力成本，所以各地水資源的調度運用複雜且困難。

9.新加坡沒有自然天災颱風、地震等的威脅，加上整個國家地勢起伏不大，因此相對台灣地理與天然災害頻仍條件，其水資源管理是簡單的多了；不過，新加坡在減低漏水率，推動節約用水，推動水價合理化上均有借鏡之處。

10.台灣在推動海水淡化的天然條件遠比新加坡嚴苛，雖然未來新加坡第一座海淡水價格僅新台幣 16 元，但是決不能以此作為台灣未來海淡水價格對照依據。蓋因台灣四周海象異常複雜，相較新加坡，必須投入更高的前處理成本。

11.新加坡推動海水淡化 BOO 之經驗難得，相關招標作業與各相關製造及採購部門合約規範事項等，均非常複雜。本次所收集到的相關資訊，值得我們仔細了解。

12.水回收再利用技術日新月異，薄膜價格相對已降低甚多，漸具競爭力。多元化水資源開發，已成為國際潮流，政府相關部門應重視此一發展，著手規劃建立水產業，並加強水處理專業人才之培植；對於工業界應用新技術於廢水回收上的獎勵措施可有效幫助工業用水回收率的提升。

13.推動水價合理反映成本，可以有效反應正確的水資源缺乏狀況，並且幫助民眾認識節約用水的重要性。新加坡在推動節約用水做法上有採取立法規範之強制措施，並透過立法提高水價。其相關立法規範措施，值得我國效行。

14.推動各工業區內建置廢水回收再利用系統，除了推行工業區內各工廠提高用水回收率之外，並由工業主管部門籌辦進行工業區內廢水

回收再利用系統委託民間經營，成為工業用水替代水源。

15.國內目前對於工業用水咸少有水權之規劃或核定之案例，工業用水大多與民生用水管線及水源相同，工業用水專管之設置更是少有，如未來設置再生水處理廠其地點應盡可能靠近需水地區，可減少設置再生水配水專管之費用；再生水之原水可將生活污水列入考量，以降低處理困難度並減少造水成本。

16.再生水水廠或是海水淡化廠的經營模式上，可以使用 BOO 的方式，讓業者自行操作而國家則負責確保水價及確認供水水質即可；不但雙方皆創造利潤，且不會造成政府管理人力上的增加。

17.目前台灣生活用水量高出新加坡甚多，除了提高水價外，可再加強宣導民眾用水減量的重要性，以提高生活用水效率，減緩因人口增加而日益上升的民生用水需求。

18.對於配水管線的管理，必須訂定一完善計畫針對老舊破損之管線進行汰換，除了可降低漏水率之外，尚可有效提高供水品質並減少因漏水而造成的公共建設損毀及民眾財產的損失。

附錄一

CONFERENCE ABSTRACTS

25 & 26 February 2003

Suntec Singapore International Convention & Exhibition Centre

Water Reuse & Desalination Conference

in conjunction with

Water and WasteTech Asia 2003

Platinum Sponsor

حائزة الأمير سلطان بن عبدالعزيز العالمية للمياه
PRINCE SULTAN BIN ABDULAZIZ INTERNATIONAL PRIZE FOR WATER

Organised by

Supported by

National Environment Agency

Public Utilities Board

AMST (The Association of Membrane Separation Technology of Japan)

Environmental Engineering Research Centre

SAFEGO

WATER RE-USE PROMOTION CENTER

NWRI National Water Research Institute

SINGAPORE ENVIRONMENT COUNCIL

REGIONAL INSTITUTE OF ENVIRONMENTAL TECHNOLOGY

JDA

ie Singapore

CONTENTS

MESSAGE BY SAFEco

The last thirty years from the time of the Stockholm Convention on the Human Environment in 1972, to the World Summits on the Environment at Rio in 1992 and at Johannesburg last year, have seen an increased emphasis on environmental management and sustainable best practices. At the national level, governments are integrating environmental considerations into development processes in recognition of the merits of sustainable development. At the international level, there is increasing international and regional cooperation to protect the environment.

Both in Singapore and in the Asia-Pacific region, there are new and active environmental markets covering the management and treatment of water, air, solid waste, hazardous waste, toxic substances and energy production. Within China and India, as well as the countries of ASEAN, there are many upcoming environmental projects that will stimulate the interest of project developers and investors.

Mindful of these exciting developments in Asia, SAFEco in partnership with the International Desalination Association (IDA), World Energy Council (WEC) and Suntec Integrated Media (SIM) has developed high quality conferences to run alongside the environmental and facility management exhibitions, to provide all participants with the latest in technologies, policies, R & D developments and best practices drawn from around the world, covering topics such as water re-use, desalination, energy restructuring, waste to energy and many more.

I hope this interactive forum and exhibition will provide you, the participant, with the most appropriate solutions to your environmental problems as well as open up opportunities for projects in the Asian region. I am confident that you will find the time you spent here in Singapore rewarding and I wish all of you an enjoyable and fruitful stay.

Edwin Khew
Chairman
Singapore Association For Environmental,
Occupational Health And Safety Companies (SAFEco)

MESSAGE BY IDA

Welcome from the IDA President

On behalf of the International Desalination Association (IDA), I have the pleasure of welcoming you to the Water Reuse and Desalination Conference of which IDA is proud to be a sponsor in conjunction with SAFEco and Suntec.

IDA held a very successful Regional International Conference on Desalination in Singapore during March 2001. Due to the relatively high availability of surface, aquifer and waste waters in this region, this Conference focuses primarily on the use of desalination technology in the treatment of water for reuse, rather than the desalination of seawater and brackish waters.

The Technical Program Chairman, Mr. David Furukawa, who is a past-President of IDA, has put together an excellent program with world renowned experts presenting papers on many aspects of water reuse, including research & development, health issues, economics, planning, and case histories.

Desalination technology has advanced significantly in recent years, with the most remarkable progress being made in the development of membranes. During the Conference you will hear of the many applications that utilize these advanced membranes for reuse applications, leading us towards a more sustainable environment. Whether you be a scientist, researcher, manufacturer, end-user, planner, or financier, I am confident that this Conference will be of great value to your future activities in water reuse, not just from the papers themselves, but also the opportunity to meet with the other attendees.

I wish you a very successful Conference on behalf of the Directors of IDA.

Dr. Bill Andrews
IDA President

CONFERENCE COMMITTEE

Water Reuse & Desalination Conference Committee

Advisor

Mr Edwin Khew, Executive Director
Vivendi Universal Pte Ltd

Program Co-Chairman

Mr Donald Goh, General Manager
SEMES

Mr David H Furukawa, President
Separation Consultants Inc

Committee Members

Mr CG Tan, General Manager
Sembcorp Utilities and Terminals

Mr Tan Yok Gin, Asst Director
Public Utilities Board

Mr Richard Jacob, Vice President
Vivendi Water Systems

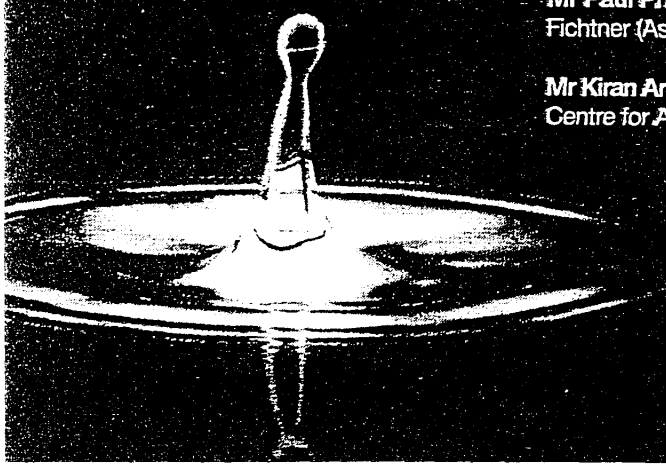
Assoc Prof Ong Say Leong
National University of Singapore

Assoc Prof Lawrence Koe
Nanyang Technological University

Mr Ron Advani, Managing Director
CH2MHILL

Mr Paul Phua, Managing Director
Fichtner (Asia) Pte Ltd

Mr Kiran Arun Kekre, Department Manager
Centre for Advanced Water Technology



Day One I Tuesday, 25th February

8.00 - 9.00 **Conference Registration**

9.00 - 10.00 **Main Event Opening Ceremony**

OPENING SESSION I

Chairs: Mr Donald Goh, Mr David Furukawa (conference technical program co-chair)

10.00 - 10.05 **Welcome Address**
Mr Edwin Khew, Chairman
Singapore Association for Environmental, Occupational Health & Safety Companies (SAFEco)

10.05 - 10.10 **Opening Address**
Dr Bill Andrews, President
International Desalination Association

10.10 - 10.25 **Address by Guest of Honour**
Mr Tan Gee Paw, Chairman
Public Utilities Board, Singapore

10.25 - 10.35 **Platinum Sponsor Address**
Prince Sultan bin Abdulaziz International Prize for Water
Dr Abdulmalik, Secretary General of the Prize
Director of Prince Sultan Research Center for Environment, Water & Desert

10.35 - 10.55 **Keynote Address**
Professor George Tchobanoglous
University of California Davis, USA

10.55 - 11.10 TEA BREAK

11.10 - 11.30 **Advanced Reuse – From Windhoek to NEWater and Beyond**
Mr Ian Law, Technology Director
Asia Pacific Region, CH2MHILL, Australia

11.30 - 11.50 **Global Overview of Membranes for Water Reuse**
Dr James D. Birkett, Proprietor
Westneck Strategies, USA

SESSION II - REGIONAL PRACTICE

Chairs: Mr Ron Advani, Mr Ghassan Ejjeh

11.50 - 12.10 **A Thirsty Planet**
Professor Ong Choon Nam,
Dept of Community Occupational& Family Medicine,
National University of Singapore

12.10 - 12.30 **Singapore's Experience on Water Reuse**
Mr Harry Seah, Deputy Director
Public Utilities Board, Water Reclamation Department, Singapore

12.30 - 12.50 **Industrial Water Practice**
Dr Totaro Goto, Managing Director
Water Reuse Promotion Centre, Japan

12.50 - 1.35 LUNCH

1.35 - 1.55 **Communal Waste Water Reuse For Potable Water - IWVA**
Mr Henk Van Den Berkmortel, General Manager, Water Division
Seghers Keppel Technology Group, Belgium

1.55 - 2.15 **Strategies to Minimize Membrane Fouling in Water and Wastewater Treatment**
Professor Anthony G. Fane, Director
UNESCO Centre for Membranes, University of NSW, Australia
Temasek Professor, IESE, Nanyang Technological University, Singapore

SESSION III - RESEARCH
Chair: Mr Ronald Linsky

2.15 - 2.40 **Membrane Improvement using Molecular Modeling: Strategies for Modeling Performance & Fouling**
Dr Harry Ridgway, President
Aquamem.com, USA

2.40 - 3.05 **Membrane Fouling : Alternative Anti-fouling Approaches**
Dr Hans-Curt Flemming, Managing Director & Professor,
Institute of Interface Biotechnology, University of Duisburg Germany

3.05 - 3.30 **Development of A Submerged NanoFiltration Membrane Bioreactor (NF MBR) for Wastewater Reclamation**
Dr Kazuo Yamamoto, Professor
Environmental Science Centre, The University of Tokyo, Japan

3.30 - 3.55 **A Novel Fouling Characterization Technique for Full Scale RO Process**
Assoc Prof Song Lianfa, Lecturer
Center for Water Research, Department of Civil Engineering,
National University of Singapore, Singapore

3.55 - 4.10 TEA BREAK

SESSION IV - HEALTH ISSUES
Chair: Dr James Birkett

4.10 - 4.35 **Health Issues Addressed by Today's Membrane Treatment Systems for Water Reuse Applications**
Dr Richard Sakaji, Senior Sanitary Engineer
California Department of Health Services (DOHD),
Drinking Water Program, USA

4.35 - 5.00 **Testing Protocols for Membrane Selection: Equivalency and Fate, Organism / Pathogen Removal**
Professor George Tchobanoglous
University of California Davis, USA

5.30 - 8.00 COCKTAIL RECERTION

Day Two I Wednesday 26th February

SESSION V - MAXIMISING REUSE VALUE
Chair: Dr Totaro Goto

8.30 - 8.55 **The Value of Water in the Urban Watershed**
Mr Ronald B. Linsky, Executive Director
National Water Research Institute (NWRI), USA

8.55 - 9.20 **5 Designer (Recycled) Waters to meet Customers Needs**
Mr Darryl Miller, General Manager
West Basin Municipal Water District, USA

9.20 - 9.45 **Ultrapure Water Production from Reclaimed Water**
Mr GuiHe Tao, Senior Research Scientist
Centre for Advanced Water Technology
Singapore Utilities International, Singapore

9.45 - 10.10 **Newly Developed Waste Water Treatment Systems Using Separation Membranes**
Dr Masaru Kurihara, Senior Director - Water Treatment Division, Technology Centre,
R & D Division, Toray Industries, Inc, Japan

10.10 - 10.35 **Cost of Current Membrane Technology**
Ms Lisa Henthorne, Partner
Aqua Resources International, USA

10.35 - 10.50 TEA BREAK

SESSION VI - MEMBRANE BIOREACTORS
Chair: Ms Lisa Henthorne

10.50 - 11.15 **New Technologies and Applications in MBR using Hollow Fiber Membrane**
Mr Tsutomu Kakuda, Director, Marketing
Mitsubishi Rayon Co Ltd, Japan

11.15 - 11.40 **Introduction of Submerged Membrane in Japan - Application to Domestic Wastewater and Industrial Wastewater**
Mr Tadaaki Sakata, Deputy Manager,
Engineering Technical Support, International Group of Membrane System Department
Kubota Corporation, Japan

11.40 - 12.05 **Integrated Water Management Approach to Chemical Complex in Jurong Island**
Mr Eugene Yan Yuegen, Asst Vice President
SUT Sakra Pte Ltd, Singapore

12.05 - 12.30 **Delivery and Performance of the Luggage Point Water Reclamation Project**
Dr Greg Leslie, Water Reuse Leader for Asia Pacific
CH2MHILL, Australia

12.30 - 1.30 LUNCH

CONFERENCE PROGRAM

SESSION VII - DESALINATION FOR SEAWATER AND REUSE
Chair: Mr John Tonner

1.30 - 1.55 **Membranes as Pretreatment to Desalination in Wastewater Reuse. Operating Experience in the Municipal & Industrial Sectors**
Mr Koh Wai Keat, Senior Business Development Manager
Vivendi Water Systems Asia, Singapore

1.55 - 2.20 **Dual Nanofiltration Process for Ocean Water Desalination**
Mr Diem Xuan Vuong, Assistant General Manager
Long Beach Water Department, USA

2.20 - 2.45 **Planning for Sea Water Desalination and WasteWater Reuse in Taiwan**
Dr Wen-Sen Chu, Chief Executive Officer
Environment & Infrastructural Technologies Inc (EITCO), Taiwan

2.45 - 3.10 **Drip Irrigation for People**
Dr William T. Andrews, President
International Desalination Association & Managing Director DWEER Technology Ltd, Bermuda

3.10 - 3.35 TEA

SESSION VIII - APPLICATIONS
Chair: Dr Masaru Kurihara

3.35 - 4.00 **Wastewater Reclamation Using Integrated Membrane Systems**
Dr Mark Wilf, Vice President
Corporate Technology, Hydranautics, USA

4.00 - 4.25 **Reuse of Nickel Refinery Wastewater by Microfiltration and Reverse Osmosis Desalination**
Mr Neil Palmer, Technical Manager
United Utilities Australia, Adelaide, Australia

4.25 - 4.50 **Water Reuse & Zero Liquid Discharge - A Sustainable Water Resource Solution**
Mr Bruce Durham, Alternative Water Resource Manager
Vivendi Water, UK

4.50 - 5.15 **Sewer Mining in Urban Melbourne**
Mr Henry Mallia, Business Manager,
Water Industry Group (Melbourne)
Earth Tech Engineering, Australia

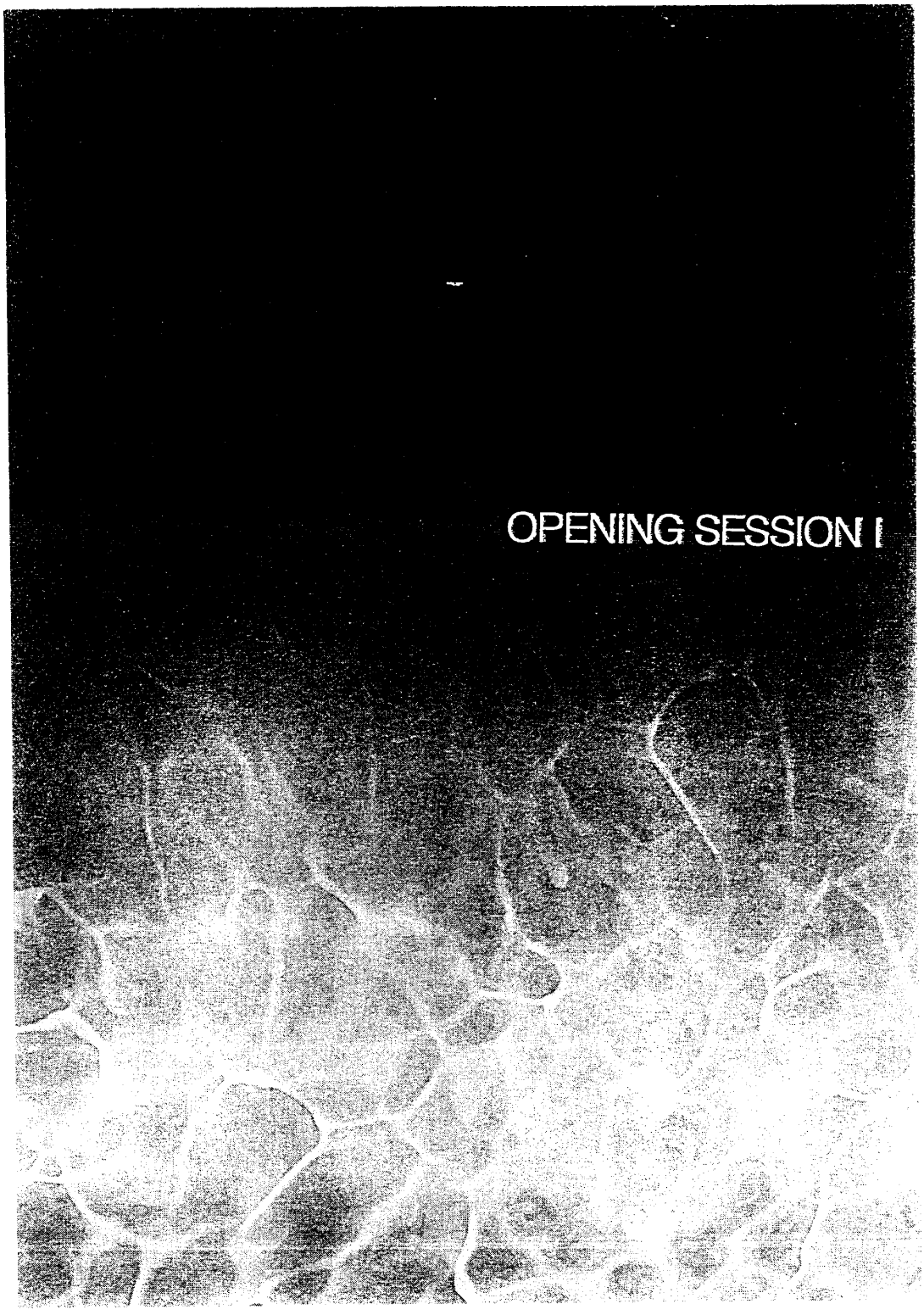
SESSION IX - CLOSING REMARKS

5.15 - 5.30 **Dr George Tchobanoglous**
University of California Davis, USA

6.30 - 9.00 CONFERENCE DINNER

Day Three | Thursday 27th February

8.30 - 11.30 Site Visit to Bedok NEWater Plant


OPENING SESSION I

THE STRATEGIC IMPORTANCE OF DECENTRALIZED WASTEWATER MANAGEMENT IN THE TWENTY-FIRST CENTURY

George Tchobanoglous
Professor Emeritus of Civil and Environmental Engineering,
Department of Civil and Environmental Engineering,
University of California at Davis, Davis, CA

>> abstract

The orderly development of urban and near urban areas is dependent on the availability of water. In areas where the available sources of water are limited or are unreliable, it is now recognized that wastewater represents a very reliable water source. In the future, as the demand for fresh water exceeds the supply and the value of water increases, the role and importance of water reuse will continue to expand. Historically, reclaimed water for reuse has been derived from centralized treatment facilities. However, as long-term strategies are developed to optimize the use of water resources to protect the environment and to sustain development, it is clear that decentralized wastewater management (DWM), which may be defined as the collection, treatment, and reuse of wastewater at or near the point of waste generation, will become an important element of those strategies. The purpose of this paper is to discuss the development and implementation of effective DWM systems that will contribute to the maintenance of public health as well as sustainable growth and development.

>> biography of presenter

George Tchobanoglous is a professor emeritus of Environmental Engineering in the Department of Civil and Environmental Engineering at the University of California at Davis. He received a B.S. degree in Civil Engineering from the University of the Pacific, an M.S. degree in Sanitary Engineering from the University of California at Berkeley, and a Ph.D. in Environmental Engineering from Stanford University. His principal research interests are in the areas of wastewater treatment, wastewater filtration, UV disinfection, aquatic wastewater management systems, solid waste management, and wastewater management for small systems. He has authored or coauthored over 350 technical publications including 12 textbooks and four reference works. The textbooks are used in more than 200 Colleges and Universities throughout the United States. The textbooks and reference books are also used extensively by practicing engineers both here and abroad. Professor Tchobanoglous serves nationally and internationally as consultant to both governmental agencies and private concerns. An active member of numerous professional societies, he is a Past President of the Association of Environmental Engineering and Science Professors. He is a registered Civil Engineer in California.

ADVANCED REUSE – FROM WINDHOEK TO NEWATER AND BEYOND

IAN LAW
Technology Director, Asia Pacific Region
CH2M HILL
ilaw@ch2m.com.au
Australia

>> abstract

Advanced reuse, and the subsequent use of the reclaimed water to supplement a community's water supplies, is a topic that often elicits debate between professionals and lay-people alike; and this has been the case ever since the first such facility was commissioned in the 1960s.

The 'precautionary principle', a term described by some as being a reason for doing nothing, is certainly applied to this form of water supply augmentation. This is despite the fact that such schemes always incorporate more 'treatment barriers' than are provided in many conventional water treatment systems that draw from raw water supplies of dubious quality.

Nevertheless, there has been much achieved in the field of Advanced Reuse and this paper provides an overview of developments since the world's first direct potable reuse plant was commissioned in Windhoek, Namibia in 1968. It notes that the improvement in the technologies applied has generally been driven by the increase in analytical capability and that, in line with this, membrane systems are finding increasing application in the treatment plants; as highlighted by the recent NEWater plants in Singapore.

Advanced Reuse systems have a role to play in securing our water supplies into the future. Much has been done and we have some 'trophy' projects either operating or under design; but there is still a lot to be done. While we have the technology to produce whatever quality is required, we do have to ensure that all regulators, water professionals and the community-at-large accept planned indirect potable reuse as a viable way of augmenting our dwindling fresh water supplies – this is the ultimate challenge.

>> biography of presenter

Ian Law holds a Bachelor of Science degree in Chemical Engineering (1969) and a Masters in Public Health Engineering (1974) from the University of Cape Town in South Africa. He is a member of the Water Environment Federation, the International Water Association, the Australian Water Association and the Water Institute of Southern Africa.

He is currently CH2M HILL's Technology Director for South East Asia, Australia, and New Zealand. He has worked throughout the Asia Pacific region in water and wastewater treatment, particularly in advanced reuse and biological nutrient removal projects. He has more than 20 years of experience in design and application of advanced reuse projects - both potable and non-potable – and has authored many papers on these subjects.

He was responsible for the design of the NEWater Demonstration Plant at Bedok WRP that was commissioned in May 2000 and is currently CH2M HILL's Project Director for the larger NEWater Plants that have recently been commissioned at Bedok and Kranji and that currently being constructed at Seletar.

GLOBAL OVERVIEW OF MEMBRANES FOR WATER REUSE

Dr. James Birkett
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>> abstract

Membranes have been considered for wastewater treatment and water reuse applications as long as there have been commercially available membranes. However the intrinsic value of the water recovered for reuse was rarely a major factor in the decision-making process.

Progress was slow but steady during the 1970s and 80s. While this research continued, other factors played a significant role in membrane development. Foremost among these in the United States was the Safe Drinking Act and its various amendments, especially the Surface Water Treatment Rule (SWTR). In addition, the whole issue of membrane configuration was rethought. Lastly, there was a new appreciation that the true value of water is not cost of the water, but rather the cost of doing without. Such thinking supported the investment in further research.

Further, the approach to municipal water reuse was no longer limited to tertiary treatment (the treatment of secondary effluent). While the latter is still being done, often successfully, there was now clever and beneficial integration of membrane separation processes upstream into the secondary treatment phase itself. The number of tertiary treatment plants in operation worldwide is certainly in the hundreds, if not thousands. The number of municipal MBR plants worldwide measures in the hundreds.

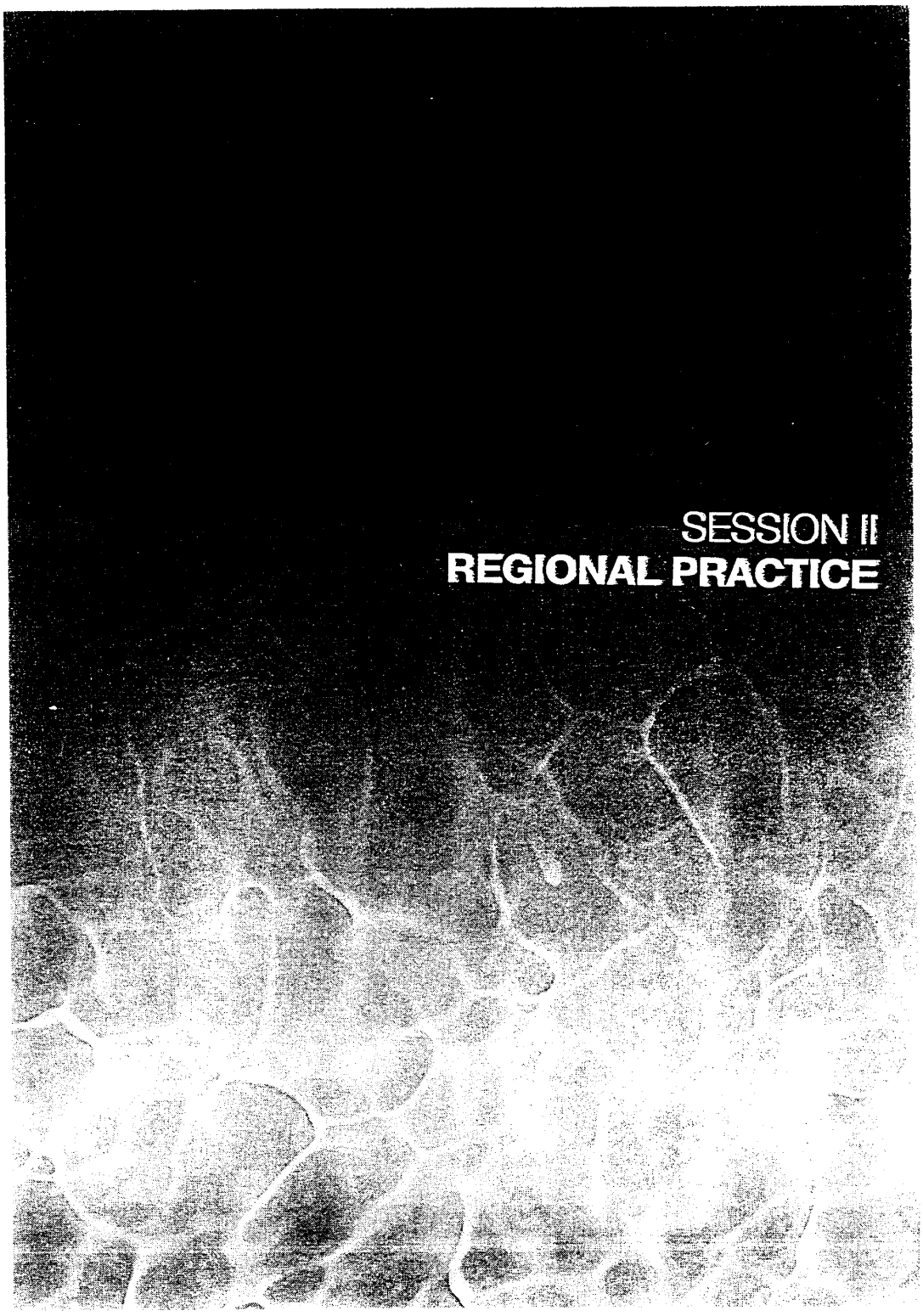
The prospects for municipal water reuse are too good not to attract additional suppliers of membranes and systems However the decision to enter this market has to be based on the ability to compete at many levels, including technical membrane capability, systems design, production, fabrication and construction considerations, and post-sales support. There will be room for many competitors; however there will not be room for all competitors. A shake-out is inevitable, but the eventual beneficiary will be the customer.

