Asia-Pacific Water Resources Management Challenges

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KEYNOTE ADDRESS

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Today's conference is about water resource management and productivity. In simple terms, productivity is to derive maximum output with minimum input. This morning, I would like to share with you some of my thoughts on how we can enhance our productivity in water resource management.

GLOBAL WATER CHALLENGE

In my view, the world today is not doing a good enough job in terms of achieving productivity in water resource management. Why do I say so? According to various reports, we are facing a widening global water divide. About 1.1 billion people, or 8 per cent of the world's population, do not have access to sufficient safe drinking water. The situation is going to be worse. By 2015, the number of people without sufficient safe drinking water is expected to increase from 1.1 billion people today to 3 billion, or about 40 percent of the world's population. And the situation will get even worse by 2025 when two thirds of the world's population is expected to face water shortage.

Why do we face water shortage? Even though 73 percent of the world's surface is covered with water, only 3 percent is fresh water. And of this 3 percent of fresh water, two third is not accessible. In other words, from among all the fresh water in this world, only less than 1 percent is accessible to us. Therefore, it is important that we continue to improve our productivity in water resource management so that the world can continue to survive based on this less than 1 percent of fresh water available to us.

This is not a trivial challenge. There is plenty that we have to do to ensure that this 1 percent of fresh water is not polluted, does not become salty and at the same time, is suitable for processing and safe use. This requires forward planning, careful management of water resources, and putting together adequate investment in infrastructure and effective technology. It also requires a new mindset as we move towards sustaining and enhancing productivity.

FIVE CHALLENGES IN WATER RESORCE MANAGEMENT

This morning, I would like to touch on five challenges. These are straightforward challenges. But it is unfortunate that many do not pay enough attention to such obvious ideas.

Challenge 1: Protect Water Resources

The first challenge is to ensure that urbanization and industrialization do not cause water pollution. Some may think that the two are ineffaceable, meaning urbanization must necessarily cause water pollution. In Singapore, we do not believe this should be the case.

To enhance our productivity in water resource management, we must first solve the pollution problem at source. Our industries ensure that water pollution does not take place. Hence, even after undergoing more than 30 years of urbanization and industrialization, Singapore continues to turn more of its limited land area into water catchments. Today, our water catchment covers 50 percent of our total land area. Over time, we hope to enlarge our water catchment even further to cover two-thirds of Singapore's total land area.

Challenge 2: Process Safe Drinking Water in as Cost Eeffective a Manner as Possible

The second challenge is to do a better job in processing the 1 percent of accessible fresh water into safe drinking water. For example, much of a heavy downpour often goes to waste, running into the sea and open areas and retained or processed into safe drinking water. The traditional sedimentation and purification methods may not be efficient and cost effective enough to process these polluted water into safe drinking water. However, with advancement of water purification technology, this is no longer the case. We no longer have to depend only on conventional methods. In fact, we can enhance our productivity of water resource management by using non-conventional water treatment methods.

Advancement in membrane technology is the most significant development in water purification technology. With current membrane technology, we can firstly turn every drop of water into safe drinking water. Secondly, we can turn every drop of used water into a new drop of water again. This is what we called NEWater in Singapore. Over time, we also intend to retain the waters at the Marina Barrage, which currently flows into the sea, and use membrane technology to process them. We can do even more to turn salt water into fresh water as well. For example, Singapore is embarking on its desalination project to be completed by 2005. It is now possible to do what we could not have done 10 to 20 years ago. In short, with advances in membrane technology, we can maximize the potential of every drop of the 1 percent of fresh water that is accessible to us.

Challenge 3: Minimise Wastage in Water Supply System

The third challenge is to minimise wastage in the water supply system or what is commonly known as unaccounted for water (UFW). This is the difference between the amounts of water supply from the water works measured by the meter versus the amount of water accounted for at consumers' end. All over the world, we are doing a bad job in minimizing unaccounted for water. In fact, I was told that in many cities, any old water pipes and many old connections with leakages need to be replaced. Many underground leakages go undetected. As a result, we waste drops and drops of water everyday. Water is precious and we must find ways to account for every drop.

Challenge 4: Water Conservation – Putting Every Drop to Good Use

The fourth challenge pertains to water conservation, which is, putting every drop of water to good use. Many people from all over the world are wasting water in everyday activities. There is indeed a lot more that we can do. Water conservation requires the collective commitment of the community. We need to nurture a culture and environment where members of the public would actually look at every drop of water and ask themselves what more they can do to conserve each drop of water. For example, toilets flushing systems in Singapore used to be poorly designed. I remember that I needed to flush five times in my younger days before a successful flush. A lot of water was wasted in the process. Over the years, PUB and HDB have replaced the old system with one which uses less water. Today, every flush works. If we apply our minds to water conservation, it can be done.