>> biography of presenter

Dr. Birkett received his A.B. degree from Bowdoin College and his M.S. and PhD. degrees from Yale University, in physical chemistry.

In 1962 he joined the staff of Arthur D. Little, Inc. (ADL) in Cambridge, Mass., USA. In 1988 he left ADL to form his own consulting practice, West Neck Strategies, in Nobleboro, Maine. Dr. Birkett draws upon his more than 35 years of experience in the study of desalination, advanced water treatment, and membrane separation industries and technologies. He works frequently and effectively providing specific industry and technology support in their strategic planning and in evaluating the commercial viability of new processes and process modifications.

Dr. Birkett is a member of the American Chemical Society, the New York Academy of Science, the Newcomen Society for Study of the History of Engineering and Technology, the American Membrane Technology Association, the American Water Works Association, and the North American Membrane Society. He is a Director and past President of the International Desalination Association. He serves on the editorial boards of the journals Desalination (Elsevier Scientific Publishing) and Desalination and Water Reuse Quarterly (Faversham Publishing).


SESSION II
REGIONAL PRACTICE

A THIRSTY PLANET

Professor Ong Choon Nam
Director,
Centre for Environmental and Occupational Health at the Faculty of Medicine, NUS.

>> abstract

Universal access to clean water is a fundamental human need, yet over a billion people in our planet do not have access to clean water, and millions die from water-borne diseases each year. Pollution, climatic change and destruction of natural ecosystems threaten the availability of this precious resource. Using water efficiently thus becomes the key to meeting current and future demands. A fundamental change in our perception and use of water resources is obviously needed and alternative approaches should be considered. Non-traditional sources, made possible through technological advances, will play an increasing role in meeting the demand for water. As an island nation, Singapore has a dearth of natural resources, especially water; with minimal of its own and imports most by from neighbouring country. Singapore consumes over 300 million gallons of water a day and this is expected to go up by a third in the next 10 years. To meet current and future needs, Singapore has had to explore alternatives for managing the demand for water, and to achieve self-sufficiency in water supply. While high quality reclaimed water treated with filtration, reverse osmosis and UV disinfection (NEWater) is being used by the IT industry, scientists in Singapore have spent the last few years analyzing the quality of the water with a primary objective to determine its suitability for indirect potable use. So far, more than 20,000 tests have been performed on over 190 parameters. This list covers tests on physical, chemical and microbiological analysis. The exhaustive range of tests exceeded the WHO and the US-EPA requirements. The evaluation included tests for newly emerging compounds and pathogens, carcinogenicity studies in mice, and observations for potential endocrine effects in fish. An expert panel that oversees these studies recently concluded that the NEWater is a safe supplement to Singapore's existing water supply and recommended that the reclaimed water be released into reservoirs; a practice that has been carried out in several US communities using different reclaim technologies.

>> biography of presenter

Professor Ong Choon Nam is the Director, Centre for Environmental and Occupational Health at the Faculty of Medicine, NUS. He has an excellent international reputation for his research. He has made important contributions to the understanding of environmental exposure to xenobiotics and carcinogenesis, in particular the molecular mechanisms of how carcinogen caused cellular and DNA damage and has published more than 170 papers in international peer-reviewed journals. Prof. Ong is a member of the International Life Science Institute (ILSI) based in Washington DC and he was the recipient of Astra-Zeneca Award for 2001. Since 1985, he has served as a consultant to the World Health Organization on Environmental Health and was involved in 12 of its Environmental Health Criteria publications. He has been an Associate Editor of Environmental Research, the foremost journal in the field of environmental health, since 1995. He is also in the editorial board of several international Environmental and Occupational Health journals. He has been a Visiting Professor to Fudan University, and Sun Yet-Sen University since the 1990's, and recently, to Nanjing Medical University. He is the Chairman of the International Expert Panel on NEWater

SINGAPORE'S EXPERIENCE IN WATER REUSE

Harry Seah
Deputy Director
Public Utilities Board
Water Reclamation Department,
Singapore

>> abstract

NEWater is high quality water of drinking water standards, produced from secondary treated wastewater effluent using proven membrane technology of microfiltration/ultrafiltration and reverse osmosis.

NEWater will be supplied direct to industries for their process use, substituting current PUB tap water. Two NEWater factories – at Bedok and Kranji, are currently in operation. The third NEWater factory is under construction and is expected to be ready in early 2004. At least 55 mgd or about 250,000 m3/d of NEWater is expected to be supplied direct to the industries by year 2012.

In February, NEWater will be a source of raw water for potable use. This indirect use is done by injecting some NEWater into existing reservoirs to blend with the reservoir water before treatment again at existing water works. 2 mgd or about 9,000 m3/d of NEWater will be injected initially and this would gradually to 10 mgd or about 45,000 m3/d by year 2011. This indirect use of NEWater for potable use has been in practice in other countries especially in the United States for more than 20 years.

>> biography of presenter

Harry Seah is the Deputy Director in the Water Reclamation Department, PUB. He is responsible for the operation of 3 wastewater treatment plants – Kranji, Bedok and Seletar. These 3 wastewater treatment plants will be the first plants to have NEWater Factories. He has been involved in the development of NEWater since 1998.

Harry Seah graduated from the National University of Singapore in 1983 with a Bachelor of Engineering Degree (Civil) Hons. He obtained his Masters Degree in Environmental Engineering from the University of Newcastle Upon Tyne, UK in 1992.

INDUSTRIAL WATER PRACTICE

Totaro Goto and Mutsuo Kawasaki
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Country: Japan

Presenter
Totaro Goto
Managing Director
Water Re-use Promotion Center

>> abstract

Water shortages are spreading all over the world. Industrial water is not an exception, and rather more serious than agriculture and domestic water, because industry is a new comer for water demand. In drought, agriculture and drinking water have higher priority for use over industry in most countries. Even in Southeast countries that have much rain, industrialists are suffering from water shortage due to land subsidence by over-pumping of ground water.

Reuse and effective use of industrial water are considered as the strong tools to cope with the situation. This paper will provide some information on reality of industrial water use, and then will focus on the reuse in practice. The followings are the conclusive remarks:

(1) Information on fresh water consumptions by industry was given. It was found that pulp & paper, chemical and iron & steel industries are the three major water-consuming industries.
(2) The kind of targeted water for reuse in industry was suggested. They are water for boiler feed, processing/washing and air/moisture conditioning.
(3) Concerning the practical reuse in industry, a general rules are given, in which reuse classification of cascade, recycling and reuse of final wastewater was presented from the past investigations data on water usage in many factories.
(4) The practical cases of reuse in a factory suggested the following conclusions:
    1) Reuse for cooling and air-conditioning is easiest and most popular.
    2) Washing/processing is the second easiest way for reuse.
    3) Boiler feed is also reused when the boiler capacity is rather large.
    4) Reuse of final wastewater with membranes will be a breakthrough technology for reuse in near future.

>> biography of presenter

1. Educational Background
Graduated from Applied Chemistry Course, Faculty of Engineering, Hokkaido University, Japan in 1953

2. Profession
(1) Employed by Daiichi Rubber Company in 1953
(2) Employed by National Institute of Material and Chemical Research, Ministry of Economic, Trade and Industry in 1956
(3) Transferred to Hokkaido National Industrial Research Institute in 1982
(4) Employed by Water Re-use Promotion Center in 1989

3. Relevant Professional Information
(1) Awards
    1) Technical Proficiency Award by the Society of Sea Water Science, Japan in 1978
    2) Technical Proficiency Award by the Society of Chemical Engineers, Japan in 1982
    3) Achievement Award by International Desalination Association in 1997
(2) Fields of Activities
Dr. Goto is now in charge of technical affairs for Water Re-use Promotion Center that covers the fields of water technology. He joined the national project of seawater desalination in 1969 and studied MSF process when he worked for National Institute of Material and Chemical Research. He extended his activity field to reverse osmosis, wastewater treatment and reuse at Water Re-use Promotion Center. He is now serving to Japan Desalination Association as the president since 2001.

COMMUNAL WASTE WATER REUSE FOR POTABLE WATER – IWVA Koksijde Belgium

Henk van den Berkmortel
General Manager, Water Division
Seghers Keppel Technology Group
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Belgium

>> abstract

Effluent from a communal biological waste water treatment plant is treated by submerged microfiltration membranes and further desalted by low pressure reverse osmosis. The RO permeate is blended with MF permeate to arrive at the required water hardness and alkalinity for potable water distribution, then disinfected and infiltrated into the dunes. The water is then treated in a conventional water treatment plant (earation and sand filtration) and distributed as potable water.

The plant is designed in 2001, erected in 2002 and started up in June 2002 and now running for nine month. In the presentation the design outline and production results will be discussed and experiences highlighted.

>> biography of presenter

1. **Educational background**
   Elementary school
   Secondary school
   University of Dordrecht: Chemical Engineering degree
   MBA courses

2. **Professional background**
   1972 – 1979 Philips Architect & Engineering Office
   Chemical engineer dealing with chemical / physical water and waste water treatment including ultra pure water preparation

   1979 – 1980 Centrilab
   Head of the Water, Air and Soil department

   1981 – 1982 ARAMCO (Arabian American Oil Company)
   Consulting engineer for Utilities water, waste water and steam

   1982 – 1989 Heineken Technical Services
   Head of the Water and Waste Water Design Department

   1990 – 2000 HAB water & milieu BV
   Director

   2000 – 2002 SEGHERSbetter technology NV
   Consultant Membrane technology

   2002 – present Seghers Keppel Technology
   General Manager, Water Division

3. **Additional Relevant Professional Information**
   Mr. Van den Berkmortel has been consulting, designing, building, starting up and operating membrane installations (MF, UF, NF, RO, MBR) since 1974 and has published several articles on RO desalination among others for Aramco, Amsterdam Water Works, Brewers Association of America's and Seghers Keppel Technology Group. He further presented several papers some of them also with IDA.

STRATEGIES TO MINIMISE MEMBRANE FOULING IN WATER AND WASTE WATER TREATMENT

A.G.Fane[1,2], S.Chang[2], B.D. Cho[2], P.Neal[2] and K.Parameshwaran[2]

1. IESE, Nanyang Technological University, Singapore
2. UNESCO Centre for Membrane Science and Technology, University of New South Wales, Sydney, Australia

Australia and Singapore

Presenter

Professor Anthony Gordon Fane
Temasek Professor
Nanyang Technological University
Singapore
Director
UNESCO Centre for Membrane Science and Technology
University of New South Wales
Australia

>> abstract

Fouling is an important and complex phenomena and its control is vital to the successful application of membrane technology in water applications. The purpose of this paper is to highlight the influence of the imposed flux and the fluid management characteristics of the module and operating mode. It is based on a review of research findings in our Centre.

Particulate fouling in the spiral wound module occurs when the flux exceeds the 'critical flux' of the particles, and this is most likely to occur for submicron particles and in the region of highest local flux, which is at the inlet close to the permeate tube. The feed channel spacers raise critical flux significantly but the best control strategies are probably flux limitation and effective pretreatment.

For hollow fibre modules operated in the dead end mode, the imposed flux influences backwash frequency and efficiency, and consequently determines membrane fouling. The optimal flux provides a trade off between backwash and productivity. For submerged hollow fibres with bubbling the critical flux increases with bubble flow rate and is enhanced when the fibres are loosely rather than tightly arranged. Thus fouling is mitigated by imposed flux and hydrodynamic effects.

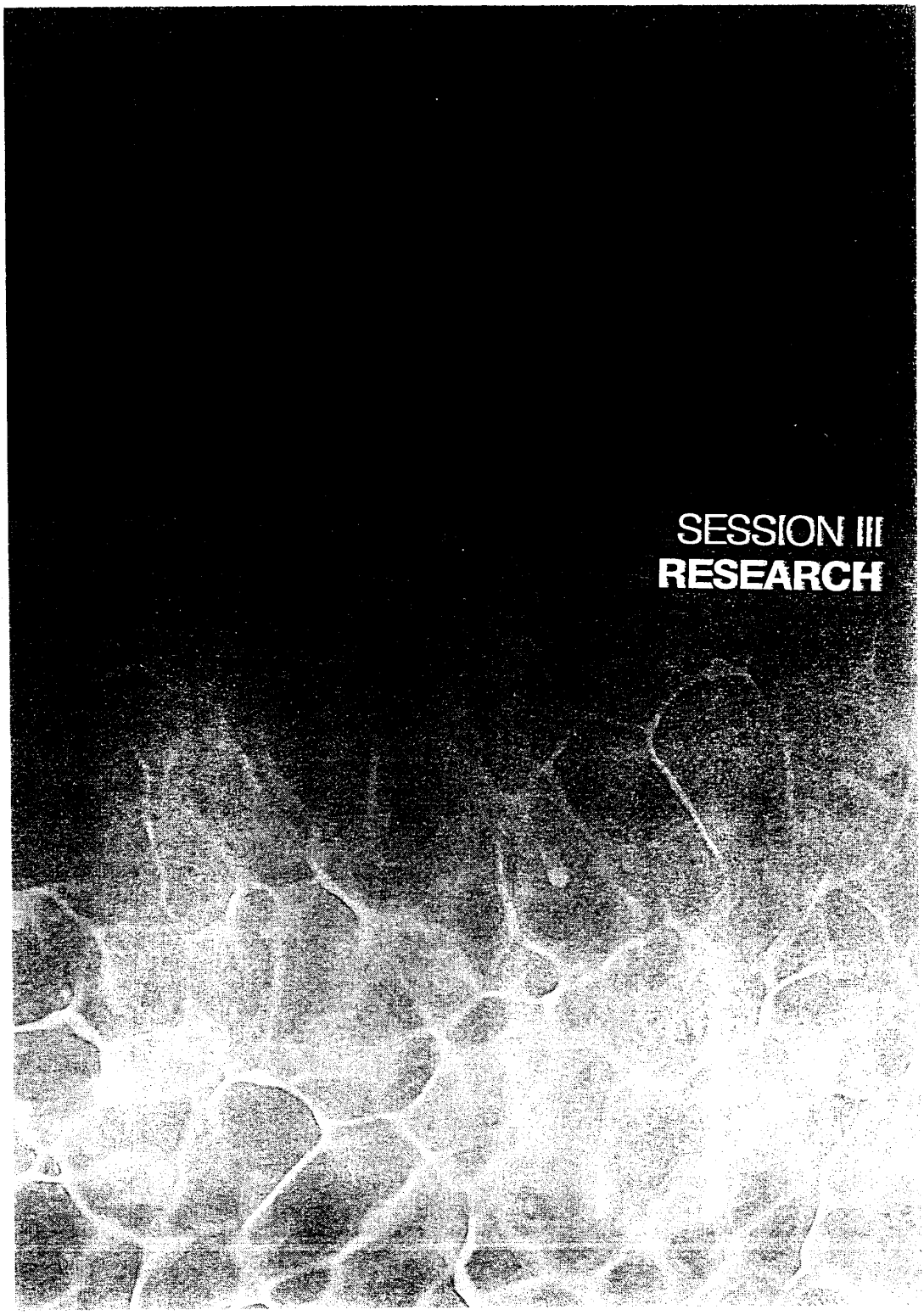
Observations of an anaerobic MBR at nominally subcritical flux showed a steady rise in transmembrane pressure (TMP) which was greater as imposed flux and organic load to the MBR were increased. For extended operation the TMP rise was characterised by a sudden rate increase suggesting a changed fouling regime. Examination of fouled membranes indicated that EPS played an important role in the fouling behaviour. Strategies for fouling control again include flux limitation as well as minicleans and MBR adjustments.

>> biography of presenter

Professor Fane is a Chemical Engineer with a BSC and PhD from Imperial College London, UK.

Since 1969 Professor Fane has lived in Australia and initially worked for the Australian Atomic Energy Commission before joining the University of New South Wales in 1973. He has been Head of the Department of Chemical Engineering and Head of the School of Chemical Engineering and Industrial Chemistry. For the past 10 years he has been co Director of the UNESCO Centre for Membrane Science and Technology at UNSW. In September 2002 he was appointed as a Temasek Professor at the Nanyang Technological University to lead a programme on Membrane Technology for Sustainable Water.

Professor Fane is an Editor of the Journal of Membrane Science and a former Board member of Desalination. He is a Fellow of the Academy of Technological Science and Engineering in Australia.


SESSION III
RESEARCH

MEMBRANE IMPROVEMENT USING MOLECULAR MODELING: STRATEGIES FOR MODELING PERFORMANCE AND FOULING

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Presenter
Harry Ridgway

>> abstract

The permselectivity and fouling resistance of reverse osmosis (RO) membranes depends on the molecular composition and architecture of the membrane and how it responds to temperature, pressure, solvation, pH and other factors. Thus, one rationale for improving membrane performance is to understand how membrane structure responds to feedwater chemistry. However, investigating the dynamics of membrane fouling and transport at the molecular scale is challenging, since few methods exist with sufficient spatial and temporal resolution to make direct observations possible. Molecular modeling provides a means to explore the theoretical mechanics and energetics of dynamic membrane processes (e.g., performance and fouling) at the atomistic scale. The goal of the present work is to predict RO performance and fouling based on the molecular attributes of the membranes. Computer programs were developed in the Tool Command Language to automatically generate and optimize randomly-crosslinked polyamide (PA) membrane models. The models are being used to study organic-contaminant rejection and bio-organic fouling via molecular dynamics (MD) simulations. Preliminary results permitted calculation of the diffusivities of water and nitrosodimethylamine (NDMA) in a PA membrane. The diffusivities were used in turn to predict water flux and contaminant rejection. The affinities of biopolymers involved in biofilm formation (e.g., bacterial alginate) for the membrane surface can also be modeled by a similar approach. The data can be used to identify and test membrane modifications or novel materials that could improve performance and minimize fouling.

>> biography of presenter

Harry Ridgway received a Bachelor of Science Degree in Microbiology/Chemistry in 1971 from San Diego State College and a Doctoral Degree in Marine Microbiology in 1976 from Scripps Institution of Oceanography. From 1976 to 1978, he pursued postdoctoral studies on the genetics and physiology of bacterial locomotion at the University of California at San Diego. He conducted additional postdoctoral research on biofilms and biofouling in municipal water systems from 1978 to 1981 at the University of California at Irvine.

Dr. Ridgway joined the Orange County Water District (OCWD) in 1981 where he formed the Biotechnology Research Department (currently Water Resources & Technology). During his tenure at OCWD, Dr. Ridgway and his colleagues conducted groundbreaking investigations into the mechanisms of bacterial adhesion and biofilm formation on reverse osmosis membranes. In 2002, Dr. Ridgway formed Aquamem, Inc., an independent research enterprise specializing in molecular modeling of membrane materials.
Dr. Ridgway was the 2002 recipient of the Athalie Richardson Irvine Clarke Prize for his work in membrane biofouling.

MEMBRANE FOULING: ALTERNATIVE ANTI-FOULING APPROACHES

Hans-Curt Flemming
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>> abstract

"Membrane fouling" refers to all types of unwanted deposition of material on membranes, including inorganic fouling ("scaling"), organic fouling, particle fouling and biofouling. This paper focuses on biofouling. Biofouling is a biofilm problem. When a membrane system is not operated completely sterile, it inevitably will be colonized by microorganisms which form biofilms. However, not all systems suffer from biofouling – only if biofilm development exceeds a certain threshold of interference which is defined operationally. Conventional anti-fouling approaches are based on a medical paradigm which believes that killing the microorganisms will solve the problem. However, practical experience reveals that is not possible and that it is more important to mitigate the unwanted effects of biofilms rather than fruitlessly trying to "disinfect" the systems. However, biofilms are the most successful form of life on earth and have developed an array of resistance mechanisms to biocides. In some cases, biocides such as formaldehyde have led to a particularly cohesive and impermeable fouling layer.

An alternative approach can be to learn how to live with biofilms without biofouling. In order to do so, it is important to keep biofilm development below the threshold of interference. For such a strategy, an integrated approach is suggested which includes the analysis the fouling situation, a selection of suitable components of the „anti-fouling menu" and an effective and representative monitoring of biofilm development is presented. The most important elements are limitation of biodegradable substances ("biofilm management") as these must be considered as potential biomass, and monitoring of deposits which provides early warning capacity and optimization of countermeasures. Another interesting element may be called "biofilm engineering", an approach which mitigates the unwanted effects of unavoidable biofilms, e.g., improvement of the permeability of the fouling layer.

In general, novel anti-fouling strategies will have to be considered increasingly important as environmental regulations continue to limit the use of biocides.

>> biography of presenter

H.C. Flemming is educated as a chemical scientist with a strong background in biochemistry and microbiology. From 1986 to 1994, he established the Biofilm Research Group at the Institute for Civil Engineering at the University of Stuttgart. From 1994 to 1996, he established the department of Biotechnology at the Institute for Water Management at the University of Munich. Since 1996, he is a full professor for Aquatic Microbiology at the University of Duisburg. He was awarded an institute which is now the Institute for Interface Biotechnology which he designed and now manages. He is also a scientific director at the IWW Centre for Water Science where he supervises the department of Applied Microbiology.

DEVELOPMENT OF A SUBMERGED NANOFILTRATION MEMBRANE BIOREACTOR (NF MBR) FOR WASTEWATER RECLAMATION

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Country : Japan

Presenter
Kazuo Yamamoto

>> abstract

Nanofiltration (NF) membrane technology has been developed rapidly and then applied to various fields. It has obtained in particular good results in the removal of organic and inorganic matters or microorganisms such as bacteria, viruses in water and wastewater. In addition, water environment has been contaminated with various chemical pollutants, and thus environmental regulations have been also strengthened in proportion to pollution severeness. Therefore, it is worth to apply NF membrane bioreactors (NF MBRs) to advanced wastewater treatment. The objectives of this study are to evaluate the applicability of hollow fiber submerged NF MBR by conducting experiments using loose and tight NF membranes, and then in near future to develop a proper NF MBR system in wastewater reclamation.

The experiment with a loose NF membrane was performed to treat synthetic wastewater. A hollow fiber type of cellulose diacetate membrane was chosen to get enough water productivity despite its biodegradability. As the result of the experiment, enough water productivity was obtained for 60 days without fatal fouling and membrane cleaning. Electrolytes were not accumulated in the bioreactor, as its rejection was also low. This low rejection enabled NF MBRs to be operated under a low suction pressure and prevented from inhibition against microorganisms, whose activity might be deteriorated by high salt concentration.

In addition, NF MBRs with tight NF membranes, i.e., cellulose triacetate (CTA) and polyamide membranes were applied for the treatment of real domestic wastewater. As a result of it, it was clear that water qualities of permeate were superior to those of a loose NF membrane. For instance, TOC concentrations in permeate of CTA and polyamide membranes are at the range of 0.7 to 1.8 mg/L. However, the reactors using them could not reach to the operation in the long term, which might be caused by serious accumulation of ionic matters and concentration polarization (CP) phenomena on the membrane surface. With these phenomena being solved, NF MBRs might be very effective and advantageous as an alternative for securing water source in densely populated urban areas.

>> biography of presenter

Biodata not available at the time of print.

A NOVEL FOULING CHARACTERIZATION TECHNIQUE FOR FULL-SCALE RO PROCESSES

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Presenter
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>> abstract

Membrane fouling is the single most important problem in RO membrane processes. Two critical issues have to be properly addressed before an effective strategy for fouling control can be developed: (1) the assessment of feed water fouling potential, and (2) the indication of fouling development taking place in the full-scale RO processes. Although SDI (silt density index) has been commonly used for assessing the fouling potential of feed water, it has long been noticed to be inadequate for fulfilling its intended purpose. In addition, the method of using average permeate flux (or recovery) of a RO process as the indicator of membrane fouling has also been found insensitive to the initial development of membrane fouling.

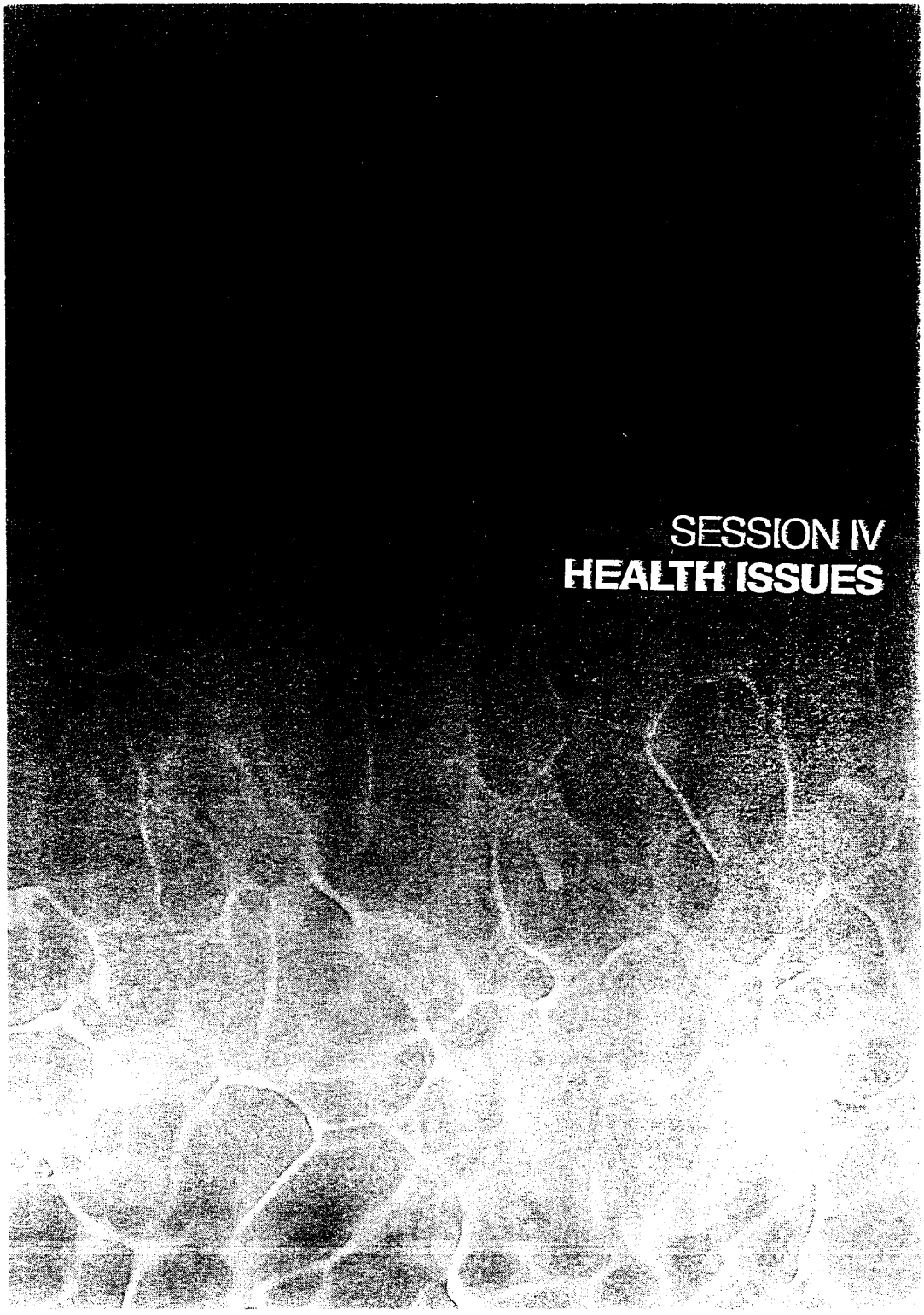
More effective fouling characterization methods are currently being developed at the Centre for Water Research, NUS. Significant progresses have been made in both fouling potential assessment of feed water and characterization of fouling development in full-scale RO process. With a new normalization method, a new fouling index has been proposed for assessing the fouling potential of feed water. This index could be readily determined via lab-scale testing within a few hours. The new fouling index can be used for quantitative prediction of fouling development in full-scale RO processes. A new fouling characterization method is also proposed in this study. We found that there are two regimes of RO operation (i.e. mass transfer controlled and equilibrium controlled) and that membrane fouling can only be effectively indicated by flux decline when it is operating under the mass transfer controlled regime of RO operation. Instead of flux decline, a newly defined filtration coefficient, intrinsically related to the overall membrane resistance of the RO process, will be used to characterize membrane fouling. In addition to being able to detect fouling in all stages of operation, the new fouling characterization method also offers a more superior alternative for evaluating the efficiency of various cleaning agents and methods.

>> biography of presenter

Dr. Song received his BS and MS degrees from Peking University, Beijing, China in 1982 and1984, respectively. After working as an assistant professor for 5 years at Beijing Normal University, Dr. Song went to the United States for further academic pursuit and obtained his PhD degree from UCLA in 1993. His PhD thesis was on the Theoretical Aspects of Colloidal Deposition in Porous Media.

Upon graduation from UCLA, he worked as a Postdoctoral Associate for three years at UCLA and the Oak Ridge National Laboratory, Tennessee. Before joining NUS, Dr. Song was an assistant professor of Civil Engineering at Hong Kong University of Science and Technology (HKUST) since1996. Dr. Song's research interests include physical and chemical water/wastewater treatments, colloidal phenomena in aquatic environments, and modelling and simulation of environmental systems. Currently, he is working with the Centre for Water Research with focus on wastewater treatment and water reclamation using membrane processes.

He is a member of the North American Membrane Society and the International Water Association.


SESSION IV
HEALTH ISSUES

HEALTH ISSUES ADDRESSED BY TODAY'S MEMBRANE TREATMENT SYSTEMS FOR WATER REUSE APPLICATIONS

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California Department of Health Services
Drinking Water Program
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Berkeley, CA 94704
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>> abstract

The practice of reclaiming municipal wastewaters for the purpose of recycling and reuse is an important means of managing existing resources. Although water reuse can entail uses that involve minimal human contact, this paper examines the role of membranes in engineered treatment systems designed specifically for the highest order of reuse, i.e., the practice of indirect potable reuse where human consumption is the end use. Membranes have a significant risk reduction role in wastewater reclamation and water recycling. Although a membrane is but one component in a multiple treatment barrier, such a component provides a physical barrier that is both strong and reliable. Given the uncertainty associated with the current suite of scientific tools, potable reuse will never be a risk-free practice. While no human engineered endeavor is ever without risk, with appropriate treatment barriers (including process control) the risk associated with potable reuse can be made acceptable in those regions where the need to provide a potable supply poses a threat to human health and welfare.

>> biography of presenter

Dr. Sakaji's background in marine biological sciences (A.B., University of California, Berkeley) and environmental engineering (M.S. and Ph.D., University of California, Berkeley) has allowed him to develop a unique technical background and public health policy perspective.

Throughout his career in research and regulatory affairs, Dr Sakaji has brought a public health perspective to all the advisory committees and the workgroups of which he was a member (National Water Research Institute, the American Water Works Association Research Foundation, and the United States Environmental Protection Agency). These committees have been assembled to discuss public health, water quality, and water treatment issue surrounding drinking water and wastewater reclamation. Currently, he serves as the Department's representative, as an ex-officio member of the Santa Ana River Water Quality and Health Study (SARWQH). Most recently he has worked with the National Water Research Institute/ American Water Works Association Research Foundation in developing the present UV disinfection guidelines. At present he is serving on project advisory committees for American Water Works Association Research Foundation and the Water Environment Research Foundation and is a member of the Research Advisory Board of the National Water Research Institute.

In addition to articles on drinking water treatment, Dr Sakaji has co-authored articles on analytical methods, microbial risk assessment, water treatment, and wastewater reclamation. Because of his technical background in these subject areas, he has been invited to several international drinking water and water reuse meetings to share his experiences and views with other regulatory, utility, consulting, and manufacturing representatives.

TESTING PROTOCOLS FOR MEMBRANE SELECTION: EQUIVALENCY AND FATE, ORGANISM/PATHOGEN REMOVAL

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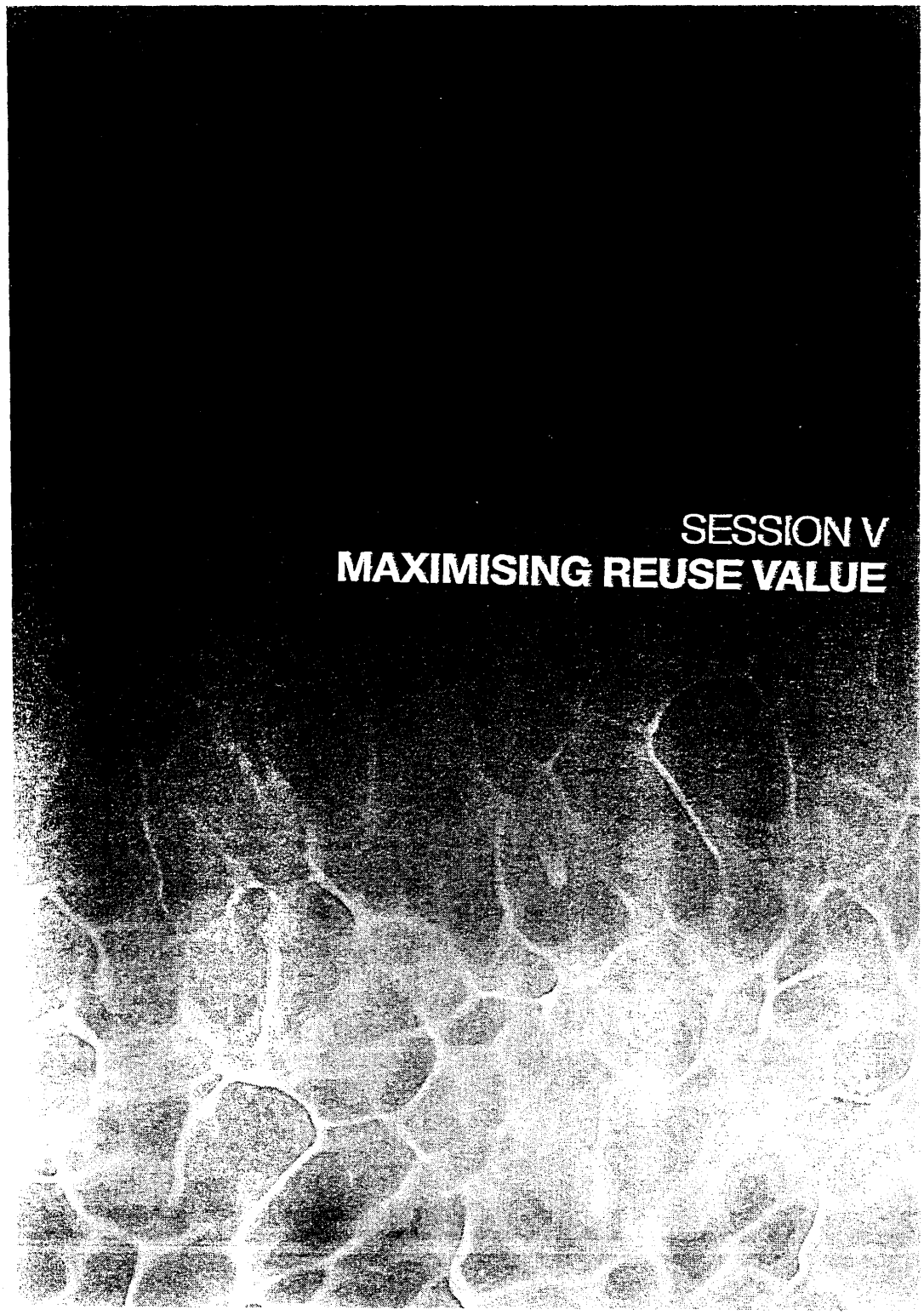
U.S.A.

>> abstract

Membrane systems are often employed in treat trains where safety from pathogens is a primary goal. Goals of this kind are particularly appropriate in reuse systems because of the magnitude of the job at hand. Methods are shown for establishing removal goals for such systems and for ensuring that these systems, once built, have some assurance of meeting the goals sought. Candidate membranes should be tested to evaluate the suitability for the project. Membranes delivered to the job site should be random tested to confirm their performance. Routine monitoring for coliphage should be used as a method of confirming integrity of performance.

>> biography of presenter

George Tchobanoglous is a professor emeritus of Environmental Engineering in the Department of Civil and Environmental Engineering at the University of California at Davis. He received a B.S. degree in Civil Engineering from the University of the Pacific, an M.S. degree in Sanitary Engineering from the University of California at Berkeley, and a Ph.D. in Environmental Engineering from Stanford University. His principal research interests are in the areas of wastewater treatment, wastewater filtration, UV disinfection, aquatic wastewater management systems, solid waste management, and wastewater management for small systems. He has authored or coauthored over 350 technical publications including 12 textbooks and four reference works. The textbooks are used in more than 200 Colleges and Universities throughout the United States. The textbooks and reference books are also used extensively by practicing engineers both here and abroad. Professor Tchobanoglous serves nationally and internationally as consultant to both governmental agencies and private concerns. An active member of numerous professional societies, he is a Past President of the Association of Environmental Engineering and Science Professors. He is a registered Civil Engineer in California.



SESSION V
MAXIMISING REUSE VALUE

THE VALUE OF WATER IN THE URBAN WATERSHED

Ronald B. Linsky
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National Water Research Institute
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Fountain Valley, California 92728
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>> abstract

Webster's New World Dictionary: value (val'yoo) n. 3. the quality of a thing that makes it more or less desirable, useful; 5. the quality of having intrinsic worth; 7. to think highly of.

The most important application of reuse and desalination technologies will be in the urban watersheds where increasing demand will exceed the abilities of local agencies to provide sustainable supplies.

Controlling water supplies, insuring water quality and quantities, and public health by engineered means have dominated the 20th century water related activities. Within the last decade however, there is an emerging recognition that technological solutions alone are not sufficient to assist in the decision-making processes required for the development and implementation of new projects. The allure of technology and the dependency on the classic cost benefit analysis to justify its application has left little room to consider the value of the product the technology was designed to create. Due to the dominant Western based perception that water is "free" the perception that water has little or no value has been perpetuated and is abused or misused with little or no consequences.

The relevance of value has for too longed escaped the water industry. The industry has devoted very little or no effort to quantify the value of the very product that the myriads of technologies have been designed to create. One must therefore ask the questions: What is the real value of water when total dissolved solids (TDS) are reduced from 1000 to 200 parts per million? What is the real value of the product waters after removing chemical contaminants? Does desalting technology create a product of higher value than naturally occurring surface or ground waters? What is the value to desalinated ocean water to future generations who will live in arid climates or under drought conditions?

This paper suggests that a paradigm shift be made from a cost based pricing to an economic value based pricing approach for water. Think about water as having value and think about your willingness to protect or pay for that value. In other words, treatment is about adding value to water.

>> biography of presenter

Mr. Linsky is currently the Executive Director of the National Water Research Institute (NWRI), whose mission is to create new sources of water through research and technology and to protect the marine and freshwater environments. In this capacity, Mr. Linsky is responsible for creating the institutional framework and designing the implementation strategies that have made it possible for the institute to become a major player in national and international water research enterprises. He created the National Centers Program in collaboration with the U.S. Bureau of Reclamation and has introduced the concept of the value of water that has been accepted as a means of recognizing and using the full potential of water supplies. Mr. Linsky serves on both national and international advisory committees that focus on water and wastewater issues, including desalination and water reuse. He is a member of the Economics Workgroup 2002 Recycled Water Task Force for the State of California. Mr. Linsky has also served as a member of the Regional Water Quality Control Board, Santa Ana Region.

Prior to his current activities at NWRI, Mr. Linsky was the Chief Technical Advisor for the United

National Development Programme, Office of Technical Cooperation for Development, stationed at the Institute of Marine Affairs in Trinidad and Tobago, West Indies. He also served as the Executive Director of the institute responsible for developing and coordinated research activities for the Caribbean area with special emphasis on insular environmental needs.

His academic career included research directorships at the University of Southern California as the founding Director of the Sea Grant Institutional Program and at the University of Hawaii as Director of the Sea Grant College and Associate Dean of Marine Programs.

Mr. Linsky received both his Bachelor and Master degrees from the University of Southern California.

WEST BASIN MUNICIPAL WATER DISTRICT: 5 DESIGNER (RECYCLED) WATERS TO MEET CUSTOMER'S NEEDS

Darryl G. Miller
General Manager
West Basin Municipal Water District
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>> abstract

West Basin Municipal Water District (WBMWD) is a public agency that wholesales water to local cities, mutual water companies, private companies and investor-owned utilities in a 200- square mile area of southwest Los Angeles County, California. WBMWD purchases treated imported water from the Metropolitan Water District of Southern California. WBMWD provides 80 percent of the water used in the district service area (the other 20% is local groundwater pumped by retail water agencies) serving a population of 851,000 people. In the early 1990's, WBMWD embarked on a large-scale conservation and recycling program to improve water supply reliability and reduce the use of imported water. The WBMWD was in the midst of the 1987 – 1992 drought when the district decided, to establish a program to drought-proof the basin. In addition to water recycling, major education, conservation, and planning efforts are carried out through the district's Drought-Proof 2000 program.

Goals of the water recycling program are to:

- Reduce dependence on outside water supplies by 50 percent;
- Provide an alternative, drought-proof, dependable local water source;
- Provide recycled water for injection into a saltwater intrusion barrier, that protects the groundwater basin;
- Reduce treated wastewater discharged into Santa Monica Bay by 25 percent;

The cornerstone of the recycling program is the West Basin Water Recycling Plant which is located in El Segundo, California. The West Basin Water Recycling Plant receives secondary-treated wastewater from the City of Los Angeles' Hyperion Treatment Plant. Once the wastewater reaches the recycling plant it is split into three parallel treatment processes that produces four qualities of recycled water on-site. The treatment processes are: Title 22 Product Water, Barrier Product Water, and Chevron Boiler Feed Water which produce a total of 42 million gallons of recycled water. In some cases, depending on the customer needs the recycled water produced by the Title 22 treatment process is given additional treatment.

Recycled water is local and extremely reliable new supply of water. It is independent of climate variability. West Basin uses only 10mgd of the 350 mgd of secondary effluent that is available for reuse. Other benefits include: no water rights considerations, independent of outside water supply resource availability, independent of climate variability, and it's environmentally sound practice.

Water is one of California's most precious resources. It is an essential element of the economic, environmental, aesthetic and social health of the state. West Basin strives to ensure its health and reliability by developing local programs such as our "designer" recycled water center. The new paradigm has been shifted to identifying customer water quality needs first, rather than building facilities and then establishing the customer base. To date, West Basin produces 5 qualities. If there is a need for a sixth, seventh or eighth quality, West Basin will produce it, within an equitable price structure.

>> biography of presenter

Education: BS/1971/Geology/Brigham Young University, Certificate/1981/Executive Management Program/University of California at L.A., Registration: Registered Geologist, California #3388 Miller was named General Manager of the West Basin

Municipal Water District and Central Basin Municipal Water District in August of 1999. The Districts are public agencies providing wholesale imported water and locally developed recycled water to local cities, mutual water companies, industrial customers, private water companies, and investor-owned utilities. The Districts serve 2.4 million people, in more than 40 cities throughout Southern Los Angeles County. A separate, five-member, Board of Directors governs each District, and both Districts share a staff of 45 professionals. The Districts provide two vitally important services: 1) as à large urban water wholesaler and a key member agency of the Metropolitan Water District of Southern California, and 2) as a major developer and supplier of recycled water. The Districts continue to invest their resources and are currently developing ocean-water desalination as an alternative water source for Southern Los Angeles County.

A 30-year water industry veteran, Miller is a member of the Department of Water Resources 2002 Recycled Water Task Force, a Board member of the National WateReuse Association, and a California Registered Geologist experienced in water resource planning, water resource management, and water quality development and protection. Miller is also an elected director since 1984 and past president of the Irvine Ranch Water District. Irvine Ranch Water District is a large water retailer and a leading recycled water developer and distributor in Orange County. Miller currently serves on the IRWD Water Resources Policy standing committees as well as on numerous ad hoc committees.

Affiliations: Director, Orange county Sanitation District, Director - Irvine Ranch Water District, Director - Aliso Waste Water Management Agency, and Director - WateReuse Association.

ULTRAPURE WATER PRODUCTION FROM RECLAIMED WATER - NEWater

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Presenter
Guihe Tao
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>> abstract

The Public Utilities Board of Singapore (PUB) designated the Centre of Advanced Water Technology (CAWT) to conduct pilot performance trials on an ultrapure water (UPW) system using NEWater as the feed source. The NEWater produced by advanced tertiary treatment of domestic sewage, using proven membrane technology, of secondary effluent in Singapore can be a source to replace the city's potable water used by the semiconductor industries.

A containerized UPW pilot plant was commissioned at Bedok Water Reclamation Plant by CAWT in October 2002. The objective of these pilot trials was to evaluate the impact on various unit operations in the typical UPW production systems and monitor the UPW quality at the point-of-use. It demonstrated that UPW of the desired quality as required by the Semiconductor Industry could be produced reliably from NEWater.

Three different configurations for UPW production were tested during this period. The profiles of TOC, Residual Ionic Impurities, Dissolved Oxygen and Particle Count Levelsof UPW produced from NEWater as feed source were benchmarked against potable water. Samples were taken once a week for THMs, Bacteria and Ions. On line analyzers for TOC, Particles, Dissolved Oxygen, Resistivity and Conductivity were used. This study established that TOC values of below 1 ppb could be achieved consistently at CAWT's pilot plant using NEWater as feed. Besides TOC, other parameters such as Ionic Levels, Particle Count and Resisitivity of UPW produceded from NEWater are also comparable with that generated from PUB potable water as feed source. The quality of the UPW produced from NEWater meets the ASTM D 5127 Type E-1.2 Standard for UPW used in the Semiconductor Industry.

>> biography of presenter

Dr. Tao received his Bachelor of Engineering in Water Supply & Sewage, Master of Engineering and PhD in Environmental Engineering from Tongji University, Shanghai, China. Following his doctorate, Tao spent two yeas at Tongji University as a Lecture and Deputy Director of Environmental Engineering Division. He also worked at The University of Hong Kong as a Research Associate in the fields of biological treatment of waste. Before joining Environmental Technology Institute in 1998, he worked for Chemitreat of Singapore in the field of ultrapure water production as well as wastewater treatment & recycling.

He has over 16 years of industrial and R&D experience in environmental engineering. His areas of expertise include the research, engineering, design, construction, operation, and management of water, wastewater, ultrapure water and solid waste systems.

He is current a Senior Research Scientist in the Centre for Advanced Water Technology (CAWT) of Singapore Utilities International Private Limited (SUI). Tao has published over 30 technical articles in the refereed international journals and conferences. He is a member of International Water Association (IWA), Water Environmental Federation (WEF) and Environmental Engineering Society of Singapore.

NEWLY DEVELOPED WASTEWATER TREATMENT SYSTEMS USING SEPARATION MEMBRANES

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Masahiro Henmi,
Masahiro_Henmi@nts.toray.co.jp

Presenter
Dr. Masaru Kurihara
Senior Director,
Masaru_Kurihara@nts.toray.co.jp,
Toray Industries, Inc., Japan

>> abstract

In pursuit of more sustainable water resources, high- grade wastewater treatment and reclamation have become one of the technologies attracting considerable attention around the world. For the purpose of wastewater treatment and reclamation, three membrane technologies have been developed. Newly developed PVDF hollow fiber membrane has high water permeability, high chemical stability and high physical stability. Therefore, PVDF hollow fiber membrane module can be used for the secondary treatment to be applied for RO membrane. PVDF flat sheet membrane for MBR has not only small pore diameter and narrow pore diameter distribution with many pore numbers but also high water flux. The flat sheet module of the membrane was operated at low trans membrane pressure and at low rate of pressure increase, as expected. The water quality of permeate will be suitable for the feed water to RO membrane. Low fouling RO membrane reduces chemical and biological fouling, because of its low adsorption property of organic substances and low adsorption property of hydrophobic microbe. A field test proved the good performance for the stable operation at a wastewater treatment facility. The combination of three membrane technologies realizes the production of water source from wastewater.

>> biography of presenter

Educational Background:
Graduated from Gunma University, Technical Department, Applied Chemistry in 1963. Doctor Dissertation at the University of Tokyo in 1970. And Membrane Research at University of IOWA, USA, as Research Associate from 1970 to 1972.

Professional Experience:
In 1963 Joined to Toray Industries, Inc. From 1963 to 1968, Polymers Researches at Basic Research Laboratory. From 1968 to 1970, Polymers Researches at Pioneering Research Laboratory. From 1972 to 1991, Membrane researches in Pioneering / Polymers Res. Labs. In 1991, General Manager, Polymers Research Laboratory. In 1992, Registered as Research Fellow of Toray Ind., Inc. In 1995, General Manager, Polymers Research Labs & Chemical Research Labs. In 1997, Director, General Manager, Chemicals Research Labs. In 1998, Director, General Manager, Polymers Res. Labs. In 1999, Director, Water Treatment Div. & R&D Div. In 2001, Managing Director, Water Treatment Div. Water Treatment Technology Center & R&D Div. And in 2002, Senior Director, Water Treatment Div. Water Treatment Technology Center & R&D Div.

Additional Relevant Professional Information:
Membership
American Chemical Society, Japan Chemical Society
Japan Polymers Society, Japan Membrane Society
Japanese Desalination Association (JDA), Vice President
North American Membrane Society (NAMS)
International Desalination Association (IDA), Board Member
American Membrane Technology Association (AMTA)
Europe Desalination Society (EDS)

Awards:
1992 Technical Award of Chemical Society of Japan
1993 Technical Award of Japan Chemical Engineering Society
2000 Technical Award of Japan Chemical Engineering Society
2002 Presidential Award of International Desalination Association
2002 Technical Award of Japan Seawater Society

COST OF CURRENT MEMBRANE TECHNOLOGY

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Partner
Aqua Resources International
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USA

>> abstract

Membrane technology has become one of the fastest growing segments of the water industry. It is being used in the municipal, industrial, commercial, military and power sectors, and is used in both water and wastewater treatment. There are various types of membrane technologies utilized in these treatment applications including electrodialysis, reverse osmosis, nanofiltration, ultrafiltration, and microfiltration. For the purposes of this paper, the cost of reverse osmosis, nanofiltration, ultrafiltration and microfiltration will be explored, to evaluate its impact on reuse and desalination applications.

The paper describes the cost reduction of an RO element, which has dropped in price by over 90% since 1980. Taking into account the productivity improvements in the RO elements, as well as cost reductions, today approximately 27 times more water can be produced for the same unit capital membrane cost of an RO element compared to 1980.

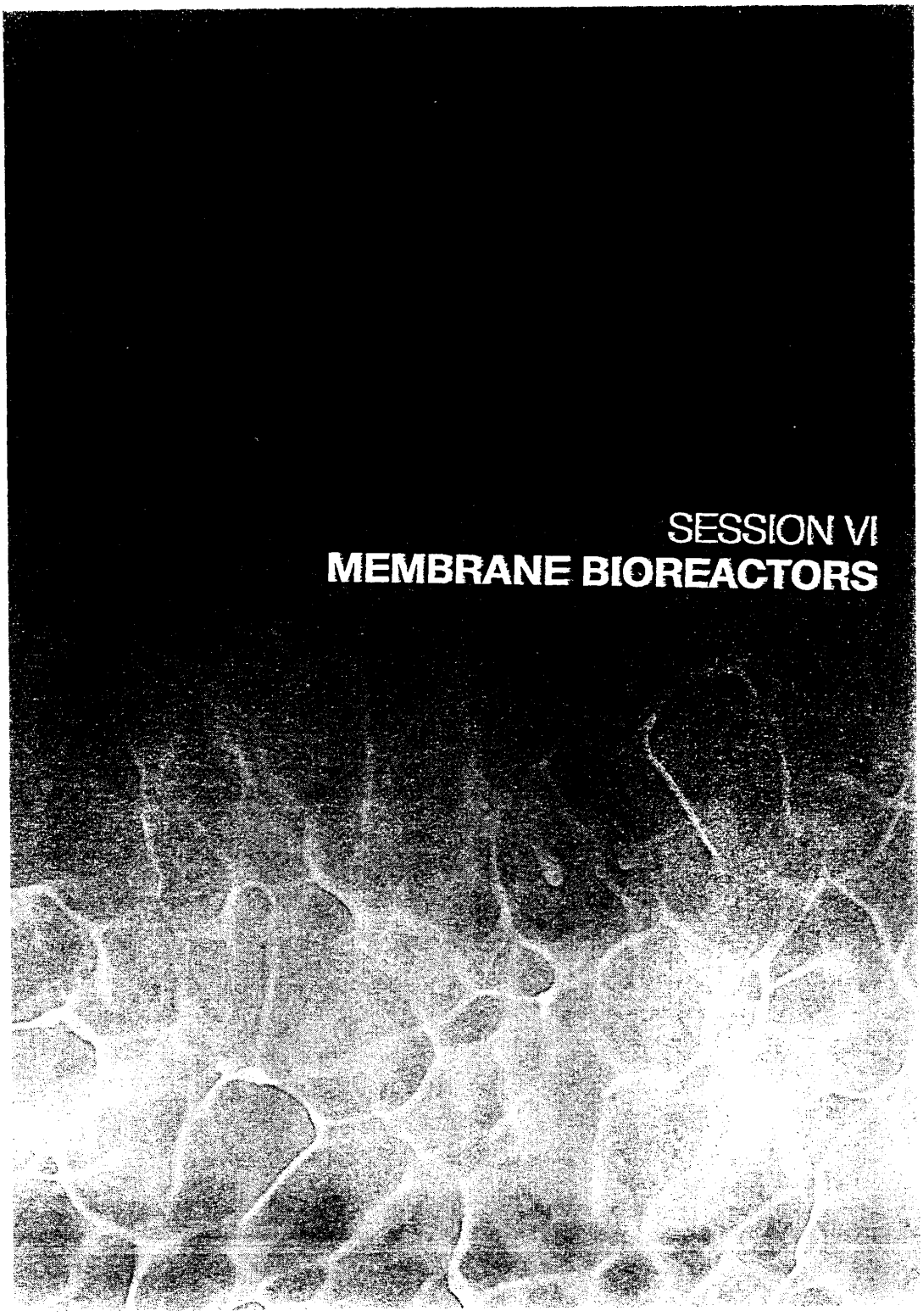
The total water cost (amortized capital plus O&M cost) of membrane-treated water has also shown a tremendous reduction over the last decade. Over the last 10-year period, the total water cost of projects utilizing RO technology has reduced over 3-fold. This is a function of reduced membrane cost, improved productivity, improved energy recovery and privatization of projects using long-term commitments.