Besides saving water, we also have to find ways to price water to reflect its scarcity. For many years, water consumption in Singapore increased by 3 to 4 percent every year. In 1997, the water tariff and water conservation tax were adjusted. As a result, water consumption increased by less than 1 percent. We will continue to ensure that every effort is made to contain the rise of water consumption.

Challenge 5: Close the Water Loop

The fifth challenge is to close the water loop. Now, we collect and treat used water before we discharge them into the sea to avoid polluting our seas. But it is a waste to release each drop of treated used water into the sea because it will become salty and it would cost us more to desalinate it. Hence, we must think of ways to reclaim treated used water so that we can turn each drop of water into more than one drop. Just imagine, with the same input, if we can change one drop into two drops, we can improve water productivity by 100 percent. This is the kind of water productivity that we should be talking about if we want to solve the global water divide 50 or 100 years from now. This can be done not just by additions to water supply, but more effectively by multiplying the water supply by turning every drop of water into more than one drop.

THE SINGAPORE EXPERIENCE

These five challenges may sound theoretical. Let me now illustrate how Singapore has translated these five challenges into action. Over the years, we have put in place a very stringent water pollution control program. As a result, 50 percent of the land area in Singapore, including the housing estates, is being used as water catchments. This will be enlarged to two thirds of the land area over the next few years. At the same time, with the use of water purification technology, such as membrane technology, we are putting in new water supply through water reclamation and desalination. By 2005, our water supply will come from four national taps - water from water catchments, water from Johor, water from NEWater, and water from the sea. At the same time, to ensure that every drop of wastewater is properly collected, processed and reclaimed in a cost effective manner, we are now implementing the DTSS, Deep Tunnel Sewerage System.

To manage water demand, we also have a community driven program called Water Efficient Homes. This program helps every home in Singapore put in place necessary thimbles to conserve water and become water efficient homes over time. At the same time, PUB will continue to minimize unaccounted for water, which is about 5 percent at present and already one of the lowest in the world. We believe that with this holistic approach, we will be able to close the water loop and keep water consumption in Singapore at 165 liter per capital to ensure that demand is managed while managing supply.

CONCLUSION

In conclusion, the global water divide is a growing challenge. But it is not an insurmountable one so long as we are able to value every drop of water and take advantage of the advances in technology. Every country has its own unique situation and circumstances. The approaches adopted by Singapore may or may not be relevant to other cities and countries. But it is certainly worthwhile to share experiences, expertise and work together.

This is the first time that Singapore is hosting the APO event which focuses on water resource management and green productivity. It is an important development. As I said at the beginning of this seminar, every one of us in the water resource management area is not doing a good enough job in striving for higher productivity. It is about time that we change our mindset and adopt a more action-oriented approach. At the same time, we should pursue new approaches to closing the water loop.

I thank the many distinguished speakers who are here to share their expertise and experiences. I hope all of you will take home some learning points which are relevant to your country. With that, I wish you an enriching and fruitful conference. It is now my pleasure to declare the symposium officially open. Thank you very much.

TRACK 1 : GLOBAL PERSPECTIVE ON WATER RESOURCE MANAGEMENT

THE WATER SCENARIO: PRACTICE AND OPTIMIZATION OF WATER DEMAND AND SUPPLY

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INTRODUCTION

Tampa Bay Water is the largest wholesale water supplier in the State of Florida and serves more than two million residents in the Tampa Bay region through its member governments in Hillsborough, Pasco, and Pinellas Counties (the Tri-County Region), as well as the cities of New Port Richey, St. Petersburg, and Tampa. The mission of Tampa Bay Water is to reliably provide its members with supplies of high-quality water, meeting present and future needs in an environmentally and economically sound manner. This Decision Support System (DSS) will help Tampa Bay Water accomplish this mission.

PROJECT HISTORY

Tampa Bay Water owns 13 groundwater supply systems, which are operated in accordance with permits issued by the Southwest Florida Water Management District (SWFWMD). Eleven of these wellfields are operated as an integrated system, using a set of simulation – optimization models that give priority to the minimization of environmental impacts, while at the same time reliably meeting water supply demands. To further reinforce the plan to operate the regional wellfields as an integrated system, SWFWMD issued a Consolidated Water Use Permit (WUP 2011771.00) on December 15, 1998, to Tampa Bay Water for the 11 wellfields. These wellfields currently supply approximately 60 percent of the Tri-County Region's drinking water.