>> biography of presenter

Lisa Henthorne received her Bachelors of Science degree in Chemistry from Missouri State University, where she graduated Summa Cum Laude. Her Masters of Science degree is Chemical Engineering was received from Colorado School of Mines.

Lisa R. Henthorne is a Partner with Aqua Resources International, LLC. She has 17 years of experience in the desalination and water treatment field. She has worked primarily in the public sector, serving as a manager for the U.S. Bureau of Reclamation in their research and desalination groups for much of her career. At Aqua Resources International she has developed strategic market and technology analysis for clients in the desalination and water treatment field; provided consulting services to privatized water developers on project development, feasibility analysis and design; and provided regional analysis to clients interested in entering new market areas. Her areas of expertise include innovative desalination technology, membrane pretreatment, desalination market analysis, and concentrate disposal issues.

Ms. Henthorne serves on the Board of Directors of the International Desalination Association (IDA) (since 1997), and is presently the Treasurer of the IDA. She serves on the Executive Committee of the Sandia National Laboratory/U.S. Bureau of Reclamation Desalination Program and also serves on a number of committees for the American Water Works Association and the American Water Works Association Research Foundation. Ms. Henthorne is a member of the American Membrane Technology Association and is a registered Professional Engineer in the State of Colorado.



SESSION VI
MEMBRANE BIOREACTORS

NEW TECHNOLOGIES AND APPLICATIONS IN MBR USING HOLLOW FIBER MEMBRANE

Tsutomu Kakuda
Director, Marketing
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Japan

>> abstract

Presently circumstances of enclosed water areas like Tokyo Bay have been deteriorating, so stringent regulations have been placed on rivers flowing into them to protect their circumstances. Furthermore, many wastewater treatment plants in industry companies and in sewage plants have almost reached the limit of their capacity owing to the increase of the amount of wastewater discharged from manufacturing processes and an increase in the population and sewage demands. To cope with these problems, in 1991 Mitsubishi Rayon developed a wastewater treatment system using submerged hollow fiber membranes. In Japan, more than 700 treatment plants have already been constructed since 1992 to treat various types of wastewater. The total treatment capacity of the plants amounts to 60,000m3/day.

The system principle is using hollow fiber membrane modules submerged in aeration tanks as a superior alternative to using settlement tank to separate treated water from activated sludge.

This system generates a far better effluent quality because of using hollow fiber membrane with micro-pores of 0.4 micron. The space requirement is strongly reduced due to the absence of settlement tanks and two to five times more concentrated MLSS compared with a conventional activated sludge system. By submerging hollow fiber membrane modules into aeration tanks, upgrading existing wastewater treatment plants can be achieved easily. And the system eases plant maintenance because the operation of this system becomes possible even if bulky sludge occurs.

This presentation will focus on the applications of wastewater treatment plants to upgrade existing plants and to re-use the treated water. It will also include explanation of membrane modules, operation conditions, chemical cleanings, placing modules in the tanks, etc. In summary, MBR using hollow fiber membranes is suitable for the expansion of the existing wastewater treatment plants and generating higher quality treated water for re-use. From now, this system will be adopted much more to wastewater treatment plants in many fields.

>> biography of presenter

I graduated from Osaka University in 1972 and received a Master degree in organic chemistry.

I began work at Mitsubishi Rayon in 1972 and have worked until now. At first, I worked as a researcher on oil adsorbing material to remove emulsified oil from water and constructed filtration systems for treating water containing any type of oil to get oil free water. Next, I was engaged in designing and constructing wastewater treatment plants in conventional activated sludge methods for sewage, industrial waste water, and water from landfills. After that, I was involved in conducting a study of membrane purification of surface water to produce drinking water. As the result of the test, it became possible to construct membrane purification plants using hollow fiber membranes submerged in tanks to get drinking water from river water.

I am currently working in designing and operating wastewater plants using hollow fiber membrane modules submerged in aeration tanks, especially operating plants installed oversea.

INTRODUCTION OF SUBMERGED MEMBRANE IN JAPAN – APPLICATION TO DOMESTIC WASTEWATER AND INDUSTRIAL WASTEWATER

Hiroyuki Takatori
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Japan

Tadaaki Sakata
Deputy Manager
Engineering Technical Support
International Group
Membrane System Department
Kubota Corporation

Presenter
Tadaaki Sakata

>> abstract

It has been eleven years since the first wastewater treatment plant with KUBOTA submerged membrane bioreactor was installed in Japan. So far, more than 900 installations have been built. Japan must be the most advanced country using submerged membranes for wastewater treatment applications. One of the applications is for Domestic Wastewater, such as Johkaso treating the domestic wastewater underneath private residences and buildings, Sewage Treatment Plant, Rural Community Plant and Night Soil Treatment Plant. Also, the water reclamation plant and industrial wastewater treatment plant are the other important applications. Kubota Submerged membrane process can remove T-N and T-P very surely and easily, which ensures the very severe regulation for effluent quality. In addition to improving the surface water quality, a compact plant is required, as Japan has very limited land area, of which mountain area covers by 70%. Our system can offer very small footprint for the total plant installation. Solid-liquid separation by submerged membrane can eliminate conventional sedimentation tank and its high MLSS concentration enables to downsize the tank.

These applications of actual treatment plant with KUBOTA submerged membrane in Japan as well as overseas will be presented with the unique design and performance record.

>> biography of presenter

Mar, 1987 :
Graduated from Department of Civil Engineering, Science University of Tokyo
Apr, 1987 :
Employed by TAISEI Corporation, Japan
Started service as a member of Design Department of Civil Structure
Dec, 1994 :
Manager of Civil Works Department, Overseas Division
Jan, 1999 :
Employed by Kubota corporation, Japan
Started service as a member of Membrane System Department
Feb, 2000 :
Deputy Manager of Kubota Membrane Europe, U.K
Jul, 2002 :
Deputy Manager of Membrane System Department

INTEGRATED WATER MANAGEMENT APPROACH TO CHEMICAL COMPLEX IN JURONG ISLAND

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>> abstract

Water is of strategic importance to Singapore and at the moment half of the Singapore water consumption is imported from Malaysia. As a water-oriented multi-utility service provider, SUT adopts an integrated water management approach for chemical hub in Jurong Island. SUT operates facilities from wastewater treatment plants, water reclamation plant, demineralisation plant, boilers, to seawater cooling system, etc. High-Grade Industrial Water (HGIW), reclaimed from secondary effluent, is supplied to tenants in Jurong Island. With the quality superior to potable water for industrial users, HGIW is ideal as cooling tower makeup and demineralised plant feed. Wastewater from petrochemical and chemical industry is collected and treated at centralised wastewater treatment plants, with discharged effluent meeting the local discharge regulations. A pilot study on industrial effluent recovery is being conducted to investigate the feasibility. SUT, in collaboration with universities, is proactively pursuing research and development, focusing on biogranulation and membrane application technologies for wastewater treatment and recycling.

With the cost-effectiveness arising from (1) economies of scale and scope; (2) application of advanced technologies; and (3) high reliability, SUT is able to manage the water resources effectively to achieve environmental protection, resources conservation and sustainable development. The integrated water management has become a viable business model for Jurong Island and other similar industrial parks.

>> biography of presenter

Eugene Yan Yuegen, PhD

Eugene Yan holds a PhD degree in Environmental Engineering from Nanyang Technological University, Singapore.

Eugene's area of expertise covers widely in the environmental engineering and utilities field, including water treatment, wastewater treatment and recycling, hazardous waste management. He has 6-year academic and 8-year industrial experiences. He has published 16 papers at peer-reviewed Journals.

Currently he is working in the technical and business development, with the Centralised Utilities & Water division, SembCorp Utilities Pte Ltd, providing utilities and water services.

DELIVERY AND PERFORMANCE OF THE LUGGAGE POINT WATER RECLAMATION PROJECT

Greg Leslie, Tom Marshall and Ian Law
CH2M HILL Australia
Len Don,
Brisbane Water, Australia

Presenter
Greg Leslie
CH2M Hill Australia
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Australia

>> abstract

Reuse of municipal wastewater has become an important strategy for meeting the expanding demands of industry for reliable supplies of high quality water. The following paper examines a recent case where reclaimed water produced using a dual membrane process was supplied to a petrochemical refinery in Queensland Australia. This Luggage Point Water reclamation Plant is a 14 MLD dual membrane system that produces high grade water from secondary effluent. The project was delivered in 44 weeks using a design and construct (D&C) project management methodology. The reclamation plant consists of a dual membrane system consisting of a 0.1 micron PVDF membrane followed by thin film composite polyamide reverse osmosis membranes. The pH of the RO permeate is adjusted using sodium hydroxide prior to delivery to the refinery. Biofouling of both the MF and RO membranes is controlled by chlorination. The reclaimed water is further chlorinated before transfer to the BP refinery, four kilometres away. Reject water from both membrane stages is routed back to the head of the WWTP.

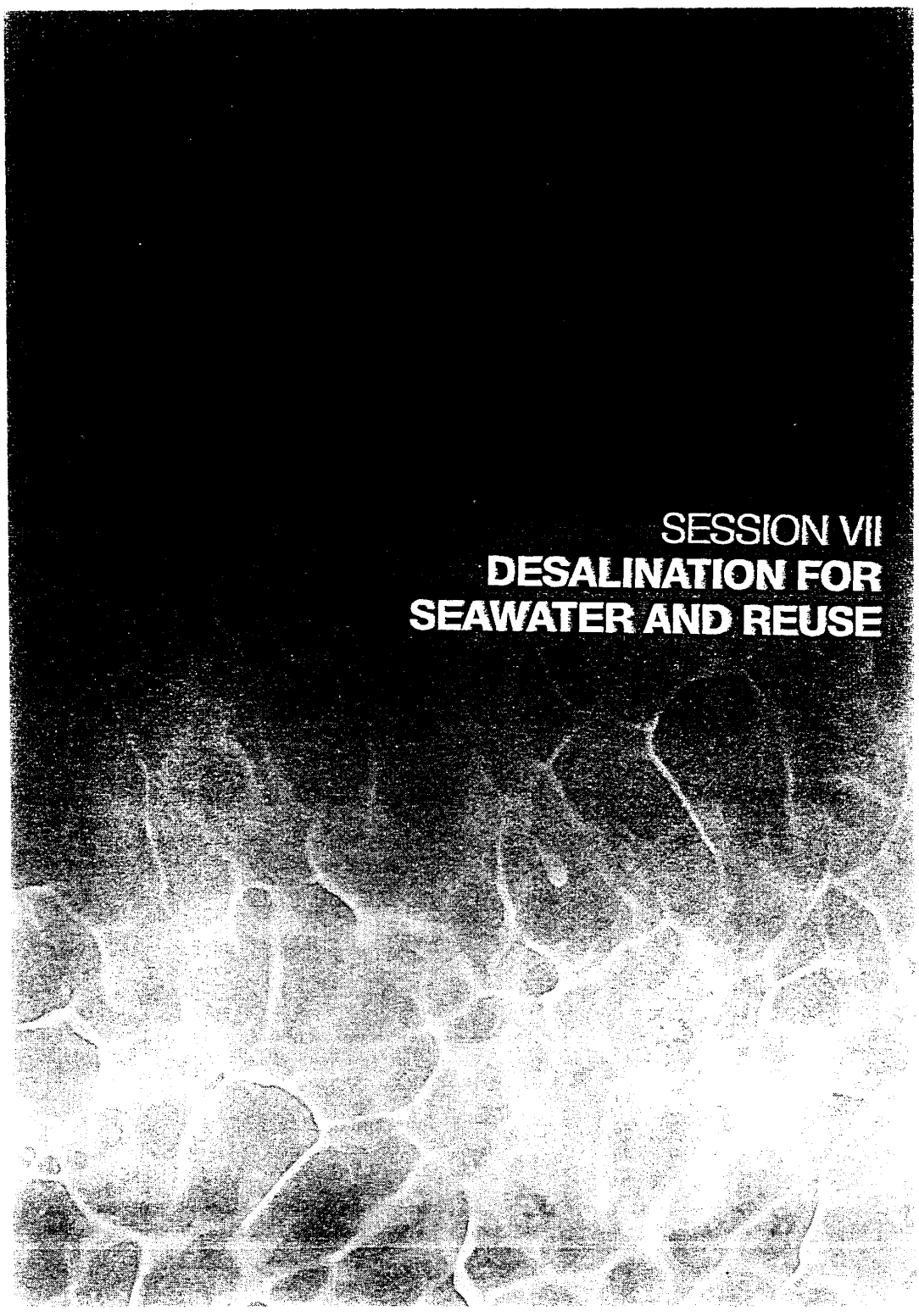
The water reclamation plant must reliably produce very high quality product water for BP to use as cooling tower make-up, boiler feedwater and other process uses. The main specified quality parameters are conductivity, turbidity, pH, free chlorine and heterotrophic plate count. The initial operation of the plant has proven quality and quantity performance. The on-line product water quality indicators are 80-100S/cm conductivity; 6.8-7.2 pH; <0.1NTU turbidity and 0.3-0.5mg/L free chlorine. Product Water composite sampling and analysis has confirmed Heterotrophic Plate Counts (HPC) are <10cfu/mL.

>> biography of presenter

Greg Leslie received a Bachelor of Science from the University of Sydney and a Doctor of Philosophy in Chemical Engineering from the University of New South Wales.

Greg is employed with CH2M Hill as the senior technologist for Membranes and Water Reuse in the Asia Pacific Region. In this capacity he has worked on the design and delivery of membrane and reuse projects in Australia, New Zealand and Singapore. In 2001 and 2002 he served as the lead process designer for the NEWater plants at Bedok, Kranji and Seletar.

Prior to joining CH2M HILL he was employed for seven years with the Orange County Water District in Fountain Valley, California. Greg has also served as part time faculty in the Schools of Civil and Environmental Engineering at the Universities of California, Los Angeles and the University of Southern California.



SESSION VII
DESALINATION FOR SEAWATER AND REUSE

MEMBRANES AS PRETREATMENT TO DESALINATION IN WASTEWATER REUSE. OPERATING EXPERIENCE IN THE MUNICIPAL & INDUSTRIAL SECTORS

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Bruce BILTOFT
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Presenter
KOH Wai Keat
Senior Manager, Business Development
Vivendi Water Systems (Asia) Pte Ltd

>> abstract

Water shortage problems are becoming more widespread and are encouraging users to treat difficult waters and to value the reuse of wastewater. Membrane processes such as reverse osmosis (RO) have been used to treat such waters as well as sea water (SWRO). The applications, particularly for wastewater, have been limited due to the sensitivity of RO membranes to fouling and the inefficiency of the conventional pretreatment process technologies used.

This paper reviews the benefits of the wastewater reuse for industrial and municipal applications. It demonstrates how continuous microfiltration (CMF) pretreatment to RO can reduce capital and operating costs of RO systems, improve their efficiency and enable reliable operation on a wider variety of water sources. This information is supported by operational data from a number of CMF – RO installations worldwide on difficult to treat feed waters.

The application and economic comparisons consider:

- Municipal wastewater reuse for process water feed to multiple refineries
- Wastewater reuse for high pressure boiler feed at a major power station
- Reuse for aquifer recharge and water banking
- Reuse for irrigation

>> biography of presenter

Koh Wai Keat is currently the Senior Business Development Manager of Vivendi Water Systems (Asia) Pte Ltd based in Singapore. He graduated with Masters of Engineering (Civil) and Bachelor of Engineering (Civil) with honours from the National University of Singapore (NUS). He was awarded the NUS research scholarship to pursue his two-year postgraduate research programme in wastewater treatment technology. He was also awarded the UOB gold medal for his outstanding performance in the Graduate Diploma in Business Administration by the Singapore Institute of Management (SIM).

Since his graduation, Wai Keat has accumulated more than fourteen years of working experience in the field of water and wastewater treatment through his various roles as process/application engineer, commissioning engineer and project sales manager in several well established water and wastewater organizations.

Wai Keat is also an active member of several professional societies including the Institution of Engineers Singapore (IES), the Environmental Engineering Society of Singapore (EESS) and the Environmental Management and Research Association of Malaysia (ENSEARCH).

DUAL NANOFILTRATION PROCESS FOR OCEAN WATER DESALINATION

Kevin L. Wattier, Diem XuanVuong, Robert C. Cheng
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divuong@ci.long-beach.ca.us
rccheng@ci.long-beach.ca.us
Country: U.S.A.

Presenter
Diem Xuan Vuong
Position Assistant General Manager
Long Beach Water Department
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>> abstract

There are two major components which contribute to the higher pressures required to desalinate ocean water by reverse osmosis membranes: 1) the pressure to overcome the osmotic pressure; and 2) the driving pressure to force water through the semi-permeable membrane. The first component is a physical characteristic of ocean water and proportionately changes by the recovery percentage of this desalination process. The second component, the driving pressure, a characteristic of the membrane, is the tightness and thickness of the membrane used in the process. The nanofiltration (NF) membrane provides the opportunity to lower the pressure of these two components. As it will not remove 100% of the salt, the NF membrane process lowers the differential osmotic pressures. It's also coarser than the reverse osmosis (R.O.) membrane, resulting in a lower driving pressure.

The use of nanofiltration membranes instead of R.O. in ocean desalination have been studied in Saudi Arabia and the Middle East, but only as a pretreatment process to remove divalentions and less than 50% of monovalent ions. This paper explains the process of dual nanofiltration to remove salt in ocean water to produce potable water in the range of 100-500 mg/l TDS. The first stage of nanofiltration removes between 75-90% of salt at an applied pressure of 500-550 psi. The second stage removes the remainder of the salt to produce potable water at 200-300 psi applied pressure.

>> biography of presenter

Mr. Vuong earned a Masters of Science Degree in Chemistry at the University of Saigon, Vietnam, and is a registered Civil Engineer in the State of California, U.S.A.

Mr. Vuong is Assistant General Manager of the Long Beach Water Department and has been with the Department since 1996. From 1980 to 1986, Mr. Vuong was an Engineering Manager with the City of Anaheim, California, U.S.A.

PLANNING FOR SEAWATER DESALINATION AND WASTEWATER REUSE IN TAIWAN

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>> abstract

With rising construction, social, and environmental costs of building new reservoirs and increasing threat of drought inflicted economic losses, finding new and reliable sources of water to minimize the risk of industrial and domestic water shortages during critical hydrologic abnormalities has become an important water resources management policy in Taiwan. These alternative or auxiliary waters include those derived from seawater desalination, wastewater reuse, rainwater harvest, off-channel and coastal artificial lakes and ponds, precipitation enhancement, and non-structural measures of agricultural water transfer, conjunctive management of surface and ground waters, water conservation, and water tariff increase.

This paper reports the planning of two seawater desalination plants along the coasts of Hsinchu and Tainan counties with dedicated pipelines to Hsinchu and Tainan Science-based Industrial Parks located respectively 15 to 30 km inland, including their planned procurement procedures and schedule. Ongoing planning to recover a portion of the 70,000 m^3/day secondarily treated effluent from Linhai-Linyuan-Dafa Industrial Parks Joint Wastewater Treatment Plant in Kaohsiung, including the building of a pilot unit, is also presented.

>> biography of presenter

Wen-Sen Chu received his Bachelor of Science degree in agriculture from Chung-Hsing University, Taiwan in 1973, and his master's and Ph.D. degrees in water resources systems engineering from UCLA in 1976 and 1979 respectively.

Dr. Chu served as an assistant professor of environmental resources engineering at Humboldt State University from 1979 to 1981, an assistant and then an associate professor of civil engineering at the University of Washington from 1981 to 1991. Dr. Chu joined ICF Kaiser Engineers (Kaiser) in 1991 and served as Kaiser's Taiwan branch deputy and general manager until 1998 when he founded EITCO.

Dr. Chu has authored more than 50 water resources related papers and articles in international journals and conferences. He is an active member of IDA since 2000 and ASCE since 1980.

DRIP IRRIGATION FOR PEOPLE

Author and Presenter:
Dr. William T. Andrews
President,
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>> abstract

Even seawater desalination, although the most expensive technology, produces water at a sufficiently low cost to meet the needs of the undeveloped world for providing a safe supply of water for drinking, cooking and personal hygiene. The problem in undeveloped areas is distribution of the potable water from the treatment plant to the consumers.

The current conventional approach to water distribution relies on pumping stations, underground pipelines, water meters, and additional controls. Leaks, unauthorized connections, water meter tampering, and unfair allocation are amongst the many problems associated with this approach.

The challenge is to provide a distribution method that could distribute treated water, desalinated or otherwise, in limited quantities and in an easily controlled fashion, such that it could be employed strictly for drinking, cooking and personal hygiene purposes. Other conventional sources of water would be used for other requirements, such as agriculture.

A novel distribution method to provide rationed potable water in undeveloped tropical areas is presented in this paper. The system is based on combining the technologies of overhead power distribution with drip irrigation. Overhead water distribution is proposed, using poles and low cost small internal diameter tubing, with the tubing having smaller self-regulating diameter as the water flows to the points of use. The system has the advantage that no additional power input or active control beyond the treatment plant would be required. Leaks, unauthorized connections, and unfair allocation would be easily visually detected. The limited flowrate eliminates the need for water meters.

The proposed approach is flexible and potentially of very low cost. Its simplicity would allow for local unskilled supervision and maintenance at all points beyond the treatment plant.

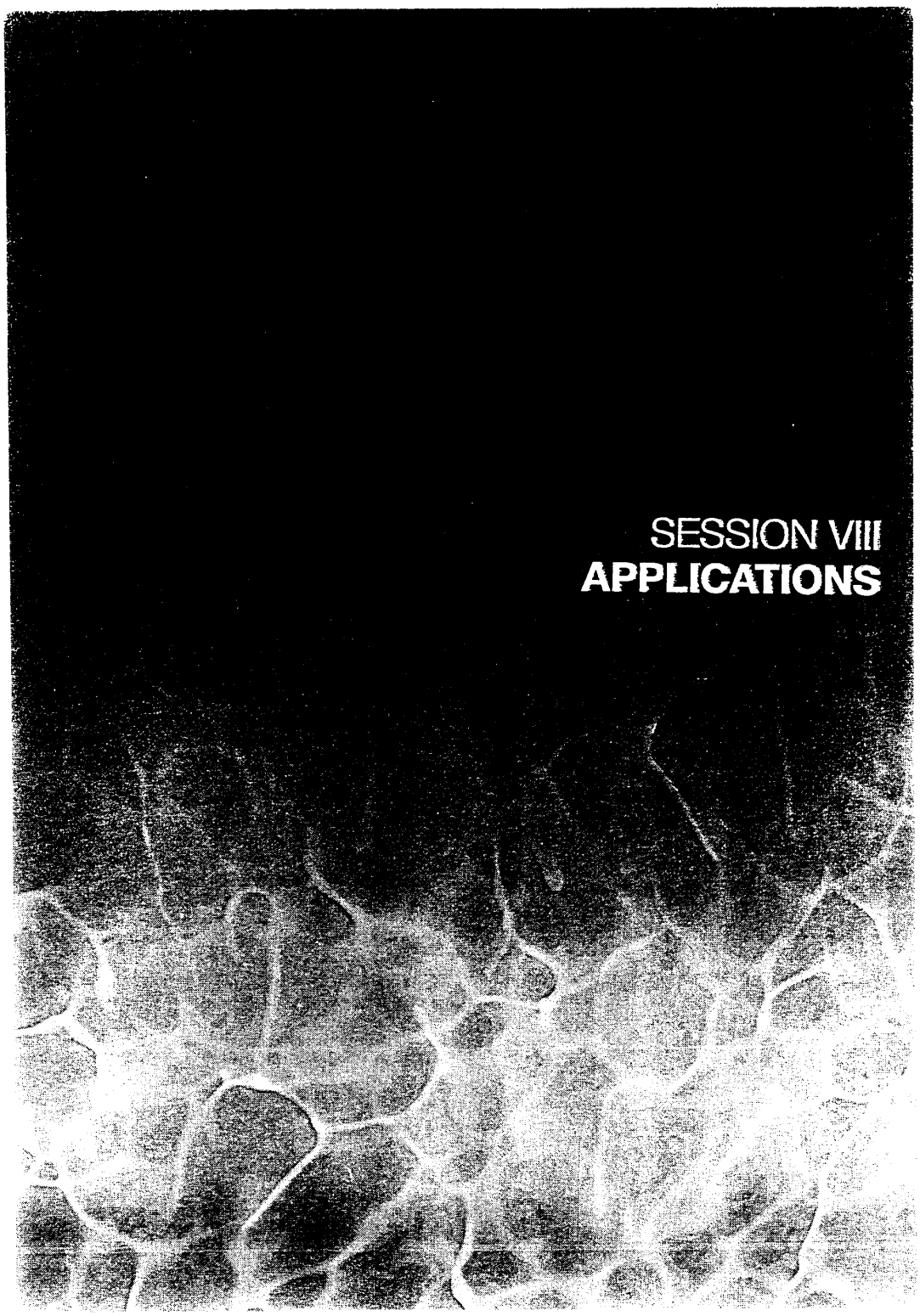
The authors believe that development and implementation of this method could have a significant positive impact upon the health and quality of life of many people in undeveloped tropical areas. In addition, the method could be of significant benefit in the aftermath of natural disasters and for refugee camps.

>> biography of presenter

Dr Andrews has a doctorate in Physics from Oxford University, where he attended as a Rhodes scholar. He is a Registered Mechanical Engineer in Bermuda and California with over 25 years experience in the desalination industry.

Until recently Dr Andrews was the Managing Director of DesalCo Limited, which provides engineering and management services for Caribbean companies that provide BOOT services, utilizing the Seawater Reverse Osmosis process with advanced energy recovery systems. He is currently spearheading DWEER Technology Ltd., which manufactures highly efficient work-exchanger energy-recovery technology for large-scale seawater reverse osmosis desalination plants.

Dr Andrews has been a Director of the International Desalination Association since 1995 and is currently its President.



SESSION VIII
APPLICATIONS

WASTEWATER RECLAMATION USING INTEGRATED MEMBRANE SYSTEM

Mark Wilf, Ph.D.
Vice President – Corporate Tech.
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>> abstract

Reuse of wastewater is quite common in locations having abundant fresh water supply. Municipal effluents, treated to various extend, are being routinely discharged to water bodies and reused after some residence time in the nature. In some arid locations with water shortage this "natural" process is being substituted by multibarrier membrane treatment technology. This process involves application of backwashable ultrafiltration (UF) or microfiltration (MF) pretreatment of secondary effluent followed by reverse osmosis and disinfection. This new membrane pretreatment technology is capable to treat secondary effluent and maintain stable performance of filtrate flow and operating pressure producing RO feed water of a very high quality. In addition to reduction of concentration of colloidal particles, membrane pretreatment achieves 3 – 5 log rejection of pathogens present in the secondary effluent. In reclamation plants that use membrane pretreatment, the fouling rate of the RO membranes has been reduced significantly, compared to plants with conventional pretreatment. The fouling rate has been reduced even more by introduction of new generation of low fouling composite membranes (LFC). The surface of the salt rejection layer of LFC membrane has been modified to make it more hydrophilic and reduce its affinity to dissolved organics. Field results of operation of the low fouling membranes in municipal wastewater reclamation systems indicate that the fouling rate is very low, comparable with that observed in RO operation with clean well water. The low fouling rate is attributed to a lower rate of adsorption of dissolved organics on the LFC hydrophilic membrane surface. Apparently, in the low fouling membranes, the bonding between the adsorbed organic layer and the membrane surface is relatively weak and foulant can be easily removed by high pH flush. Use of membrane pretreatment and low fouling membranes reduced organic fouling as a major problem in RO wastewater reclamation systems. It has been replaced with phosphate scaling, especially in the tail elements. High phosphate concentration level in secondary effluent is a result of use and disposal of washing detergents. Potential phosphate scaling limits the recovery rate of RO units which, affects capital and operating cost. Optimization of system design to achieve improved process economics has to account for the fouling and scaling potential. The paper will describe properties of low fouling membrane technology and present results of its application with conventional and capillary pretreatment. Performance in municipal wastewater reclamation applications will be compared with that of conventional membrane technology. Results of operation of capillary UF/MF membrane pretreatment with municipal secondary effluent and optimization of operating parameters will be described as well.