DEMAND FORECASTING AND WATER SUPPLY DEVELOPMENT

Optimizing demand forecasting and water supply development for Tampa Bay Water integrates both long term planning and operational strategies. The long-term probabilistic demand forecast for Tampa Bay Water was developed based on the statistical analysis of the member government water use billing data. The billing data was aggregated into broader spatial units called traffic analysis zones (TAZs) and related to socioeconomic and other characteristics of the customer base. Weather variables such as temperature and rainfall were also included in developing the sectoral models (single family, multi-family, and non-residential). Other variables used to develop the models included housing density, income, household size, housing units, and reclaimed water use. The probabilistic forecast was generated by using Monte-Carlo simulation techniques against the distributions defined for the variables that make up the individual models.

The models used for supply availability forecasting were empirical in nature, relying primarily on the observed time series data and not on simulations of the underlying mechanics (i.e., stream flows, diversions, permit conditions, weather, etc.). The historical data for the Enhanced Surface Water System (ESWS) was generated based on the Southwest Florida Water Management District's withdrawal rules from surface water bodies, inclusion of the regional reservoir, and the 66 MGD potable water treatment plant owned by Tampa Bay Water.

The probabilistic demand forecast and the supply availability forecast were combined to determine additional new supplies required beyond 2008, when the annual permitted withdrawal limits from the consolidated well fields are reduced from the current 121 MGD to 90 MGD. Short term exceedences of the permitted withdrawals would be met through the use of emergency supplies identified in the Drought Mitigation Plan, so long as the annual average did not exceed permitted wellfield capacities.

INTEGRATED RESOURCE MANAGEMENT AND THE DECISION SUPPORT SYSTEM (DSS)

Two surface water supply facilities, a desalination facility and an additional groundwater sources are being added to the current wellfield management program. As Tampa Bay Water adds multiple, diverse water supplies over the next several years, the Optimized Regional Operation Plan (OROP) must be updated to include these new sources. With the addition of new, diverse water supplies, resource management must shift to include water quality impacts to estuarine and river systems, source water quality concerns, and transmission system water quality considerations. Additionally, water supply management must integrate ecology, engineering, economics, administrative structures and processes, weather prediction, and the impacted community. The approaches needed to manage this diverse supply must be multi-purpose and multi-objective, and recognize that availability and rotation are dynamic processes. It will also be paramount that all Tampa Bay Water functions be brought together in the development of a decision support system that is capable of simultaneously meeting the needs related to managing a more complex water supply system.

DSS PROJECT PURPOSE

A decision support system typically links three components: models/analytical tools, databases and a graphic user interface (GUI). In general, decision support systems grew from a need to evaluate large unstructured problems that involved management judgment and decision-making.

A DSS offers immediate benefits to Tampa Bay Water. Significant contributions will be to:

- Increase efficiency in decision-making and operating new supply sources
- Enhance the management effectiveness of complex water resource systems
- Improve the agency's data collection, storage, and retrieval process
- Facilitate regulatory compliance and reporting
- Provide for repeatable decision-making in a complex and dynamic water supply environment

The "Water Resources DSS Program" project is divided into two phases. Phase I involves an assessment of needs and the overall design of the DSS. Phase II focuses on the implementation of the solutions identified in Phase I. The following tasks were included in Phase I:

1. Assessment of current business and operations systems, processes, and staffing relevant to the DSS
2. Gathering and analysis of business and operations process requirements for the DSS
3. Assessment of the integration of the DSS into future infrastructure and water production changes
4. Development of a proposed integrated DSS solution for Phase II
5. Development of a plan for implementing the DSS

A variety of methods and interactive approaches were used to complete this project. These approaches included user interviews, interactive workshops, and document/database reviews. In addition, information was periodically presented to a cross-functional steering committee for technical review, comment and recommendations. The steering committee was also instrumental in the initial needs definition and identification of agency requirements. A management and oversight committee was also established to help guide the project.

REQUIREMENTS DEFINITION AND DSS FUNCTIONALITY

Needs Assessment

Clearly identifying the decision support needs of multiple departments and individual employees was a key project activity. Two workshops were conducted with the steering committee to identify these needs. The workshops resulted in a generalized listing of user needs, functions, and requirements. These were then assembled into a list of 14 decision support requirements. Participants also identified several criteria which would be used to rank the requirements. The criteria and related weighting to be used for prioritizing the requirements are shown in Exhibit 1.

Exhibit 1 Requirements Evaluation Criteria

Criteria	Evaluation Weighting (on a scale of 0-100)
Provides cost savings through increased efficiency or productivity	82.5
Meets multiple needs/requirements -cross functional	72.5
Enhances credibility and repeatability of decision making	71.5
Improves operational reliability	60.0

In a workshop with the management committee, the 14 requirements were discussed, refined, and scored using the criteria and weights presented in Exhibit 1. The requirements of the DSS, listed in priority order, are shown in Exhibit 2.

Combined Requirements Data Flow Diagram Development

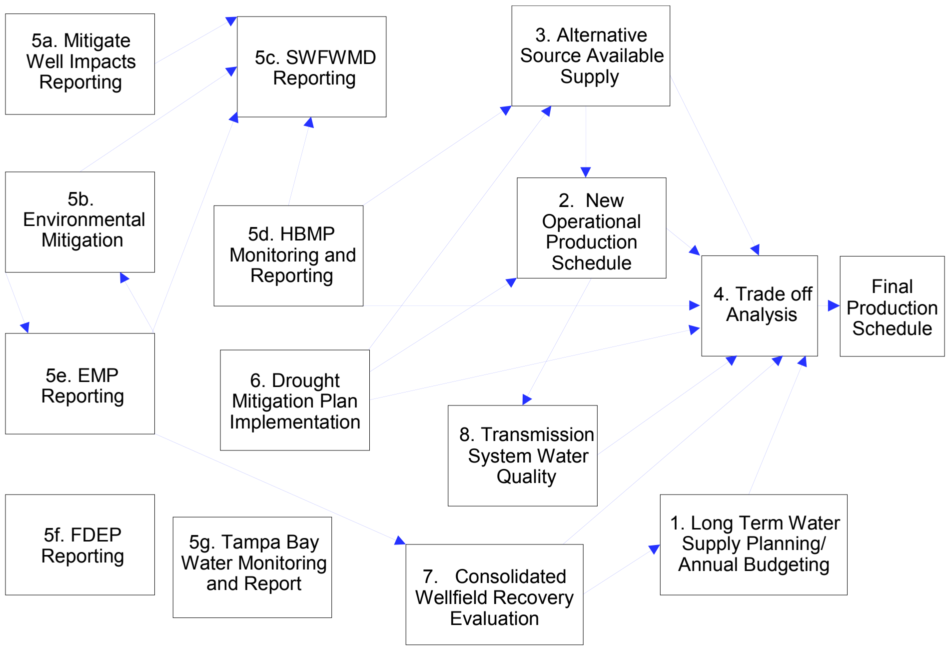
Once the requirements had been identified, CH2M HILL conducted detailed investigations into the operational functions and data needed to support decisions related to each of the 14 requirements.

Exhibit 2 Prioritized Requirements

Requirements (Requirement No.)	Total Weighted Score
1. New Operational Production Schedule (2)	96.9
2. Transmission System Water Quality (8)	96.9
3. Long-Term Water Supply Planning/Annual Budgeting (1)	96.4
4. Alternative Source Available Supply (3)	89.6
5. Operations Trade-off Analysis (4)	88.0
6. Tampa Bay Water Reporting (5g)	87.1
7. Consolidated Wellfield Recovery Evaluation (7)	78.7
8. Drought Mitigation Planning (6)	77.5
9. SWFWMD Reporting (5c)	74.1
10. EMP Reporting (5e)	65.6
11. Mitigation Well Impacts (5a)	43.0
12. Environmental Mitigation Report (5b)	43.0
13. HBMP Reporting, Salinity Changes input into requirement 3 and 4 (5d)	35.9
14. FDEP Reporting (5f)	28.7

A generalized data flow diagram showing the relationships between these fourteen requirements is shown in Exhibit 3.

Exhibit 3 Requirements Relationship Diagram



In conjunction with the existing system reviews, both existing and future DSS data requirements were identified and charted. These were documented and reviewed with users during a workshop.