>> biography of presenter

Dr. Wilf joined Hydranautics in 1985, with more than 28 years experience in membrane technology and desalination field. Currently he oversees the development of membrane products for reverse osmosis and ultrafiltration applications and process design. Evaluation of commercial reverse osmosis plants operation. Design of commercial reverse osmosis desalination plants. Field research and pilot system operation. Evaluation of economics of membrane processes. Computer programs for equipment design, performance projection parametric analysis and performance follow up. Other responsibilities include identifying new technologies, implementation of new technologies developed by the technical staff and ensuring proper use of current technology by Hydranautics' customers. Dr. Wilf is active in the of all Hydranautics projects.

Before joining Hydranautics, he severed as Head of Membrane Projects Department at Mekorot Water Co. Ltd, in Tel Aviv Israel. Were he developed reverse osmosis systems, data analysis, developing new processes, identifying new technologies, and developing project test plans.

Prior to that he served as an Research Associate at McMasters University, Hamiliton, Ontario.

REUSE OF NICKEL REFINERY WASTEWATER BY MICROFILTRATION AND REVERSE OSMOSIS DESALINATION

Neil Palmer
Technical Manager, United Utilities Australia
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Chris Bedem
Process Engineer, Queensland Nickel
Private Mail Bag 5, Mail Centre
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Presenter:
Neil Palmer

>> abstract

Queensland Nickel Pty Limited commissioned a water recycling facility incorporating micro-filtration and reverse osmosis to treat wastewater from its Yabulu Nickel Refinery in North Queensland. Used process waters are brackish and unsuitable for reuse in the refinery. They have traditionally been stored in tailings ponds for evaporation, or discharged to sea under environmental authority. The development has demonstrated the potential for large-scale industrial desalination plants by recycling wastewater for reuse in the plant. By recycling this 12 ML/day waste stream, the refinery's new water input has been reduced by 40%.

The water recycling facility was provided as part of a design-build-operate agreement between United Utilities Australia and Queensland Nickel Pty Ltd. The plant was designed and constructed by O'Donnell Griffin Water Technologies of Adelaide using Vivendi Memcor hollow fibre microfiltration and the novel Grahamtek electromagnetic antiscaling technology from South Africa. The plant, commissioned in December 2000, is operated by United Utilities.

The wastewater has a salinity in the range 5,500 - 7,500 mg/L TDS and contains significant amounts of ammonia, sulphate and magnesium. It also contains the sparingly soluble salts barium and strontium, and at one stage during commissioning, significant amounts of ferrous iron caused by seasonal changes in the tailings pond chemistry.

Extreme variations in water quality from the active tailings pond were brought under control by the inclusion of a shallow intermediate pond prior to the water recycling facility and pH correction using aeration and dosing with caustic soda when necessary.

This is the first use of Grahamtek electromagnetic anti-scaling technology on such a large scale treating industrial wastewater. The technology has been effective in preventing magnesium silicate scale formation even though the two-stage RO process operates at an overall recovery of 85%, well above normally accepted limits for this type of scale. However, barium sulphate fouling has been observed and its control has required a more conventional approach.

The difficulties faced and overcome in implementation of desalination using an EMF anti-scaling system are expected to enable broader use of the application.

>> biography of presenter

Neil Palmer graduated with a Bachelor of Engineering (Civil) from the University of Adelaide in 1974 and completed a Master of Engineering Science (Public Health Engineering) at the University of New South Wales in 1983.

He worked as a professional engineer for the South Australian Government's Engineering and Water Supply Department from 1975 to 1994 in water supply and sewerage planning, design, construction and operation. During this period he worked in Fiji for the Public Works Department in 1989 and 1990. From 1994 to 1997 Neil was Principal Wastewater Adviser with the South Australian Environment Protection Authority. In 1997 Neil joined United Utilities Australia as Water Quality Manager, progressing to Technical Manager. He is also Operations Manager of the company's first Australian desalination plant located at the Queensland Nickel Refinery in Townsville.

Neil is a member of the Institution of Engineers, Australia and is an active member of the Australian Water Association. He is currently a member of the AWA's Federal Executive and also national Finance and Administration Director.

WATER REUSE & ZERO LIQUID DISCHARGE - A SUSTAINABLE WATER RESOURCE SOLUTION

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France & UK

Presenter
Bruce Durham

>> abstract

National Governments and leading institutions are promoting sustainable environmental solutions as the only way forward.

Water shortage problems due to change in rainfall, flood contamination of good quality water and over abstraction of groundwater are becoming more widespread. These changes combined with new legislation are encouraging the development of sustainable water resource strategies. Many national policies include the promotion of wastewater reuse and governments and regulators are providing financial incentives to promote this beneficial strategy.

Zero Liquid Discharge (ZLD) has been regarded for many years as an uneconomic solution. This paper will discuss the practical options available to developers of new industrial plants and for the optimisation of existing plants. It will describe innovative solutions from manufacturing and municipal industries. It will describe how to rationalize the selection of treatment processes, balance the capital and operating costs and integrate the process solution into a reliable ZLD water management system.

The following case studies and applications will be discussed:

- Car manufacturing plant where ZLD is saving in excess of US$ 1 million a year in water and waste charges.
- This ZLD Power station is saving approximately US$ 0.6 million a year through reusing secondary sewage.
- Island City. 45,000 m3/day of potable water was made available for the community by industry reusing wastewater rather than potable water.
- Water resource management. Reuse and desalination of secondary sewage is used for aquifer recharge and specialised irrigation in agricultural areas with soil salinisation.

>> biography of presenter

Bruce Durham is responsible for the Alternative Water Resource market and international business development for Vivendi Water. This includes water resource management, water reuse & desalination for municipal and industrial applications.

His experience includes over 30 years in the water and wastewater treatment industry working in most industries. This includes fourteen years with Vivendi and seven years consultancy in water injection and enhanced recovery consultancy for oil and gas production in Europe, Africa and the Middle East.

SEWER MINING IN URBAN MELBOURNE

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United States

Henry Mallia
Business Manager
Water Industry Group (Melbourne)

>> abstract

The Victorian Government is developing a Water Recycling Strategy to promote the adoption of water recycling practices across Victoria. Melbourne Water Corporation has set a target to recycle twenty percent of the effluent of its two major wastewater treatment plants. Conventional strategies call for the construction of a centralized water recycling facility at these major plants. The wastewater must first be collected and delivered to the treatment plants on the outskirts of the city. Then, the recycled water must be delivered to customers. Urban customers are the most costly to serve due to their lack of proximity to the wastewater treatment plants. There are many parks, sports ovals and greenbelts in urban Melbourne that could benefit from the availability of low cost, reliable water supply.

Sewer mining is a concept whereby wastewater is taken directly out of a sewer main and treated to Class A recycled water standards. The raw wastewater is screened and delivered into a membrane bioreactor system for biological and membrane filtration treatment. The effluent from the membrane bioreactor is then treated with reverse osmosis membranes and is then used to irrigate a 1-hectare area of parkland in the King's Domain Gardens.

This innovative project uses a new technology, membrane bioreactors, to take advantage of the fact that there is an abundant supply of water (albeit of impaired quality) running directly beneath large demands for non-potable water supply. This technology allows for the recycling of wastewater in cost effective manner with a small footprint system. The King's Domain Garden project successfully showed that Sewer Mining could be accomplished in an urban setting, producing very high quality water, without negatively impacting the surrounding areas.

>> biography of presenter

Henry is a Civil Engineer with post-graduate qualifications in Public Health Engineering (M.Sc, London University on a WHO Fellowship) and business administration (MBA, Deakin University). He has some 30 years experience and has worked on projects in Australia, Dubai, Libya, Malta and Saudi Arabia.

Prior to joining Earth Tech, Henry occupied a number of roles including Project Engineer for the construction of pre-treatment works and submarine pipeline for the main sewerage outfall from the island of Malta. Other assignments were Resident Engineer for the construction of a road intersection project outside Tripoli, Libya and Division Head for an international consulting firm undertaking multi-discipline projects in the Middle East.

Henry's current responsibilities at Earth Tech include direction of a team of some 30 design professionals undertaking water and wastewater projects for public and private sector clients. He is currently the Design Manager for an AUS $40m BOOT project awarded to Earth Tech in November 2002 by a regional Water Authority in Victoria. The project includes a new wastewater treatment plant, utilising UASB and intermittent aeration processes, to reclaim about 2 GL/yr of water to augment the irrigation water supply of farm properties participating in this project.

In recent years, Henry has been taking an active interest in the application of membrane systems for the production of high quality reclaimed water. This led to his appointment as Project Manager for the On-Site Water Recycling Demonstration Plant described in the paper presented at this Conference. Henry is currently the Project Manager for another trial of the upgraded Plant investigating the use of Class A Water to top up a recreational lake in Melbourne.

附錄二

TECHNICAL EXCHANGE PROGRAMME BETWEEN TAIWAN WATER RESOURCES AGENCY AND PUBLIC UTILITIES BOARD

PROGRAMME FOR 2-DAYS TECHNICAL SEMINAR IN SINGAPORE

27 Feb 03 (Thu)

0900	Arrival of TWRA delegates
0905	Opening Address
0910	Presentation on Overview of Singapore Water Supply by Mr Koh Boon Aik, Dy Director (Development), Water Department
0935	Presentation on Water Reclamation and discussion by Mr Harry Seah, Dy Director (Supply-I), Water Reclamation Department
1030	Tea-break
1100	Presentation on Wastewater Reclamation for Industrial Parks in Taiwan and discussion by Dr Chang Chen Chang of Kintech Technology Co Ltd
1200	Presentation on Rainfall Harvesting in Taiwan and discussion by Professor Andrew Lo, President of IRCSA
1230	Lunch
1400	Visit to NEWater Visitor Centre
1600	Visit to Hyflux
1730	Departs for hotel
1930	Welcome dinner for TWRA delegates

28 Feb 03 (Fri)

0900	Presentation on Desalination and discussion by Mr Arasu Sivaraman, Sr Manager (Planning), Water Department
1000	Presentation on Seawater Desalination and Water Reuse in Taiwan and discussion by Dr Chu Wen Sen, CEO, EITI
1030	Tea-break
1100	Presentation on Water Resources Developments and Allocations in Taiwan and discussion by Mr Chen Kuei Chih, Section Chief, TWRA
1130	Presentation on Governmental and Non-governmental Reactions and Efforts to 2002 Taiwan Drought and discussion by Mr Chang Kuang Chih, Senior Engineer, TWRA
1200	Presentation on Drought Prevention and Emergency Measures for Hsin-Chu Science-Based Industrial Park in Taiwan and discussion by TWRA
1230	Lunch
1400	Presentation on Ultrapure water from NEWater for use in Wafer Fabrication Plants and discussion by Dr Bruno Coniglio, Director, CAWT
1500	Presentation on Water Demand Management and discussion by Mr Chong Hou Chun, Dy Director (Transmission & Distribution), Water Department
1600	Tea-break
1630	Closing session
1700	Seminar ends

LISTING OF PUB DELEGATES FOR 2-DAYS TECHNICAL SEMINAR ON 27 AND 28 FEB 03

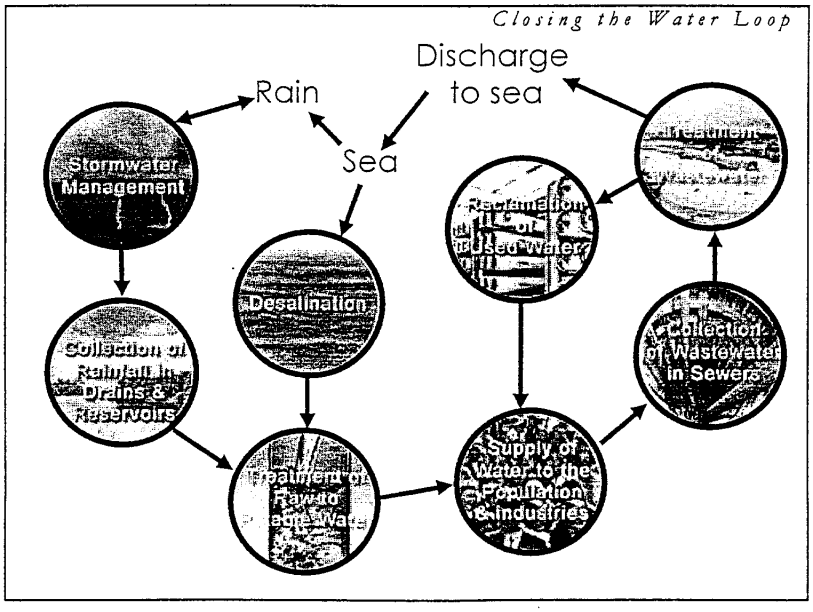
	Name	Designation	Department	Remarks
1	Mr Chan Yoon Kum	Director	Water	
2	Mr Lim Chiow Giap	Director	Water Reclamation	
3	Mr Koh Boon Aik	Deputy Director (Development)	Water	Speaker
4	Mr Chong Hou Chun	Deputy Director (Transmission & Distribution)	Water	Speaker
5	Mr Arasu Sivaraman	Senior Manager (Planning)	Water	Speaker
6	Mr Wong Yong Yang	Assistant Director (Reservoir & Catchment)	Water	
7	Mr Tan Nguan Sen	Assistant Director (Treatment Singapore)	Water	
8	Mr Tony Soh	Senior Manager (Maintenance)	Water	
9	Mdm Cheng Geok Ling	Executive Engineer (Planning)	Water	
10	Mr Harry Seah	Deputy Director (Supply-I)	Water Reclamation	Speaker
11	Mr Kan Lock Meng	Executive Engineer (Policy & Enterprise)	Water Reclamation	
12	Mr Tan Yok Gin	Assistant Director (Supply-II)	Water Reclamation	
13	Mr Lim See Gan	Assistant Director (Policy & Enterprise)	Sewerage	
14	Miss Lo Siew Hong	Executive Engineer (Development)	Drainage	

	Name	Designation	Department	Remarks
15	Mr Wah Yuen Long	Assistant Director (Water Reclamation)	Deep Tunnel Sewerage Department	
16	Dr Bruno Coniglio,	Director	Centre for Advanced Water Treatment	Speaker
17	Dr George Yang	Department Manager	Centre for Advanced Water Treatment	
18	Mr Rajiv Dixit	Deputy Vice President (Business Development)	Centre for Advanced Water Treatment	

LISTING OF TWRA DELEGATES

	Name	Designation	Department	Remarks
1	Dr. Jin-San Huang	Director	Taiwan Water Resources Agency	
2	Mr Chang Kuang Chih,	Senior Engineer	Taiwan Water Resources Agency	
3	Mr Chen Kuei Shing	Section Chief	Taiwan Water Resources Agency	
4	Mr Kuo Hsing Chang	President	Kintech Technology Co. Ltd	
5	Dr Chang Chen Chang	Division Head	Kintech Technology Co. Ltd	
6	Mr Wen Tze Wen,	Manager	Industrial Technology Research Institute	
7	Lee Tung Feng	Associate researcher	Industrial Technology Research Institute	
8	Dr Chu Wen Sen,	Chief Executive Officer	Environment & Infrastructural Technologies Inc.	
9	Professor K. F. Andrew Lo	President	International Rainfall Collection System Association	

Presentation on Overview of Singapore's Water Supply by Mr Koh Boon Aik, Deputy Director (Development), Water Department, Public Utilities Board



Presentation on Overview of Singapore's Water Supply by Mr Koh Boon Aik, Deputy Director (Development), Water Department, Public Utilities Board

Singapore

Land Area	682 km^2
Average Annual Rainfall	2,400 mm
Total population	4 million
Water Demand	1.35 mil m^3/day (300 mgd)

Singapore's supply through 4 sources

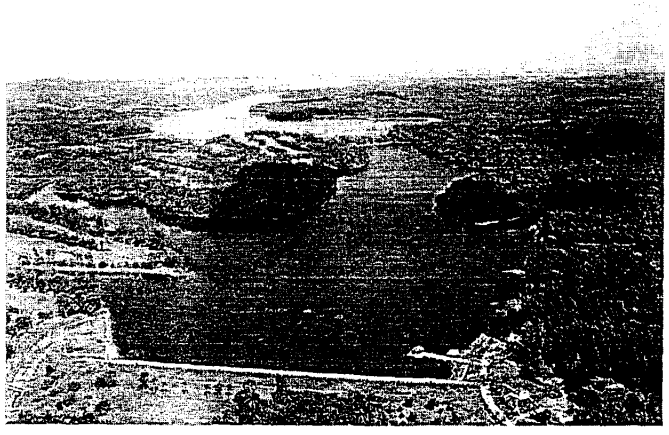
- Catchment Water
- Imported Water – Johor Water
- Desalted Water
- NEWater

Local Water Catchments

At present, about half of Singapore is water catchments

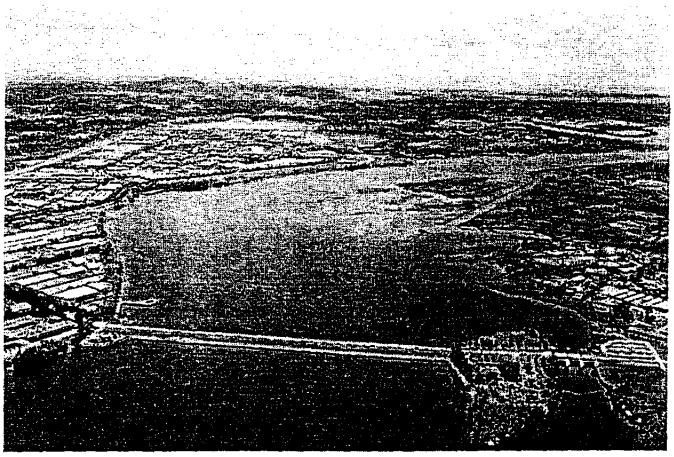
By 2011, two-third of Singapore will be water catchments

Reservoirs in Central Catchments

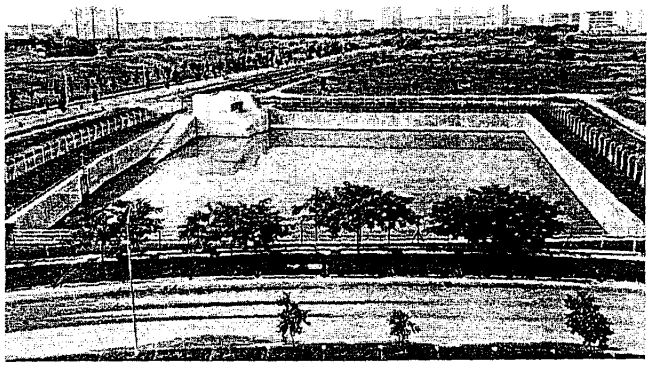


Presentation on Overview of Singapore's Water Supply by Mr Koh Boon Aik, Deputy Director (Development), Water Department, Public Utilities Board

Kranji Reservoir



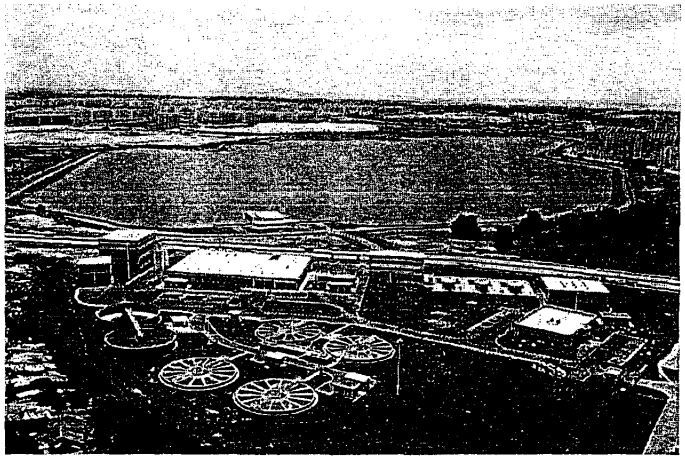
Urban Stormwater Collection Pond



Presentation on Overview of Singapore's Water Supply by Mr Koh Boon Aik, Deputy Director (Development), Water Department, Public Utilities Board

Bedok New Town (Urbanized Catchment)

Bedok Waterworks



Future Catchments

- Marina Basin
- More reservoirs downstream of existing Lower Seletar Reservoir
- Reservoirs integration scheme

Under Singapore Green Plan 2012

Unconventional sources account for 25% of water needs by 2012

Desalted Water
NEWater

The Desalted Water Tap

- Build-Own-Operate (BOO)
- 30 million gallons per day
- Bidders can choose from a wide range of available desalination processes (RO, MED, MSF and hybrid of these systems)

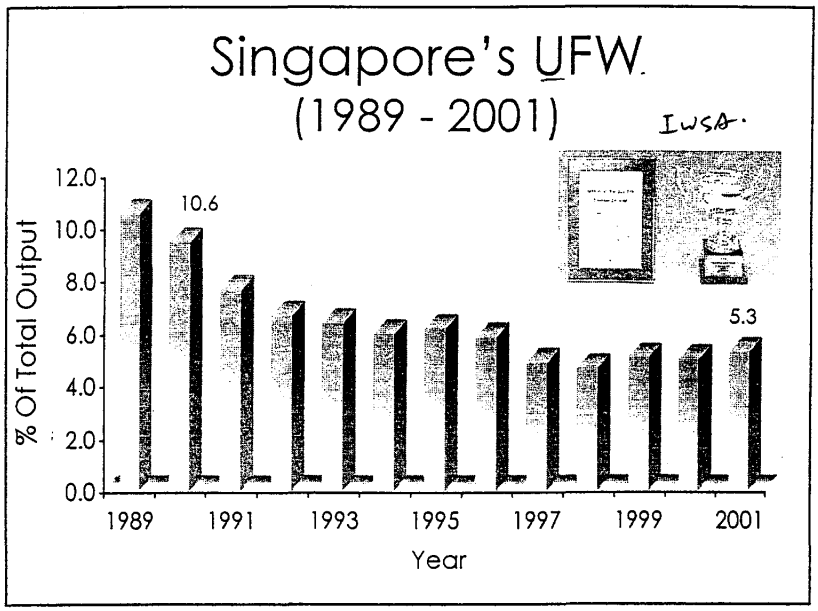
NEWater

Non – Potable Supply to Wafer Fabs and Industries

Demand Management

Water Conservation Measures

- By Law
  - Mandatory installation of water saving devices
  - Fiscal policy – tariff
  - Legislative measure
- Through close partnership
  - water reuse/recycling
  - substitution of potable water
  - incentives for investment in water conservation equipment
  - water audit & advice
  - education & publicity


Singapore's UFW
(1989 - 2001)
IWSA
% Of Total Output
12.0
10.0
8.0
6.0
4.0
2.0
0.0
10.6
5.3
1989
1991
1993
1995
1997
1999
2001
Year


Thank You

Supply of NEWater

Content

- History
- NEWater
- Direct Non-Potable Supply to Industries
- Indirect Potable Use

History

- In Early 1970s, Industrial Water was supplied to the Industries in the Jurong area for industrial use.
- Industrial Water supply extended to Tuas and Jurong Island.
- Current demand is 80,000 m3/d

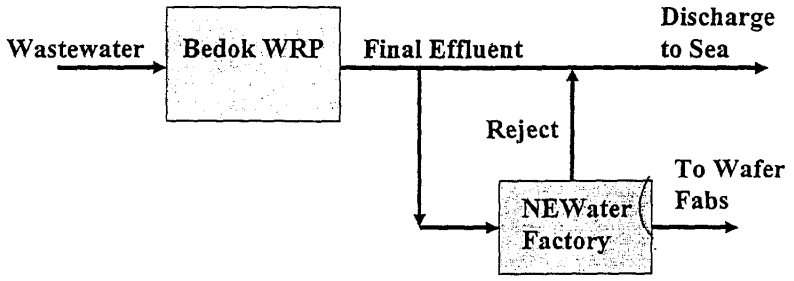
History

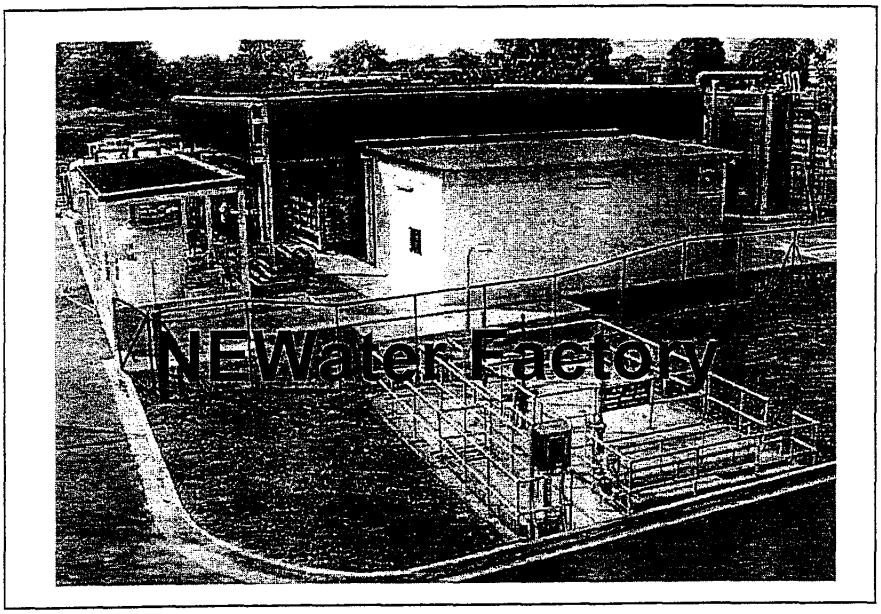
- In 1970s, ENV/PUB did a study on advanced water reclamation technology – water quality exceeding Industrial Water
- Study found that reclaimed water of drinking water standards was possible with advanced conventional treatment processes (ammonia stripping, ion exchange, AC columns...) . RO membranes were used. But it was costly.

History

- With great advances in membrane technology, it is now possible to have reliable supply of water from drinking water standards from many sources – sea water, treated used water...., at affordable price.
- 1998, ENV and PUB started the 2-year study to test membrane technology to recover water of drinking standards from treated used water.