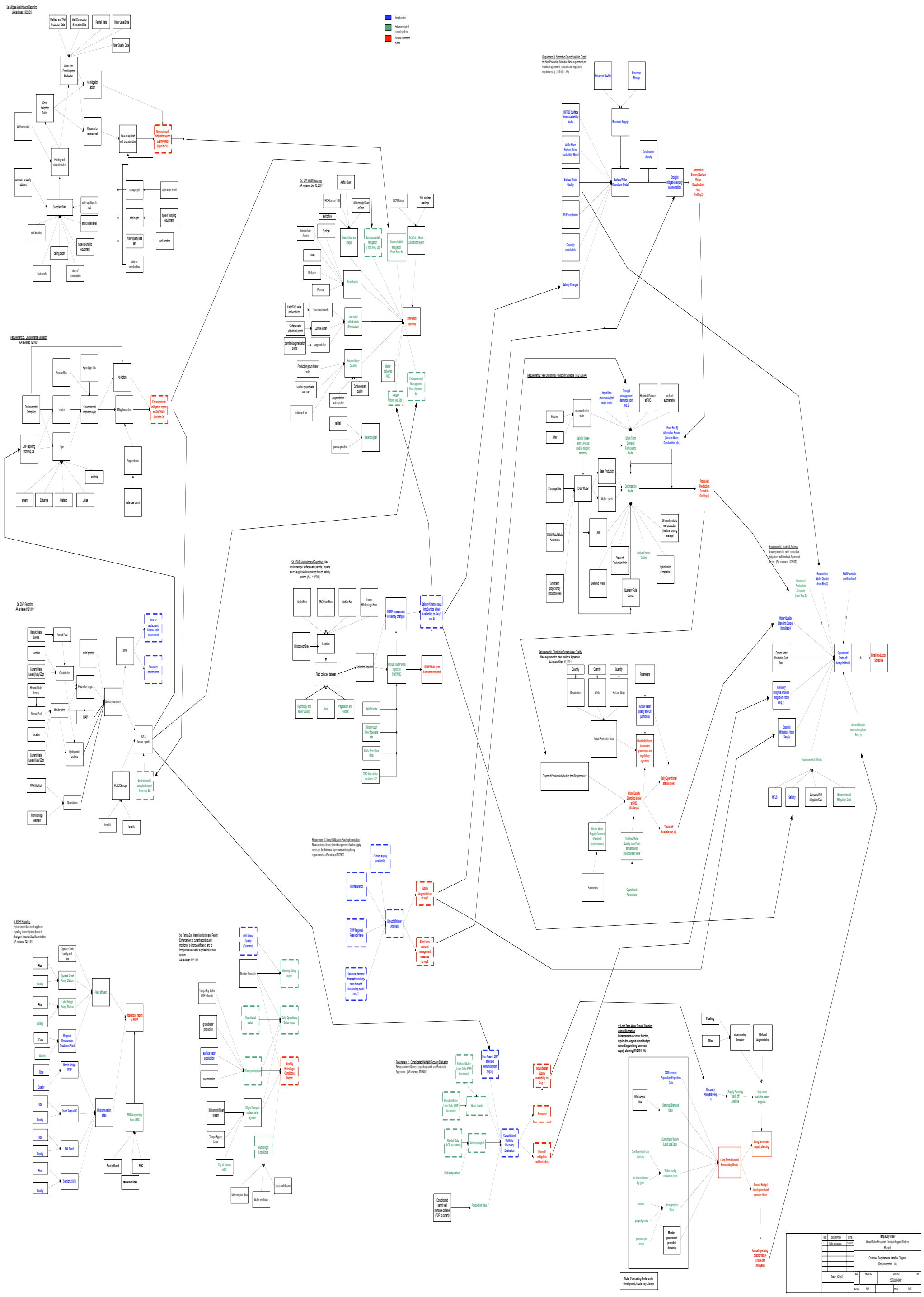
Individual data flowcharts and data sets were compiled. The requirements identify various functions, models, data sets and data elements of existing data and new/enhanced data. These are working documents that will continue to evolve during the life of the Decision Support System.

When considered comprehensively, the data flow diagrams for each of the requirements can be compiled into an overall DSS data flow chart. Exhibit 4 shows the data inputs required for each requirement, as well as the relationship of one requirement to another.

Data Collection and Database Recommendations

Tampa Bay Water requires that data of various types, from a variety of sources and locations, be collected and made available to support the agency's water supply mandate, support the DSS system, facilitate Regulatory Report production, and facilitate monitoring and control of the supply facilities under Tampa Bay Water's management. Data collection currently occurs in the following manner: real-time (SCADA), manually using both recording equipment and staff readings, and obtained from an outside agency or third party.

Exhibit 4 Data Flow Diagram



In addition to SCADA and external data collection efforts, Tampa Bay Water has monitoring equipment at more than 1,700 sites. These sites collect water level data at production wells, a variety of ecological data, and hydrologic data. The 1,700 sites are distributed as follows:

- 208 well field sites
- 764 ecological sites
- 695 hydrologic sites

The nature of the data collected at the remaining 33 sites is unknown. Data from these sites is collected in one of two ways: either by data loggers, which continuously record data, and or by staff readings. In either case, Tampa Bay Water employees must visit these sites to download or record the appropriate information.

SCADA DATA COLLECTION

All real-time data collection is conducted through the agency's SCADA system. The SCADA system must meet resource management and operational control needs for the increased amount of data collected, as well as the need for enhanced data timeliness, quality, and collection efficiency. While the existing SCADA system operates satisfactorily, it will become obsolescent and will incur increasing maintenance and support costs. In addition, it does not comply with Tampa Bay Water Information Technology (IT) standards, thus making it difficult to support upgrades, changes, and routine and emergency maintenance.

Outside Agency Data

In addition to the manually-collected and SCADA-collected data, a considerable amount of external data is required by users. This data comes from the following external agencies: U.S. Geological Survey (USGS), Southwest Florida Water Management District, National Oceanic and Atmospheric Administration (NOAA), and National Weather Service (NWS). Tampa Bay Water currently has no central repository for storage and maintenance of data gathered by other agencies. Data typically is obtained by staff on either an as-needed or continuous basis.