Overview





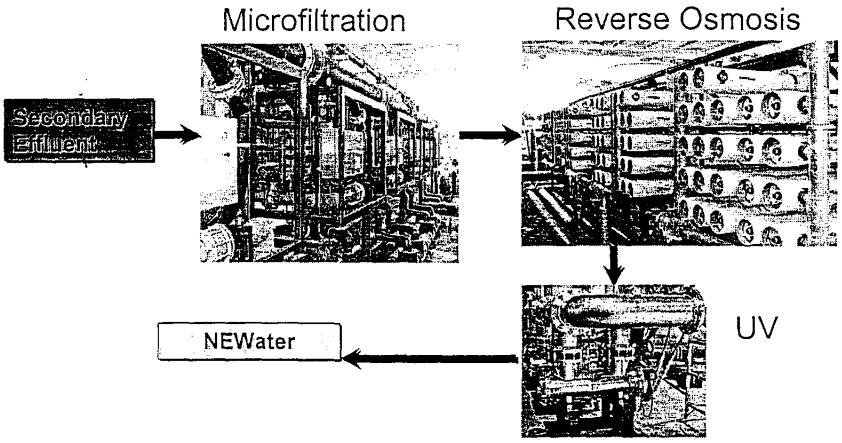
NEWater Factory

- Built at the cost of $6.5 M
- Construction period - 7 months
- Operational since May 2000
- 10,000 m^3/d production capacity

Plant Process Units

- ❑ Microfiltration
- ❑Reverse Osmosis
- ❑UV Disinfection

NEWater FACTORY



Water Quality Comparisons

Water Quality Parameters	PUB Raw Water	PUB potable water	NEWater	USEPA/ WHO Stds
Turbidity (NTU)	0.5 – 11	< 0.1	< 0.1	5
Total Dissolved Solid (mg/l)	117 – 154	149.5	16.3 – 41.3	500
Lead (mg/l)	< 0.013	0.002	< 0.0005 to 0.002	0.01
Mercury (mg/l)	<0.00003	<0.00003	<0.00003	0.001
Estrogenic Compounds (ug/l)	ND	ND	ND	Not Specified
PCBs (ug/l)	ND	ND	ND	0.5 30
Dioxin (pg/l)	ND	ND	ND	Not Specified
Total Organic Carbon mg/l)	2.6 – 6.2	1.9 – 3.5	<0.1	ND
Total Coliform (cfu/100 ml)	3 - 967	ND	ND	ND
Enterovirus	ND	ND	ND	

ND – Non detectable

NEWater is well within WHO and USEPA Drinking Water Standards

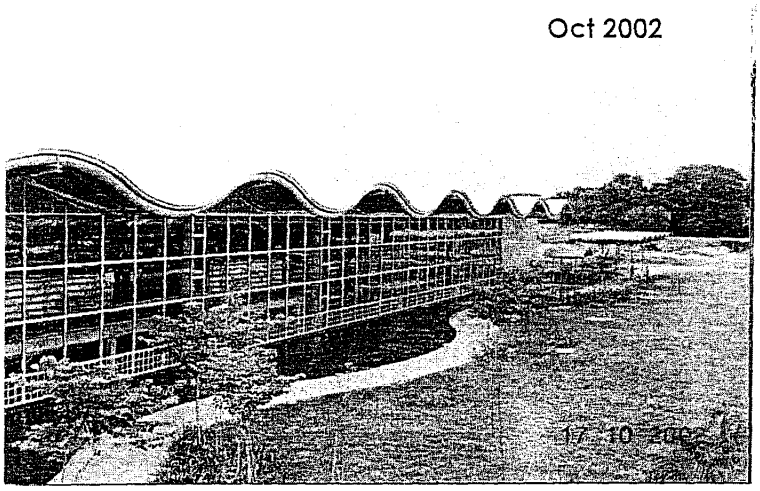
Direct Non-Potable Supply to Industries

Direct Non-Potable Supply to Industries

- 2 NEWater Factories in operation
  - Bedok and Kranji
  - 16 mgd or 72,000 m3/d
- Supply to the wafer fab
- Supply to commercial buildings for air con cooling
- Supply to other industries for process use, cooling.....
- Target – at least 55 mgd or 250,000 m3/d by year 2012

Bedok NEWater Factory

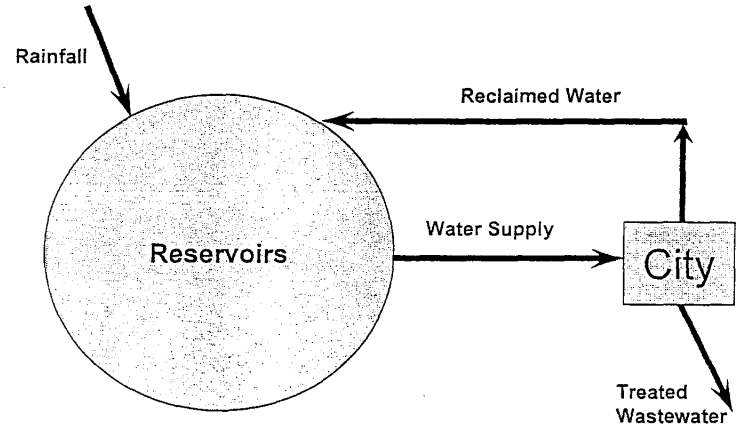
Oct 2002



Kranji NEWater Factory

Indirect Potable Use

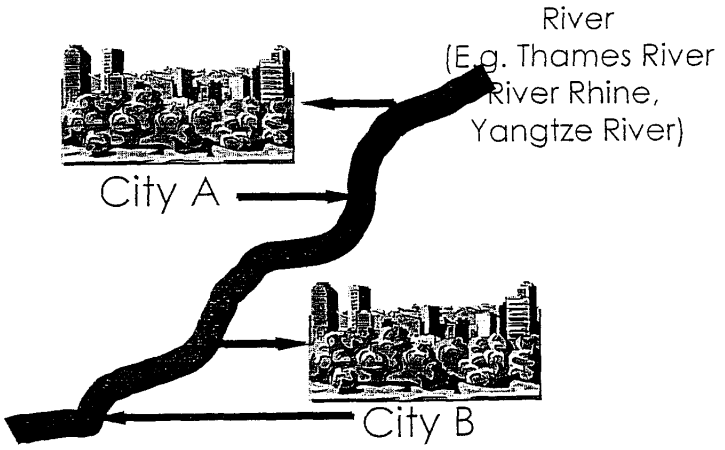
Planned Reuse

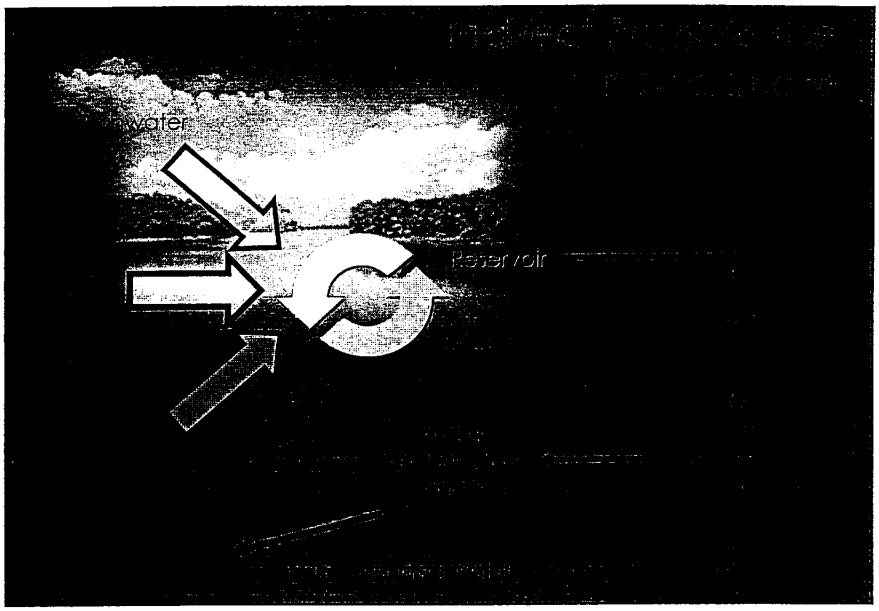


Indirect Potable Use

- Not new, has been in practice in the United States for more than 20 years
- NEWater will blend with reservoir water and treated again at existing water works
  - helps to overcome psychological barrier
  - physical separation
  - blending provides the salts essential for health
- Unplanned, has been going on since early civilisation

Indirect water reclamation





Indirect Potable Use

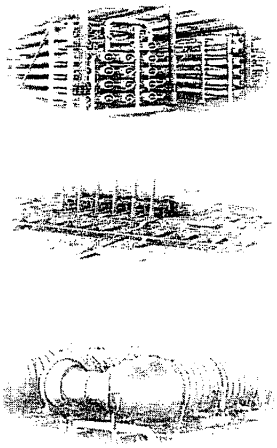
- 2 mgd in year 2003
- Increase progressively to 10 mgd by year 2011

Thank You

Presentation on Desalination by Mr Sivaraman Arasu, Sr Manager (Planning), Water Department, Public Utilities Board

PUBLIC UTILITIES BOARD

Desalination – The Build-Own-Operate (BOO) Approach



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Structure of Presentation

1. **Desalination as a Source of Potable Water**

2. **Project Outline**
   - Tender approach
   - Project Structure

3. **Technical Aspects**
   - Desalination Processes
   - Water Quality Standards
   - Connection to PUB's Water Transmission System

4. **Commercial and Legal Aspects**
   - Risk allocation
   - Tariff Structure

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Desalination as a Source Of Potable Water

- Surrounded by the sea.
- Drought-proof source.
- Advances in desalination technology.

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Desalination As A Source Of Potable Water (Cont'd)

PUB has been keeping abreast of developments in desalination for more than two decades.

- Since the 1970s, PUB's officers have been making trips to countries which have desalination plants to learn from their experiences.
- In the mid 1980s, PUB with the assistance from consultants studied in detail the 3 main technologies in desalination i.e. MSF, MED and RO.
- In the mid 1990s, a comprehensive review of desalination was carried out.
- PUB continues to monitor trends in desalination.

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Desalination Trends

- Distillation remains as the main desalination process in countries where there is abundant natural supply of oil and gas.
- For countries not having abundant natural supply of oil and gas reverse osmosis (RO) process is favoured compared to distillation processes
- Recent private sector led projects show lower prices.

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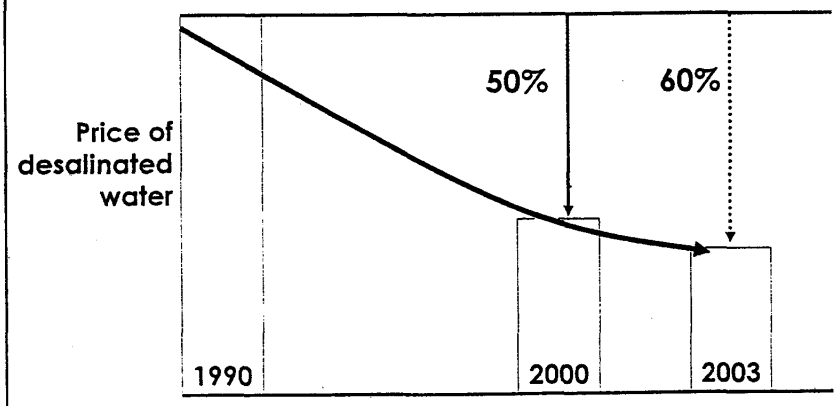

Cost is coming down

Public Utilities Board

2. Project Outline

- Project is first of its kind in Singapore.
- Build-Own-Operate (BOO) structure. There is no transfer of the desalination plant to PUB at the end of the Term.
- 20-year Term starting from project's commercial operation date

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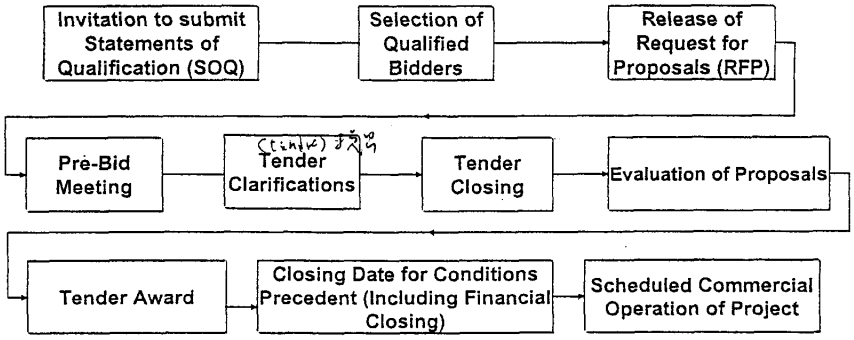
Tender Approach



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Pre-qualification of Bidders

- Advertised on 23 Mar 2001.
- Closed on 1 Jun 2001.
- A total of 17 applicants submitted Statements of Qualifications (SOQs).
- 11 of the 17 applicants were pre-qualified as bidders.

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List of Pre-qualified Bidders

1. The AES Corporation
2. Bechtel Enterprises/ PowerSeraya Ltd/ Preussag Wassertechnik Gmbh
3. Cadagua S.A./ Inima S.A./ Proyectos E Instalaciones De Desalacion S.A.
4. Ionics Inc.
5. KeppelFELS Energy Pte Ltd
6. Mirant Corporation/ Hyflux Ltd
7. Ondeo-Services/ Ondeo-Degremont
8. SembCorp Utilities Pte Ltd
9. Tuas Power Ltd/ Mitsubishi Corporation
10. Union Fenosa Internacional/Jurong Engineering Ltd/ IDE Technologies Ltd/Actividades De Construccion Y Servicios
11. Vivendi Water S.A.

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Bids Received

Tender closed on 31 May 02. Bids were received from 4 bidders:

Name of Bidder	First-Year Price of Water (S$/m^3)
Singspring (Consortium comprising Ondeo and Hyflux Ltd)	0.78
SembCorp Utilities Pte Ltd	0.96
Tuas Power Ltd	Base Proposal: 1.07 Alternative Proposal: 1.01
Keppel FELS Energy Pte Ltd	1.40

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Tender Award

- Tender awarded to SingSpring on 17 Jan 2003.
- SingSpring will be employing reverse osmosis process.
- Plant scheduled to commence supply by 2nd half 2005.

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BOO Project Structure

- Project structure is complex by virtue of the number of parties involved and the corresponding number of contracts.
- The success/failure of a party will have an effect on more than the immediate counterparty.

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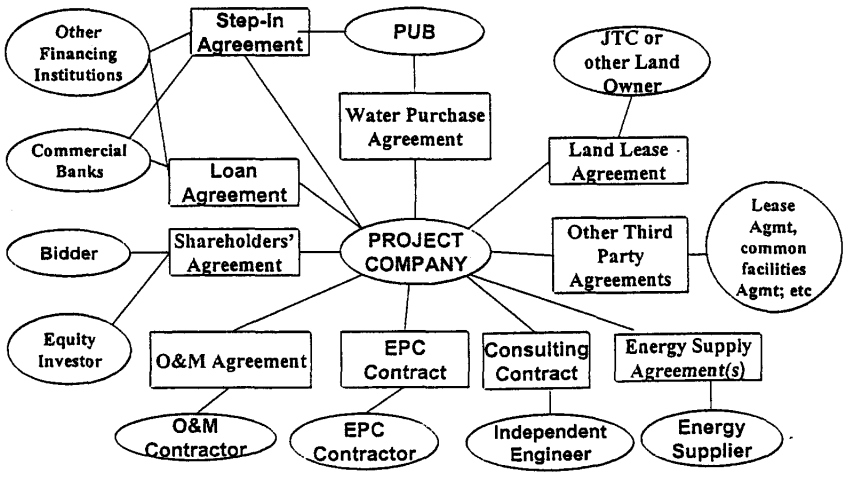
Possible Structure of the BOO Project



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Water Purchase Agreement (WPA)

- Provides for the purchase of the desalinated water by PUB from the Project Company based on agreed price and conditions.
- Contains all the technical, commercial and legal terms and conditions for the supply and purchase of desalinated water

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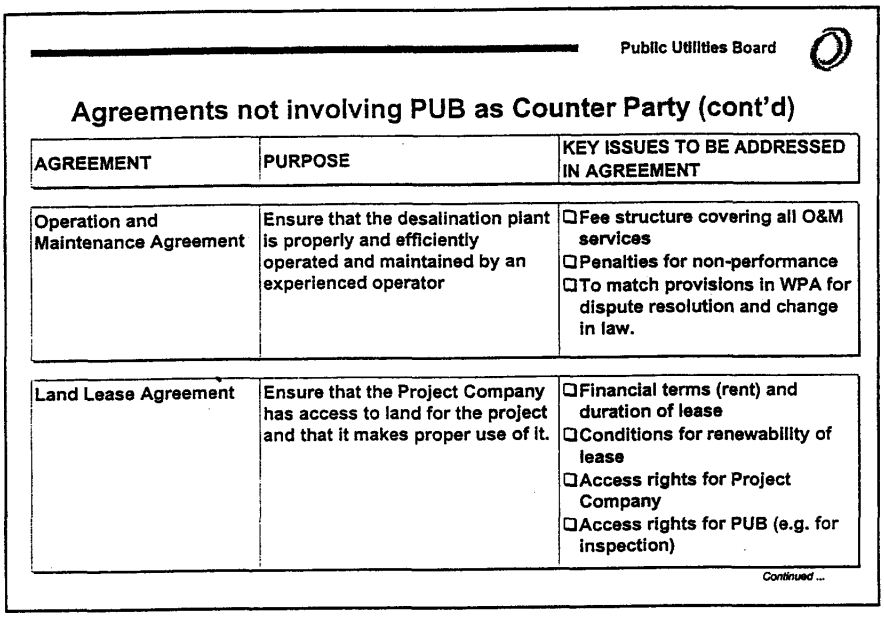
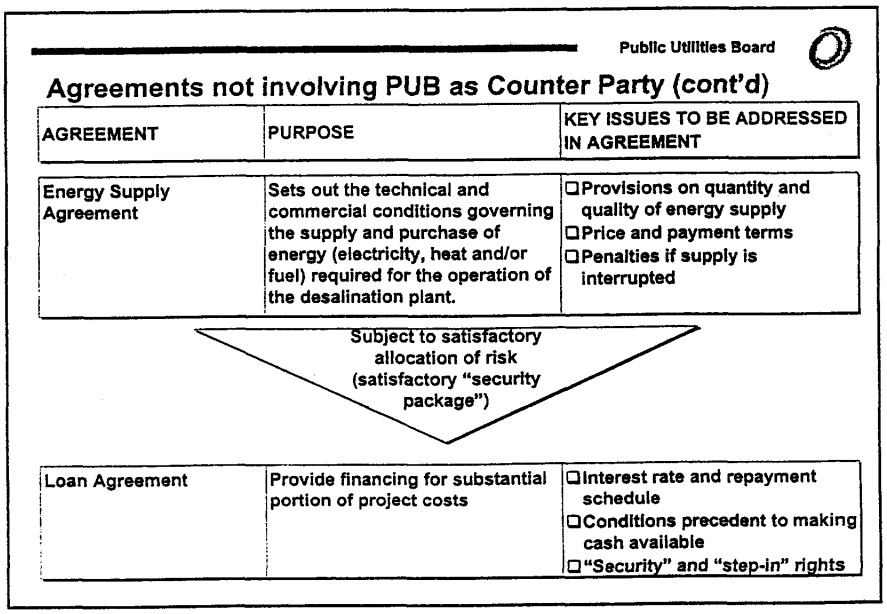
Agreements not involving PUB as Counter Party

AGREEMENT	PURPOSE	KEY ISSUES TO BE ADDRESSED IN AGREEMENT
Shareholders' Agreement	Defines the relationship between Project Company's shareholders, including rights and obligations, and describes the form as well as purpose of the Project Company.	❑Extent of liability of each shareholder ❑Restrictions on sale of equity ❑Ability of Project Company to engage in certain activities or assets
EPC Contract (Engineering, Procurement and Construction)	Ensure that the desalination plant is built on time and within budget by an experienced contractor	❑Fixed-price "turnkey" contract terms ❑Penalties/LD for completion delay, shortfall of output, etc. ❑To match provisions in WPA for testing and commissioning of plant, dispute resolution and change in law.

Continued ...

Presentation on Desalination by Mr Sivaraman Arasu, Sr Manager (Planning), Water Department, Public Utilities Board





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3. Technical Aspects

Developers are free to choose from a broad range of desalination processes with internal or external energy sources, in particular:

➢Thermal processes:

- Multi-Effect Distillation (MED)
- Multi-stage Flash Evaporation (MSF)

➢Membrane processes:

- Reverse Osmosis (RO)

➢Hybrid Processes of the above

Innovative designs are allowed but they must be proven.

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4. Technical Aspects (Cont'd)

Technical requirements are mainly functional to encourage attractive bidding:

- Only basic requirements are defined for the design and structure of the plant - to provide bidders with the highest degree of liberty in terms of process selection and configuration.
- Requirements focus on assuring state-of-the-art technology and achieving performance and availability objectives.
- Bidders are free to lease the safeguarded site at Tuas or secure their own sites – need to connect to PUB's T&D system.

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4. Technical Aspects (Cont'd)

- Bidders may combine the chosen desalination process with alternative internal or external energy sources to achieve high efficiency, reliability and competitive costs.
- Technical information and documentation requested from Bidders to enable fair and transparent evaluation of bids based on different desalination processes and configurations.

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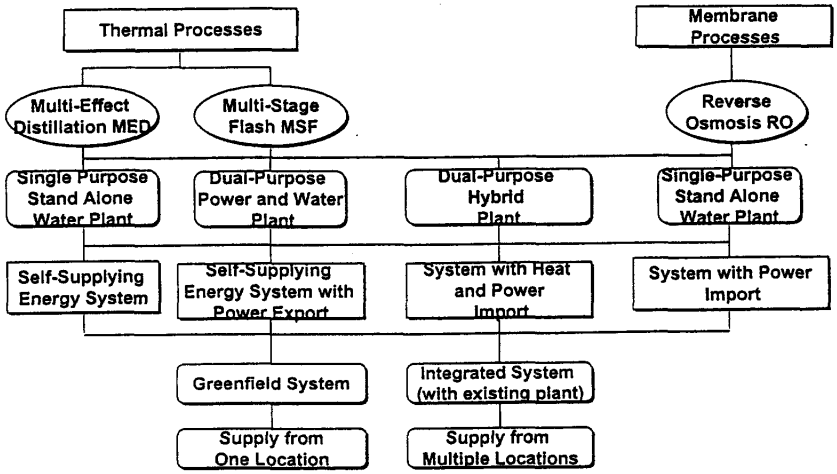
Possible Desalination Processes



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Water Quality Standards

- Generally to comply with WHO Guidelines for Drinking Water
- Additional requirements to meet local conditions

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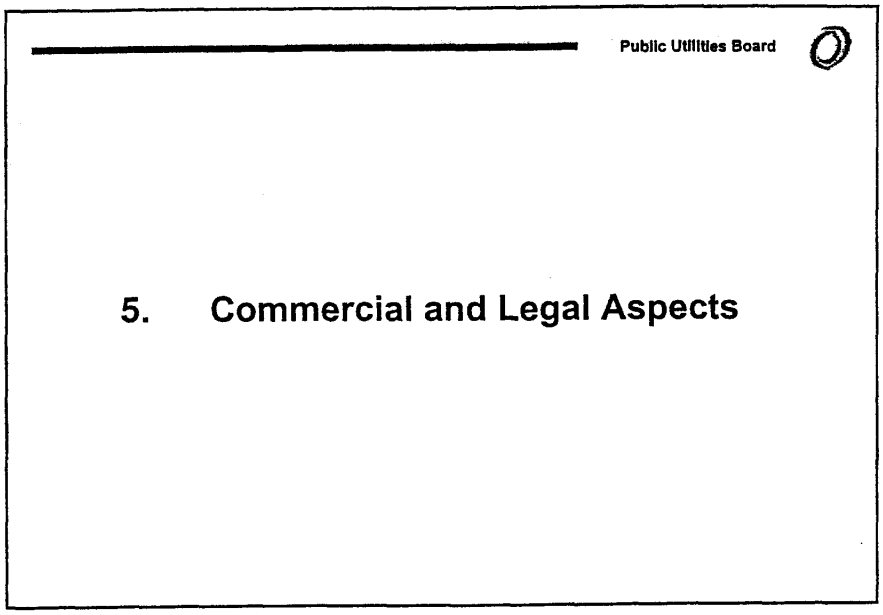
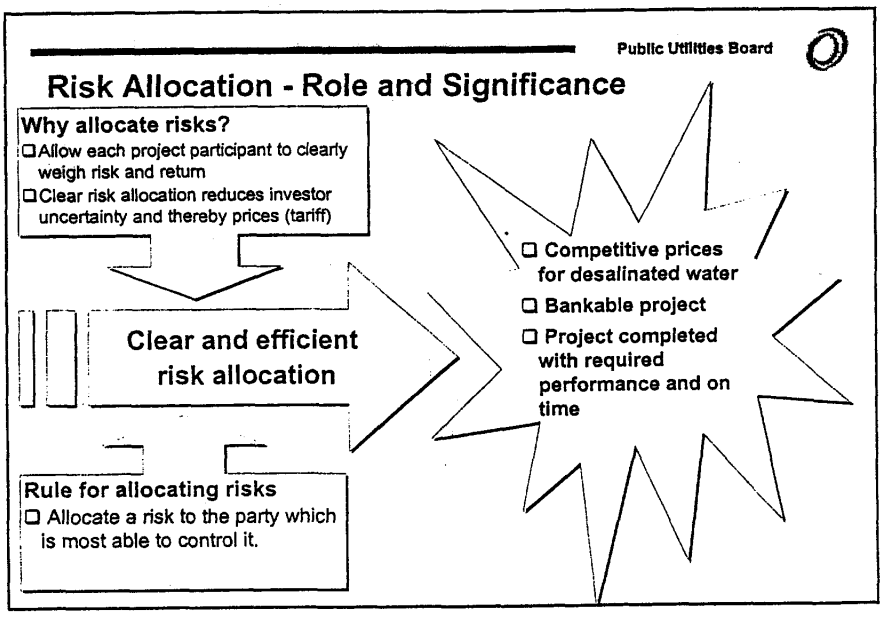
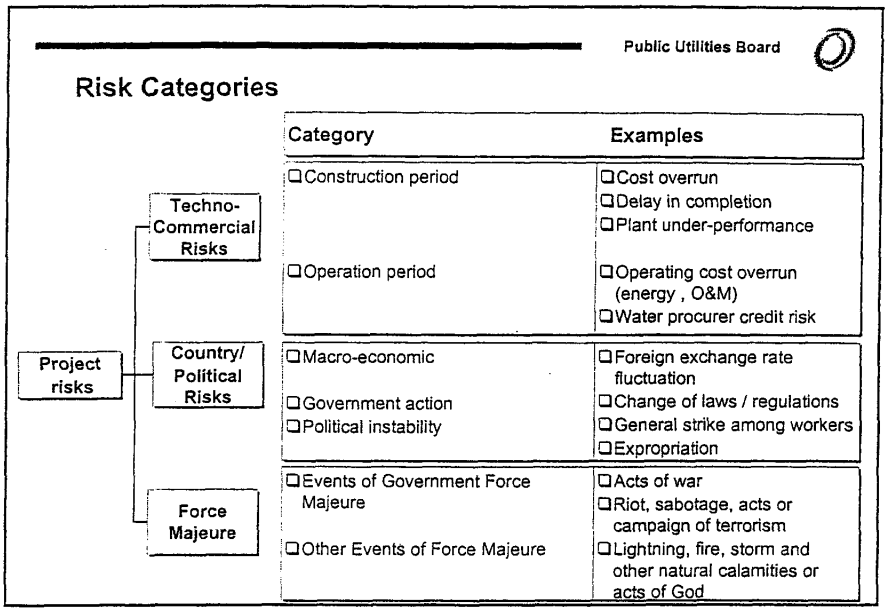
Connection to PUB Water Transmission System

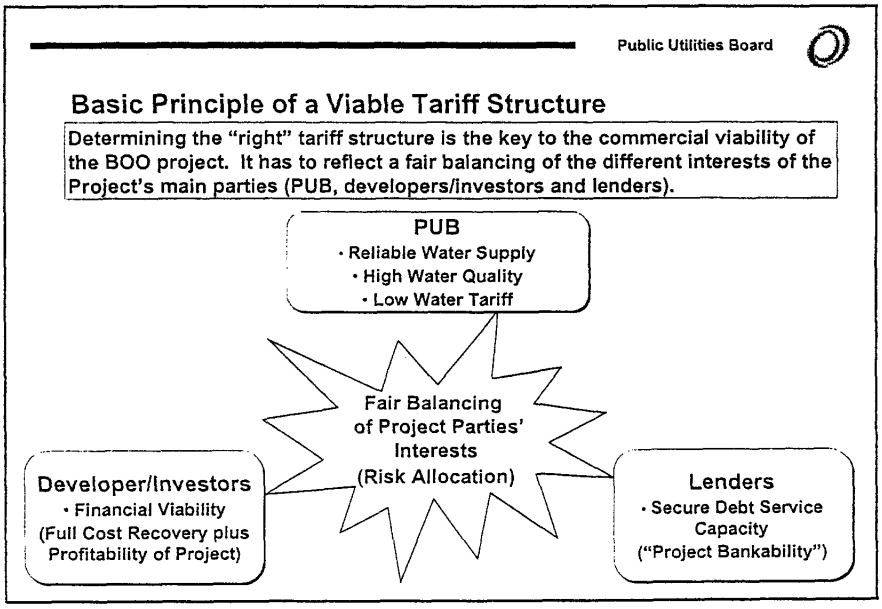
- Location of Connection Point from Desalination Plant to PUB Water Transmission System