Much of this data supplements the existing Tampa Bay Water data made available to staff. Several problems have been identified as being related to how Tampa Bay Water collects and stores this data. Issues identified include:

- Duplication of effort since several users require similar data from the same agencies.
- Delays in receiving data from these sources, both in terms of time to respond to the request as well as the requirement that no provisional data be provided by some agencies. This can result in a several month delay in obtaining data.
- Quality control processes are not implemented and manual data entry is sometimes required.

- Data received is typically saved to personal computers, where it is not available to other users.

Time required on the part of the users to request, manipulate, analyze and store the data can be considerable.

Proposed DSS Database

The proposed DSS Database must address several issues to be effective. These issues include:

- Consolidating existing stand-alone databases (primarily on personal computers) into an "enterprise" DSS database.
- Implementing Time Series Functionality through the DSS Manager to provide the necessary temporal data manipulations and transformations.
- Integrating the database with a DSS Manager for query and reporting, model run construction, model run scheduling, establishing and maintaining a metadata repository, and interfacing with individual model and databases. Each of these issues is discussed in the following sections.

The proposed database will provide a common structure for data collection, manipulation, and retrieval to support Tampa Bay Water staff, contractors, regulators, member governments, consultants, and models in the Tampa Bay Water decision making processes. The database is central to the overall DSS solution and should be a consolidated and optimized repository that supports the data needs of all DSS components.

The DSS data requirements include storage, retrieval, and archiving support of model, data analysis, and reporting applications. Data sources include legacy data from existing systems, SCADA data, model output, manually-collected data, and data received from external organizations. The database will contain links to other databases and/or applications which exist outside the DSS and are maintained/enhanced by other groups within the Agency. QA/QC would be performed by the applications and/or processes providing data to the database.

Data Accessibility and User Retrieval (DSS Manager)

User Interface

The purpose of the DSS Manager is to provide user access to the subordinate subsystems of the DSS. The DSS Manager Graphical User Interface (GUI) is the primary interface that users of the DSS will utilize to create queries and reports; create, schedule, and manage model scenarios; and analyze data on an ad hoc basis.

Functional elements of the DSS Manager include:

- Query Development
    - Query to allow Ad Hoc data analysis to be performed by users
        - Performs queries of Transactional (OLTP) and Multidimensional (OLAP) databases
        - Predefined
        - Ad Hoc

- Reporting
    - Predefined
    - Static (as of date) and Dynamic reports
    - Ad Hoc
- Model Scenario Construction
    - Constructs a scenario for a particular model run
        - Perform query and return data
        - Verify data
        - Format in preprocessor
        - Set model parameters
        - Model
        - Postprocess data
        - Post data
- Model Run Scheduler and Metadata Repository
    - Schedule or immediately launch previously constructed model run scenario
    - Manage metadata (data about the data) that describes each scenario for each model
    - Use Scheduler to manage computing resources
- Individual Model I/O and Messaging
    - Allows model or model components to talk to the DSS Manager and vice versa
    - Allows the DSS Manager to talk to the Databases
    - Use messaging (i.e., semaphore, auto signaling) to send run completion information to the DSS Manager

Time Series Functionality

The purpose of time series functionality for the database is to provide Tampa Bay Water with the ability to produce time series data, reports, and electronic datasets to meet several of the 14 requirements. Currently, the SQL database does not allow users to conduct mathematical manipulations of time series data directly from the database. Users must download data into other applications (e.g., Excel) to conduct these manipulations. Time series functionality is provided by Oracle 8i (8.1.6) Time Series Option for the OROP. Other time series manipulations are performed in individual spreadsheets; because individual spreadsheets are not always identical, occasionally results from one spreadsheet may not match those from another.

Models and Analytical Tools

Modeling and analytical tools are important components of the DSS and are critical to its success. These models and tools are used to analyze data and provide decision support in the operation of Tampa Bay Water's regional water supply system. They provide the ability to respond to water supply and demand changes and to predict the impact of those changes so that system operations can be forward-looking and not just reactionary. Tampa Bay Water currently uses a number of models, and additional models are in various phases of evaluation or development to meet the diverse needs of the agency.

Models and analytical tools in three distinct categories were identified as necessary for development of a comprehensive DSS: existing models and analytical tools; models under development; and enhancements to OROP. Existing models and models under developed were reviewed in the development of the implementation plan and needed changes were identified. These models included the OROP, Integrated Hydraulic Model (IHM) and the wellfield decision/optimization model, and short-term and long-term demand forecasting models. New models necessary for the DSS also were identified, and are discussed in the following subsection.

New Models and Analytical Tools

As Tampa Bay Water adds additional water resources to its supply mix, additional models and analytical tools must be developed. The dynamic nature of DSS development and the changing needs of Tampa Bay Water have necessitated a modified list of models and analytical tools since the project began. The following new models, each of which can be linked to one of the agency requirements, include:

- Hillsborough River and Tampa Bypass Canal Flow Generation and Hydraulic Routing Model Development
- Alafia River Statistical Flow Generation Model Development
- Water Supply Operations Model Development
- Transmission System Water Quality Model Evaluation
- Reservoir Water Quality Model Evaluation
- Trade-off Analysis Development

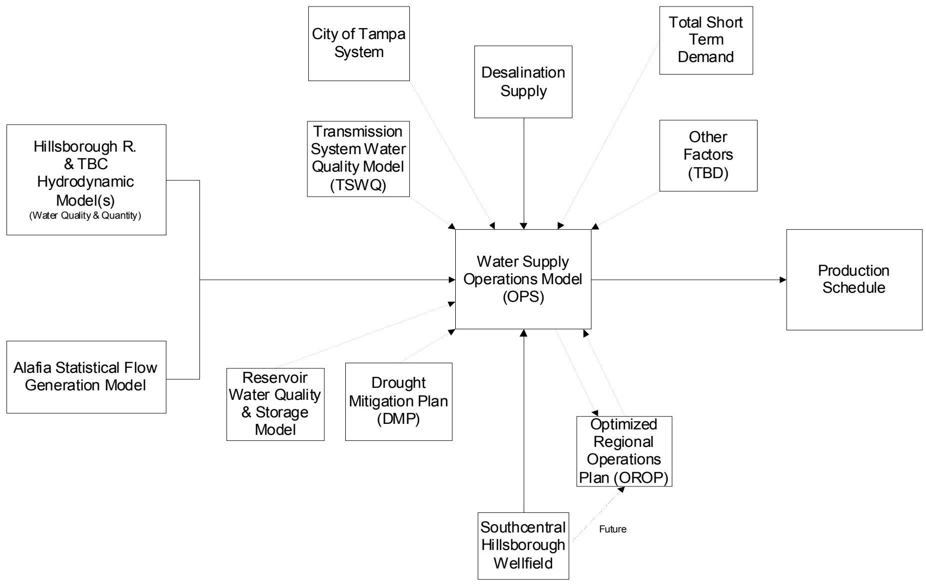
Each of these models must either be developed or reviewed for appropriateness for operation of the complex water resource system. For those models being developed, the initial effort must focus on the science and engineering to characterize the physical system. Subsequent steps include software development of the VB.net application of the model. VB.net technology is consistent with Tampa Bay Water's Information Technology strategic plan. Upon completion of the existing model evaluation, it will be determined if additional science and engineering are needed to enable the model to perform as an operations tool rather than a planning tool. If additional science and engineering are needed, each model would then undergo the same steps as those models being developed. The integration of these models is depicted in Exhibit 5, "Water Production Scheduling Database Schematic".

DSS Functionality Definition

The final step in completing the Phase I DSS was to define the DSS functionality. The following key DSS development strategies were selected as a result of detailed investigations and evaluations conducted as part of the process of defining DSS functionality:

- Develop additional analytical tools as needed (e.g., hydrodynamic flow models)
- Develop an enterprise-wide DSS database

Exhibit 5 Water Production Scheduling Database Schematic



- Establish a standard approach to be used for time series functionality (standard statistical method to develop and analyze time series data , e.g., water levels)
- Convert OROP to a Windows environment
- Develop and implement a DSS manager application

Implement identified SCADA improvements to meet resource management and operational control needs for the increased amount of data collected, as well as the need for enhanced data timeliness, quality, and collection efficiency.

Five sequences of work (identified as A, B, C, D, and E projects) have been identified for Phase II implementation to provide for rapid implementation of the highest priority work and because, in some cases, preliminary designs and evaluations must be accomplished before succeeding activities can begin. In addition, a DSS Program Management and Quality Assurance/Quality Control task is included to provide overall integration of individual elements as the DSS is developed and to establish cross-project standards and quality assurance procedures using the Rational Unified Process for software development. Four sequences of work (Project Sequences A through D) pertain directly to the implementation of the DSS. Sequence E pertains specifically to recommended SCADA improvements discussed in more detail in the *Tampa Bay Water SCADA Improvements Implementation Plan*, reported separately.