Public Utilities Board
5. Commercial and Legal Aspects

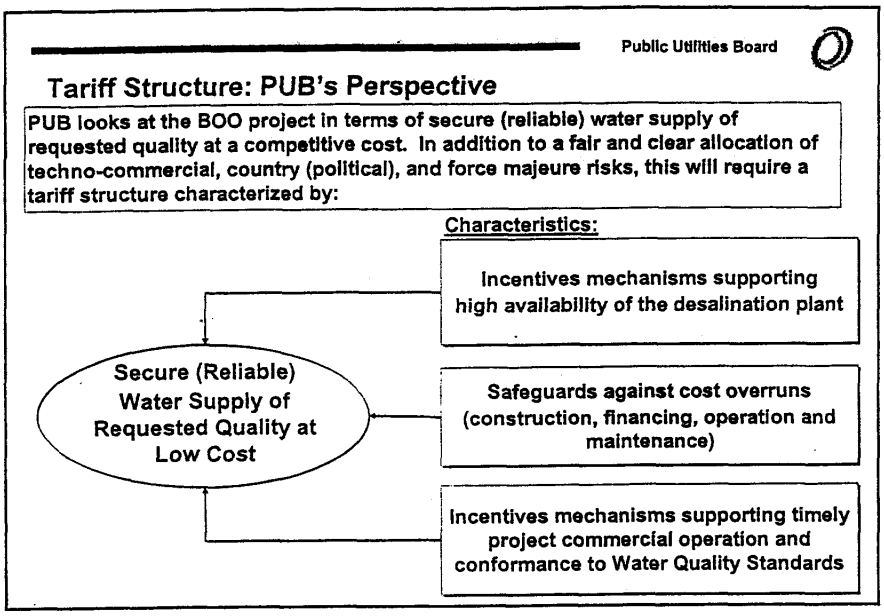

Public Utilities Board
Risk Allocation - Role and Significance
Why allocate risks?
Allow each project participant to clearly weigh risk and return
Clear risk allocation reduces investor uncertainty and thereby prices (tariff)
Clear and efficient risk allocation
Rule for allocating risks
Allocate a risk to the party which is most able to control it.
Competitive prices for desalinated water
Bankable project
Project completed with required performance and on time

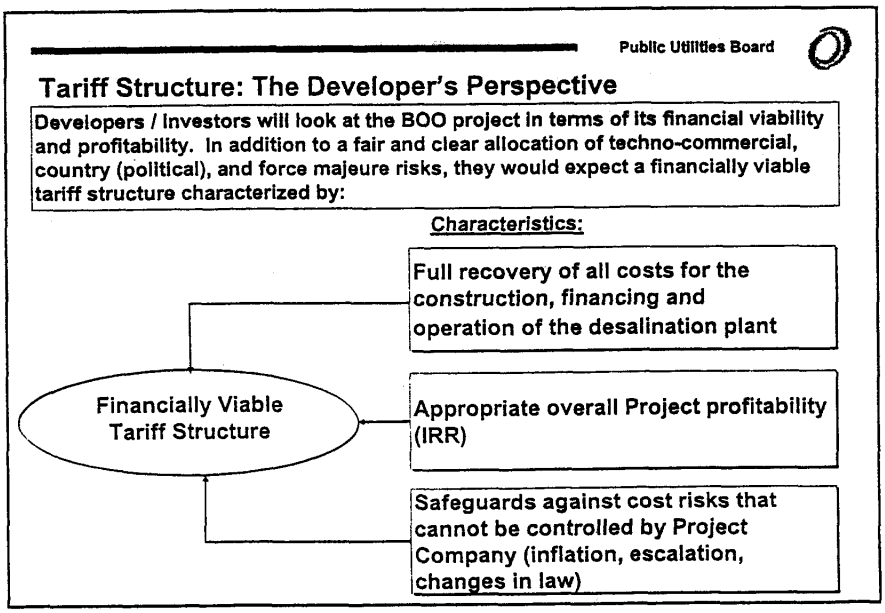
Presentation on Desalination by Mr Sivaraman Arasu, Sr Manager (Planning), Water Department, Public Utilities Board

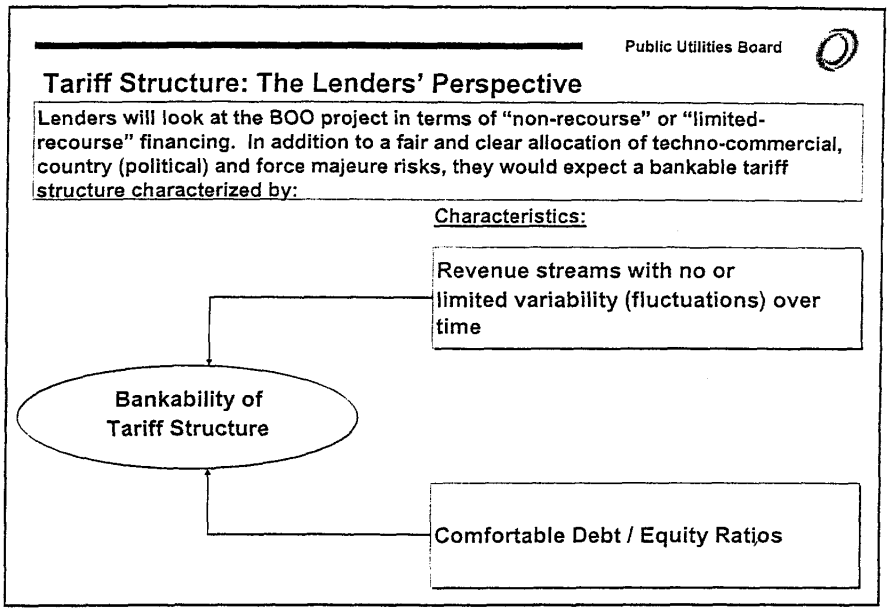


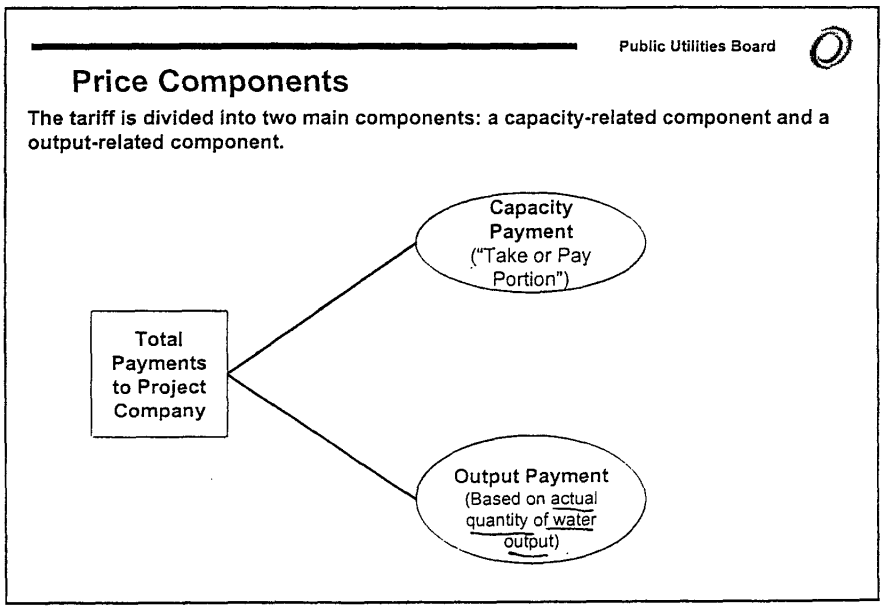


Presentation on Desalination by Mr Sivaraman Arasu, Sr Manager (Planning), Water Department, Public Utilities Board






Public Utilities Board
Tariff Structure: The Lenders' Perspective
Lenders will look at the BOO project in terms of "non-recourse" or "limited-recourse" financing. In addition to a fair and clear allocation of techno-commercial, country (political) and force majeure risks, they would expect a bankable tariff structure characterized by:
Characteristics:
Revenue streams with no or limited variability (fluctuations) over time
Bankability of Tariff Structure
Comfortable Debt / Equity Ratios


Public Utilities Board
Price Components
The tariff is divided into two main components: a capacity-related component and a output-related component.
Capacity Payment ("Take or Pay Portion")
Total Payments to Project Company
Output Payment (Based on actual quantity of water output)

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Price Adjustments

- Price is not static throughout the Term
  - Inflation
  - Fluctuation of Fuel Prices

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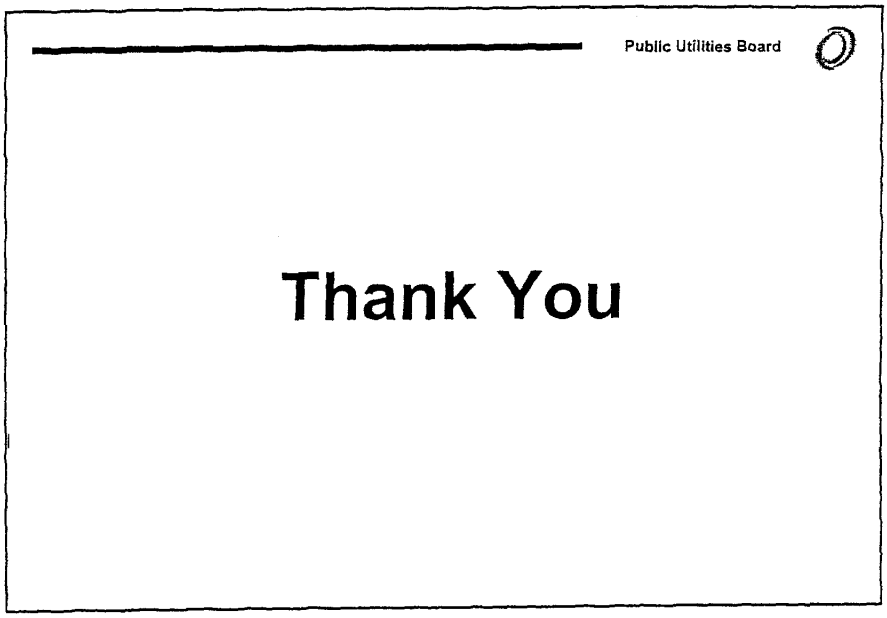
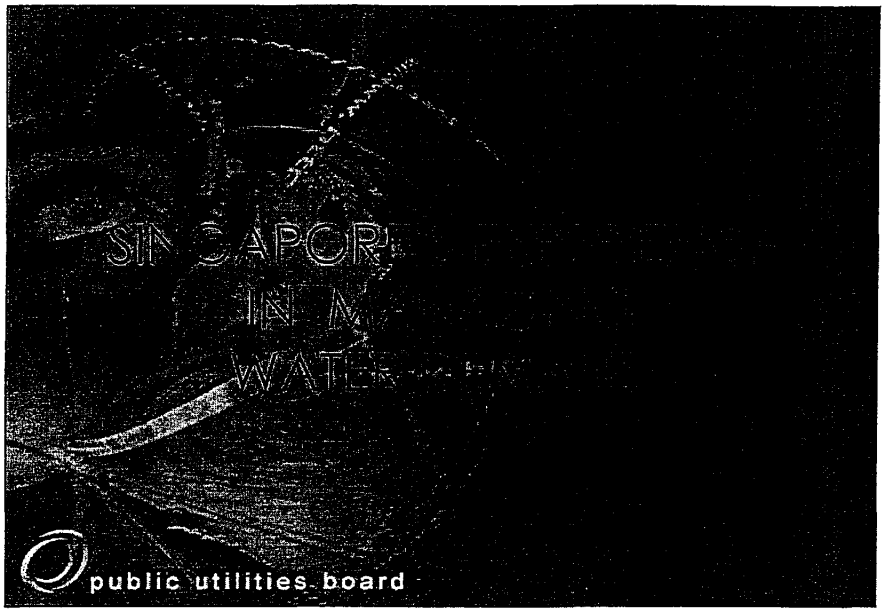
Future Desalination Plants

Development of future desalination plants will depend on various factors

- water demand
- availability of supply from alternative sources
- price of desalinated water.

Presentation on Desalination by Mr Sivaraman Arasu, Sr Manager (Planning), Water Department, Public Utilities Board



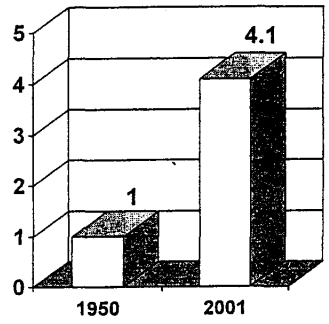


Singapore's Water Supply

Total population	4 million
Water Demand	1.3 mil m^3/day (300 mgd)

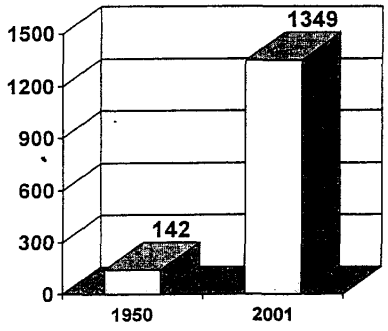
GROWING DEMAND

Population (in millions)



4.1 Times

Daily water consumption (in thousand cubic metres)



9.5 Times

Total Approach In Demand Management

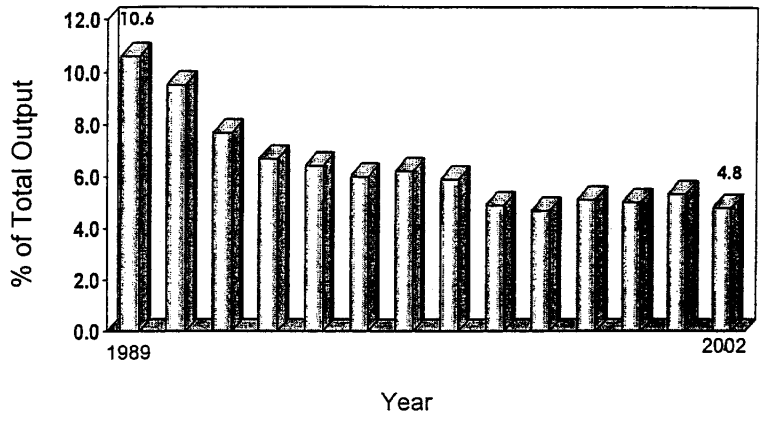
PUB Supply Network

- UFW Control

Customers' Premises

- Water Conservation

SINGAPORE'S UFW (1989 - 2002)



Measures To Reduce UFW

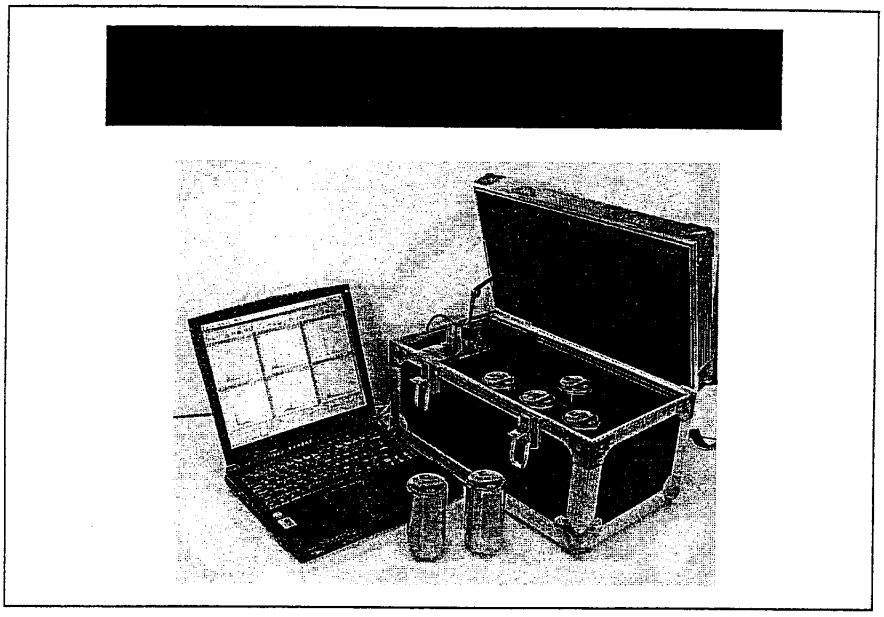
- Leakage Control
- Accurate Metering
- Proper Accounting of Water Usage
- Strict Legislation

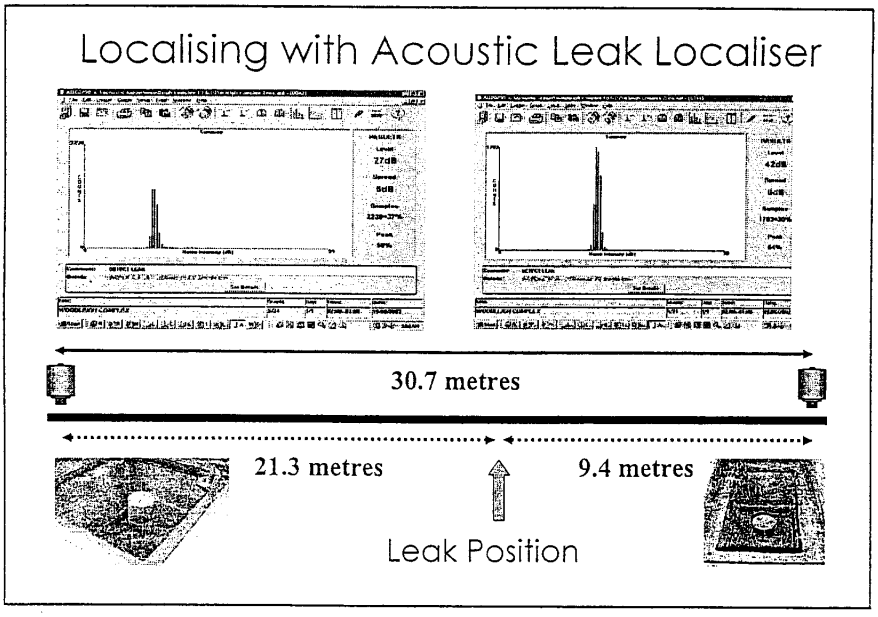
Leakage Control

- ✓ Use Better Quality Pipes & Fittings
- ✓ Mains Replacement Programmes
- ✓ Leak Detection Programme
- ✓ Quick Response to Public Reports

Use Of Suitable Pipes & Fittings

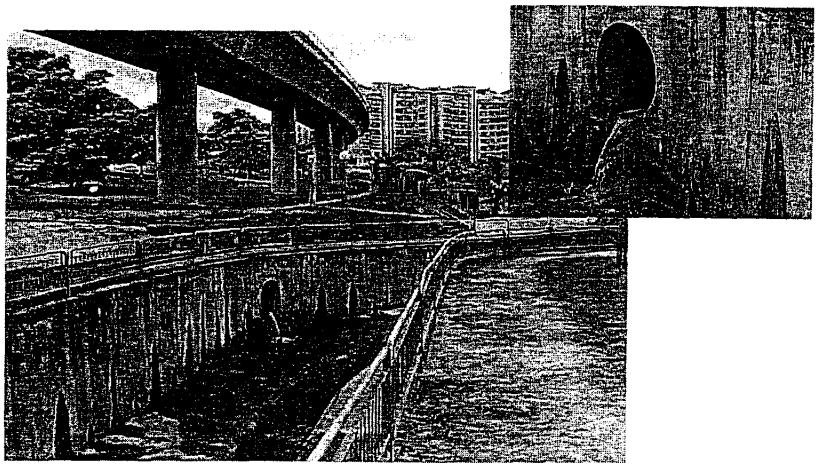
- Prohibit use of unlined CI and GI pipes
- Use of more durable and corrosion-resistant piping materials:
  - Unlined GI ⇒ SS or Cu
  - Unlined CI ⇒ 100 – 300 mm cement-lined DI
    : ≥ 700 mm cement-lined steel

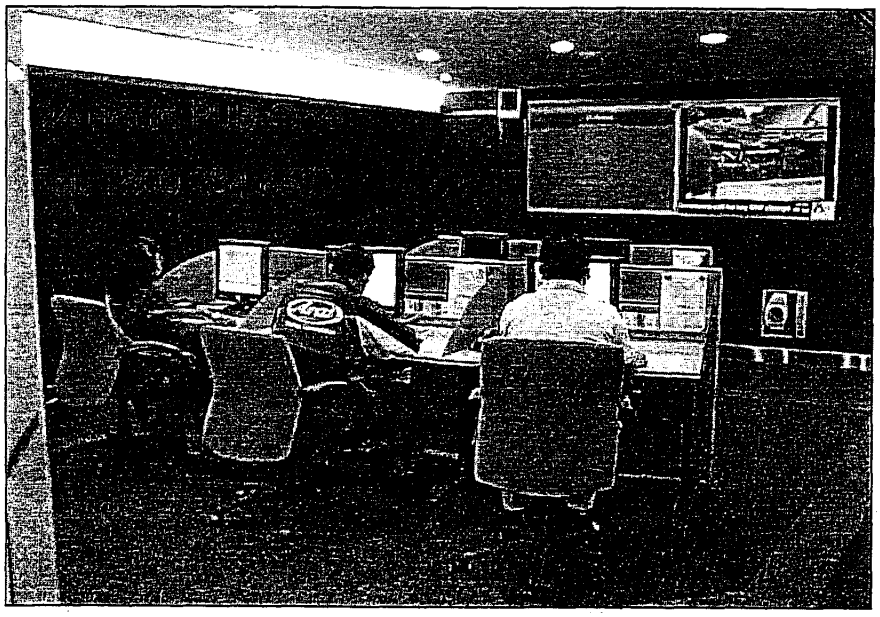



Localising with Acoustic Leak Localiser
30.7 metres
21.3 metres
9.4 metres
Leak Position


ELECTRONIC
LISTENING STICK

Excessive Dry Weather Flow

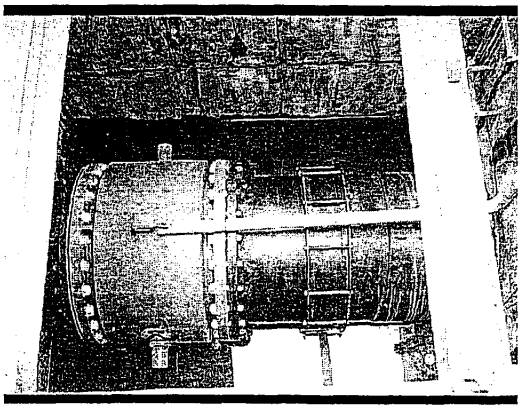




Accurate Metering

- 100% metered
- Waterworks use electromagnetic flowmeters
- Customers meters are accurate to within 3% allowable error through :
  - ✓ Purchasing accurate meters
  - ✓ Replacement of meters through bulk-changing programmes

Waterworks' Output Meters

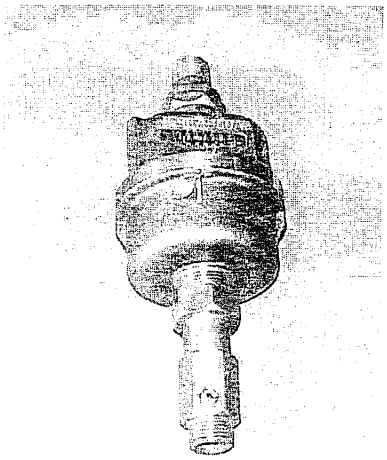


Electro-magnetic flowmeter

- Reliable and Accurate (±1%)
- More Expensive
- Calibration Tests

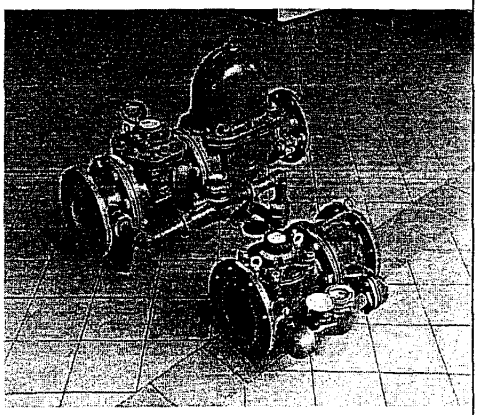
Domestic Meters

- 15 mm
- Comply with ISO 4064/1 Class C
- Volumetric Type
- Accuracy : Within 2% (New) & 3% (In Use)



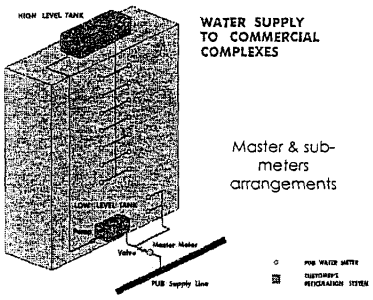
Non-domestic Meters

- 25 to 200 mm
- 50, 100 and 150 mm are compound type
- Able to capture high and low flows



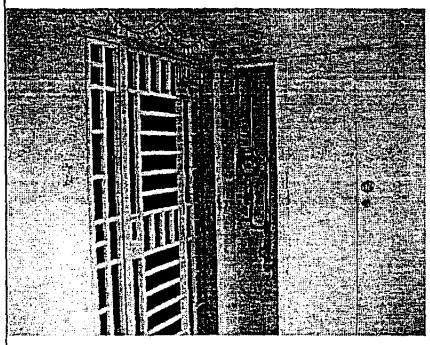
Meter Arrangement

Multi unit premises -Master & Sub-meters

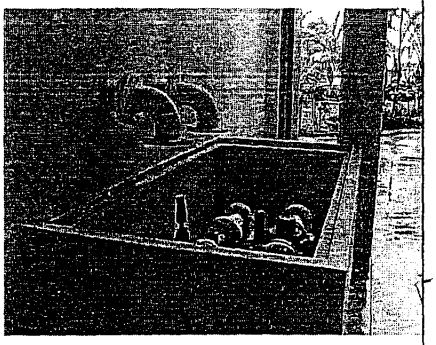


Meter Arrangement – Multi Units Premises

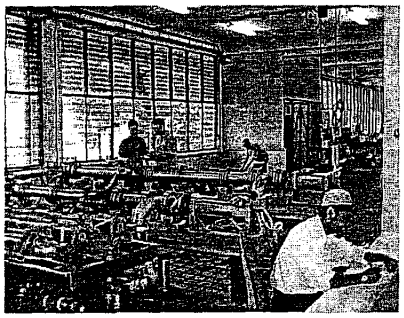
Meter in service duct



Master meters in meter chamber



Meters Maintenance & Replacement Programme



Meter Workshop

- Servicing of meters
- Testing of meters
  - Pre-qualification tests
  - Delivery - Batch testing
- In service Testing

Replacements or Bulk-changing Programme

- Ensure meter function within 3% allowable error
- 15mm meters – 10-year cycle
- Large meters – 7 years

"Clean" network and customer's water reticulation system

Reliable and Accurate Metering

Proper Accounting of Water Used

- Commissioning of new mains and service reservoirs
- Flushing for maintenance of mains
- Structured monthly reporting system

Strict Legislation on Illegal Draw-Offs

- Very Few Cases
- Strict Enforcement
- Public Utilities Act

Water Conservation Plan

- Mandatory Installation of Water Saving Devices
- Fiscal Policy
- Legislative Measure
- Water Recycling & Substitution
- Water Audit
- Public Educational and Publicity Programme

Mandatory Installation of Water Saving Devices

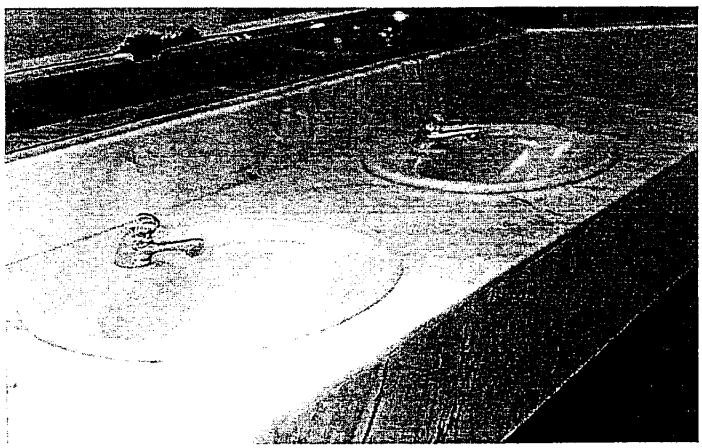
Since 1983

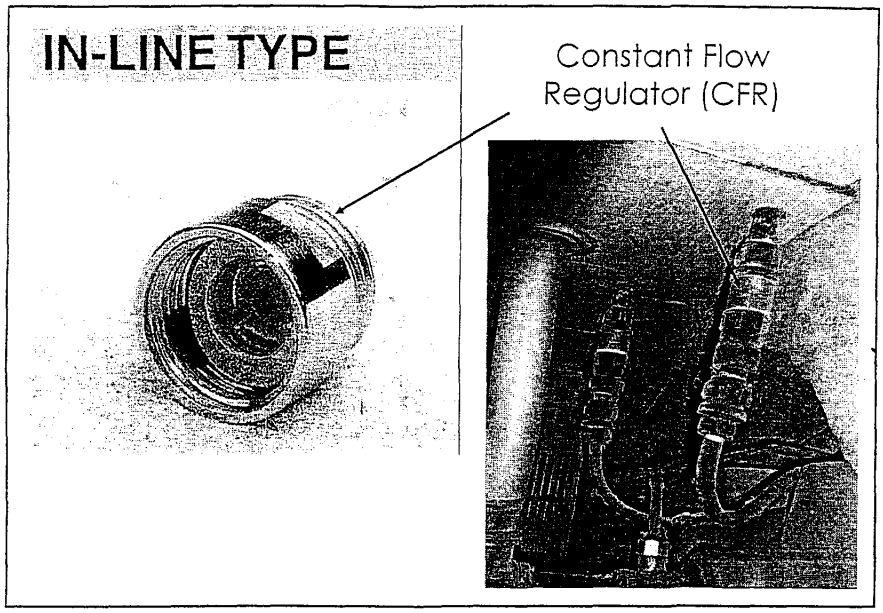
- Self-Closing Delayed-Action Taps
- Constant Flow Regulators

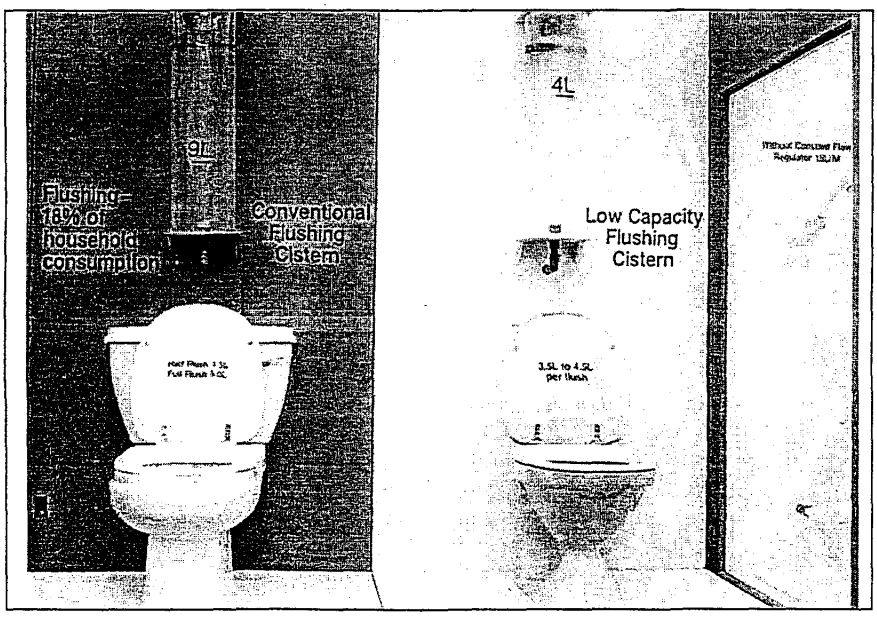
Since 1997

- Low Capacity Flushing Cistern

Self-Closing Delayed Action Taps

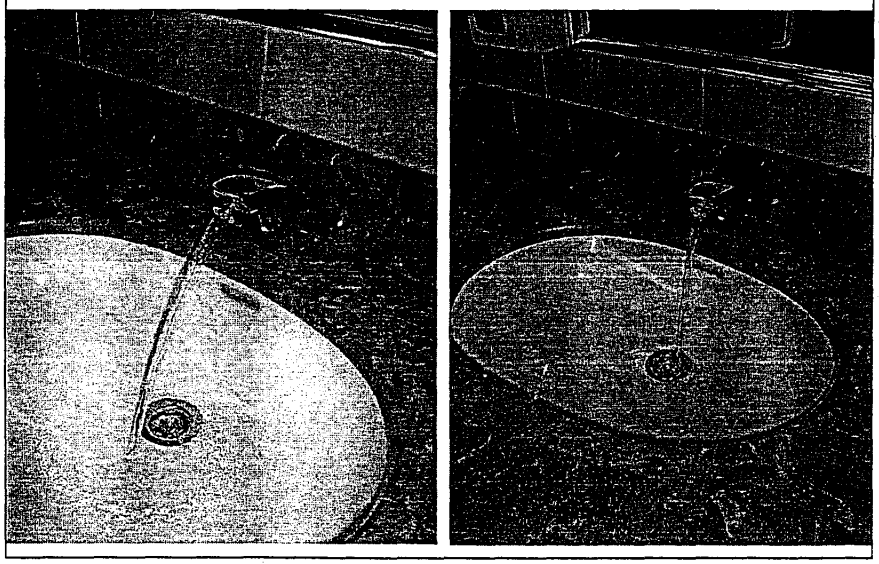



IN-LINE TYPE
Constant Flow
Regulator (CFR)


9L
Flushing=
18% of
household
consumption
Conventional
Flushing
Cistern
4L
Low Capacity
Flushing
Cistern

Revision in Flowrates

Area of Usage	Maximum flowrate		Remarks
	Existing	New	
Basin tap & Self-Closing Delayed Action Basin tap	8 litres/min	6/litres/min	For Self-Closing Delayed Action basin tap, the timing shall remain at between 2 and 3 sec
Sink/kitchen tap and wash area	12 litres/min	8 litres/min.	
Shower tap & Self-Closing Delayed Action Shower tap	12 litres/min	9 litres/min (except for hotels - remain at 12 l/min	For Self-Closing Delayed Action shower tap, the timing shall remain at between 13 and 15 sec
Other areas	12 litres/min	8 litres/min	



Tariff Structure

- Rationale for restructuring
  - Reflect strategic importance and scarcity of water
  - Dispel notion that households are entitled to contain quantum of water charged at cheaper rate

Water Tariff

		Before 1 July 1997				W.e.f. 1 July 2000			
Water category	Consumption block (m^3 per mth)	Tariff ($/$m^3$)	WCT (%)	Total (¢/m^3)	WBF (¢/m^3)	Tariff ($/$m^3$)	WCT (%)	Total (¢/m^3)	WBF (¢/m^3)
Domestic	1 to 20	56	0	56.0	10	117	30	152.1	30
	20 to 40	80	15	92.0	10	117	30	152.1	30
	Above 40	117	15	134.6	10	140	45	203.0	30
Non-domestic	All units	117	20	140.4	22	117	30	152.1	60
Shipping	All units	207	20	248.4	-	192	30	249.6	-

WCT : Water Conservation Tax - Broad-based Tax levied by the Government
WBF : Waterborne Fee - Statutory charge collected by PUB for maintenance and extension of the public sewerage system.

Legislative Measures

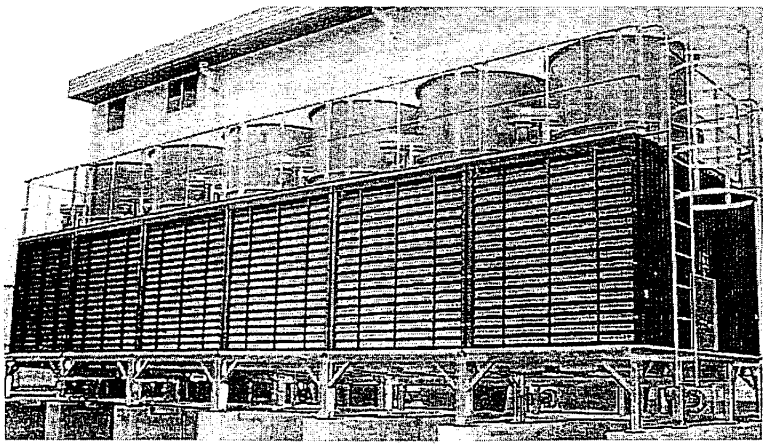
- Public Utilities Act
- Public Utilities (Water Supply) Regulations
- Code of Practice for Water Services, Singapore Standard, CP 48

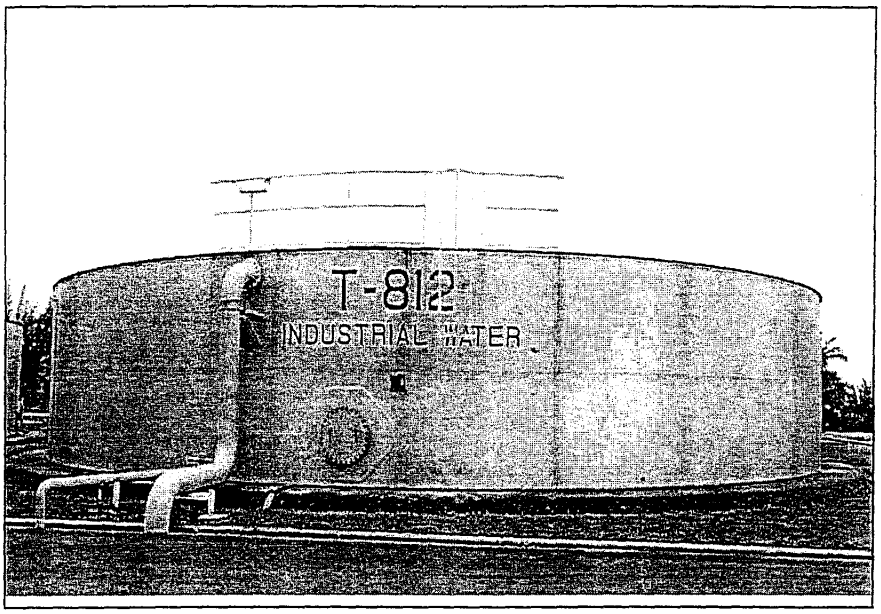
Water Recycling

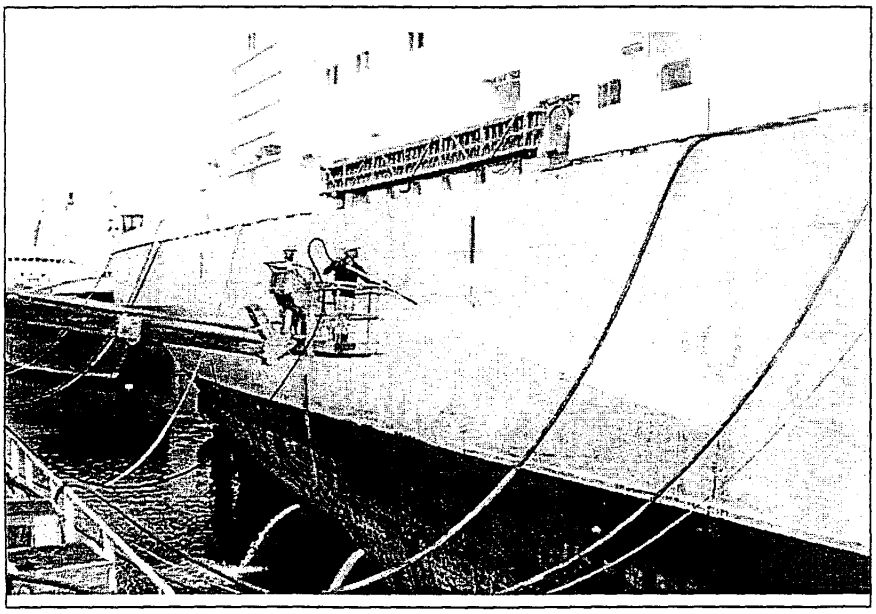
- All application for water supply are submitted to PUB for approval
- Encourage recycling of process water

Water Substitution

- NEWater
- Industrial water
- Seawater




T-812
INDUSTRIAL WATER

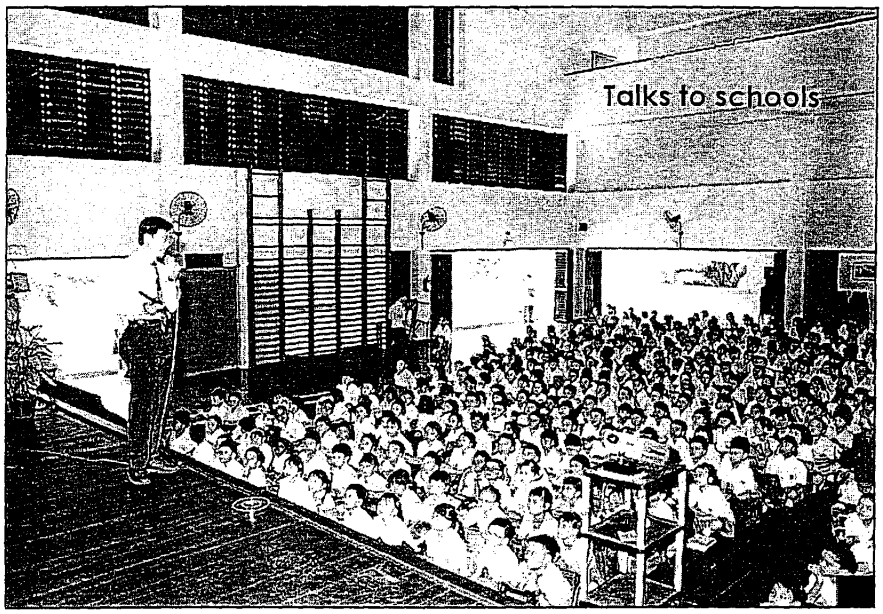


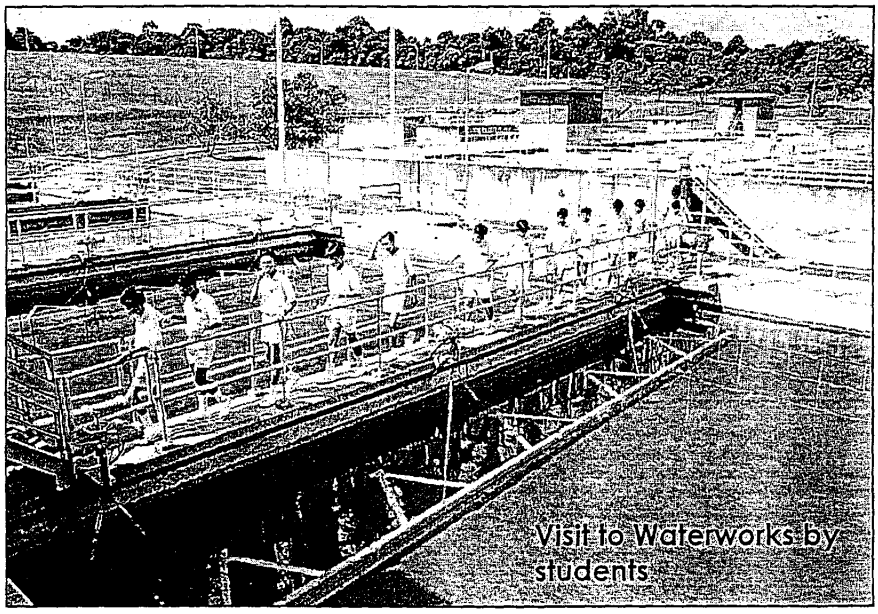
Water Audit

- Market-Oriented Programme
  - Gather Industries' Feedback
  - Implementation of Water Conservation measures
- Large Customers ≥ 5000 m^3/mth
  - Annual Visits
- Customers: 1000 – 5000 m^3/mth
  - Request them to self conduct or engage LP to conduct

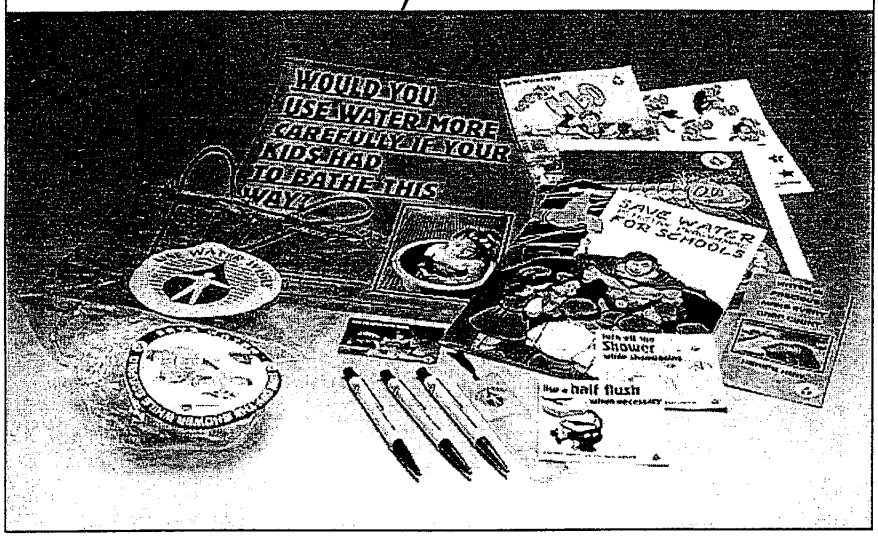
Public Education and Publicity Programme

- Educating Our Young
- Save Water Campaigns and Publicity Programmes
- Working with Grassroots/Institutions


Talks to schools


Visit to Waterworks by students

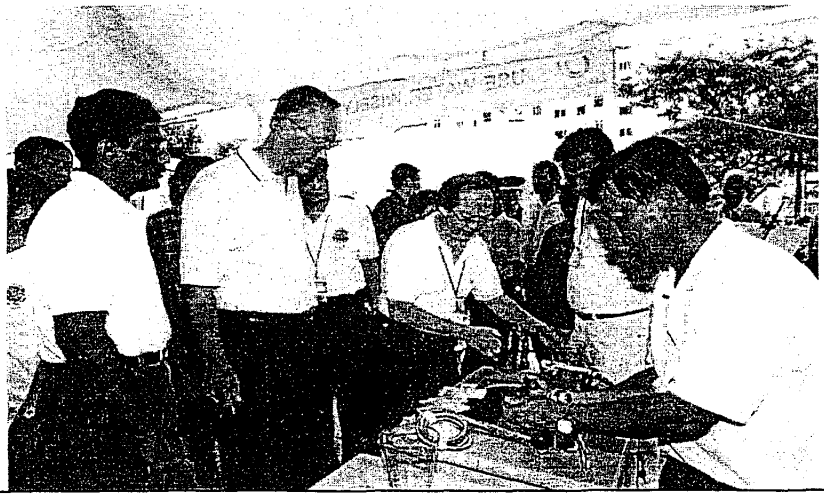
Publicity Materials



' TURN-IT-OFF ' EXERCISE (1998)

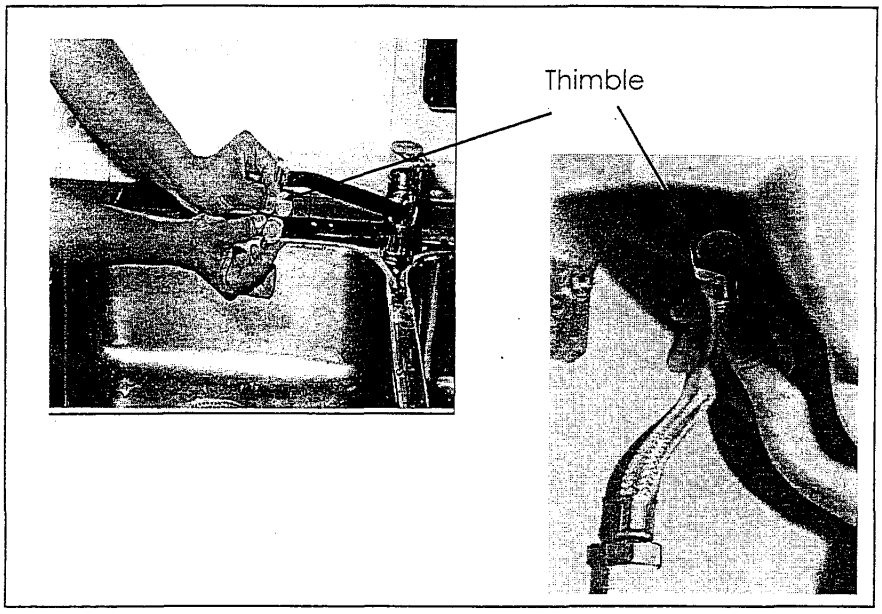
- to remind public that water is a strategic and precious resource
- to let them have a feel of what it would be like should the taps run dry

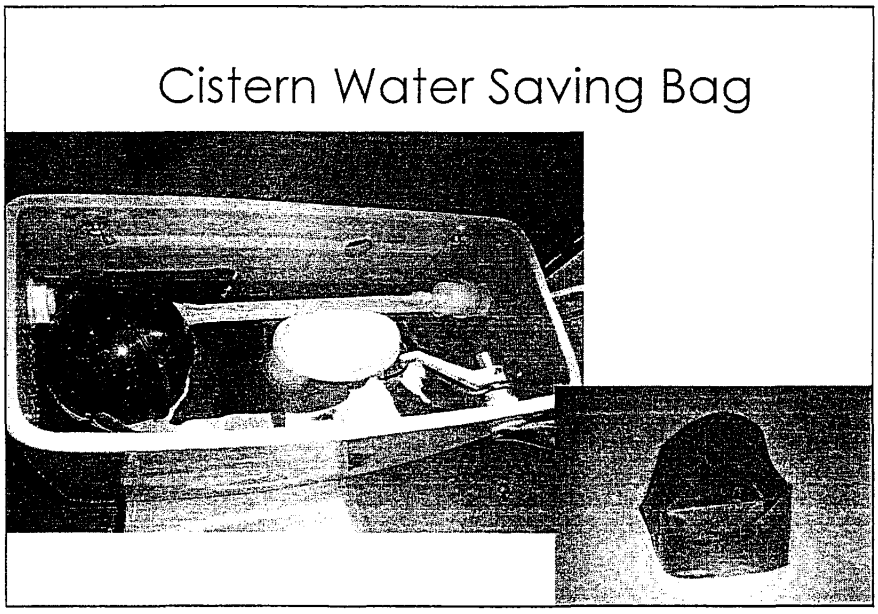
Exhibitions At Constituencies - 2002



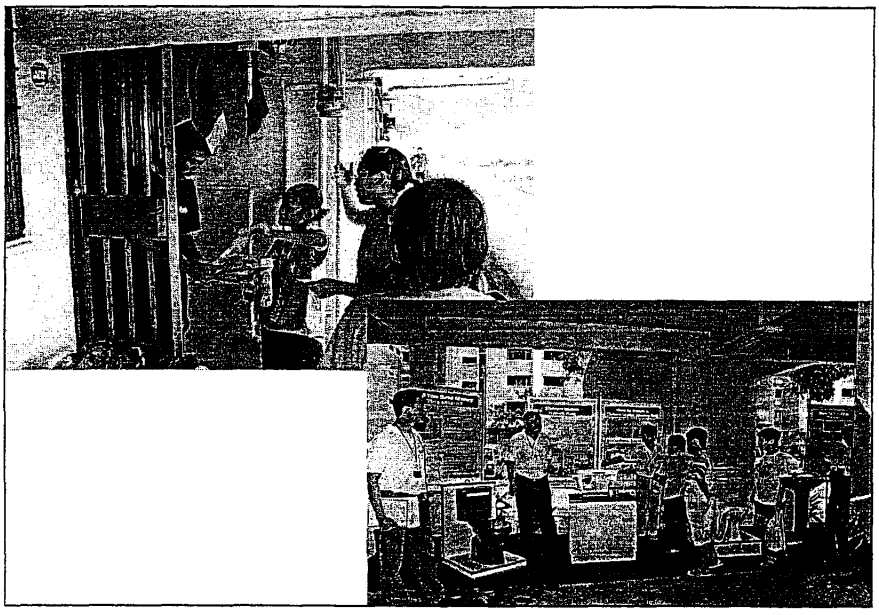
Water Efficient Homes Programme (New Initiative)

- Pilot project on installation of thimbles and cistern water saving bag
- Average household consumption reduced by 5-8 %
- Community-driven programme
- Water Saving Kit
- Mobile Exhibition
- Targeted at 800,000 households island-wide

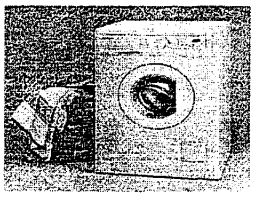

Thimble

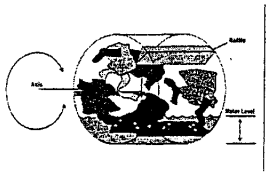

Cistern Water Saving Bag


ENT HOMES PROGRAMME LAUNCHING CEREMONY
23 FEBRUARY 2003

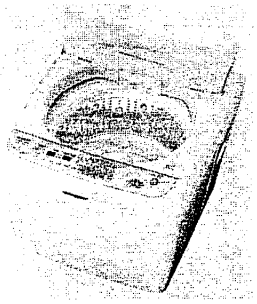


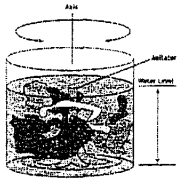
Washing Machines





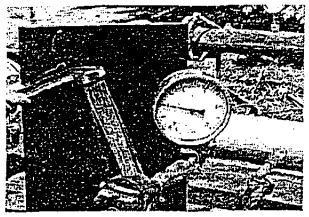
Drum-type



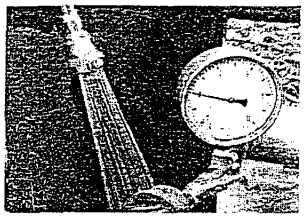


Tub-type

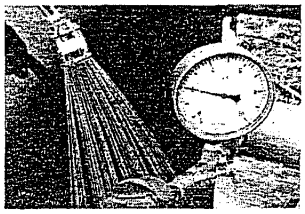
Pressure at 2 bar



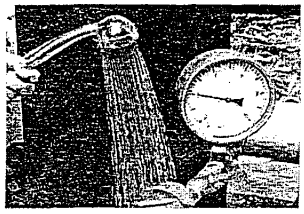
12.0 l/min



8.0 l/min

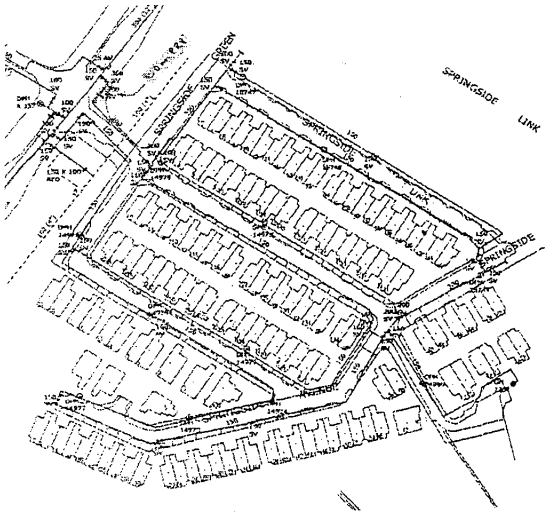


6.0 l/min



6.5 l/min

Pressure Reducing Valve




THANK YOU