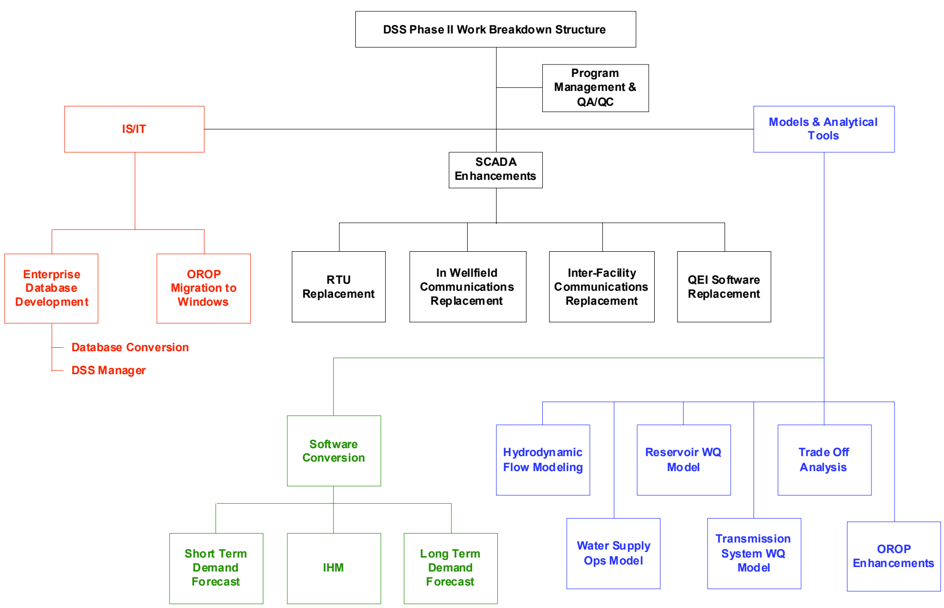
IMPLEMENTATION PLAN

Phase II projects and tasks have been defined to facilitate DSS implementation. DSS implementation will require execution of a variety of projects and tasks as shown in the Exhibit 6 "Phase II Work Breakdown Structure". Projects have been grouped into five priorities to accommodate needs, logical sequencing and dependencies between individual projects, and agency funding priorities:

Sequence A: Commenced June 2002

- DSS Program Management and QA/QC Implementation
- Conversion of the existing database into a structure suitable for long term implementation of the OROP and DSS, including conversion and integration into the DSS of certain stand-alone applications currently run on individual personal computers (Software development)
- Development and implementation of a graphic user interface to provide capability for Tampa Bay Water staff to manage the execution of the OROP, decision support analysis and associated models, and to report and store the results (Software development)
- Conversion of the existing Unix/ORACLE OROP software to Windows-based system (Software conversion)
- Development of the Hillsborough River and Tampa Bypass Canal Hydrodynamic Flow Models – Phase I (Science and Engineering evaluation)
- Evaluation of a Transmission Water Quality Model for operational use
- Evaluation of the Reservoir Water Quality Model for operational use

Exhibit 6 DSS Phase II Work Breakdown Structure



Sequence B: Expected to Commence about October 2002

- Trade-Off Analysis Prototype

- Water Supply Operations Model
- Drought Mitigation Plan rainfall deficit model (Software development)
- OROP Enhancements
- Short-term water level predictions using artificial neural networks (ANN) (Developing science)
- Stochastic Optimization (Research and evaluation)
- DSS Program Management

Sequence C: Expected to Commence about October 2003

- Hydrodynamic Flow Models of the Hillsborough River and Tampa Bypass Canal– Phase II (Software development)
- Transmission Water Quality Model software development
- Reservoir Water Quality Model software development
- OROP Enhancements
- Prediction of Salinity changes software development
- Stochastic Optimization software development
- ANN software development
- DSS Program Management

Sequence D: Expected to Commence about October 2004

- Transmission System Water Quality Model Programming or upgrades
- Reservoir Water Quality Model Programming or upgrades
- Model Software Program Conversions (VB 6 to VB.NET)
- Integrated Hydrologic Model (IHM)
- Long-Term Demand Forecast
- Short-Term Demand Forecast
- Aquatrack model
- DSS Program Management

Sequence E: SCADA Projects

- Phase E.I – RTU Replacement – October 2003
- Phase E.II – In–Wellfield Communications Replacement (Copper cable) – October 2003 - 2004
- Phase E.III – Inter-facility Communications Replacement (Home-Run Copper and Leased Line) – October 2003 - 2005
- Phase E.IV – QEI software upgrade/replacement – October 2005

PHASE II BUDGETARY COST

The costs for the DSS are comprised of many elements integrated into the overall DSS solution. The budgetary estimates for the various projects that are included in the DSS are summarized in Exhibit 7. These budgetary projections have varying degrees of accuracy, and should be considered preliminary cost opinions. As the project is executing through the various phases described previously, cost estimates will be refined.

Exhibit 7 Budget Projections by Priority Group and Fiscal Year

Projects	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	Total
Priority A	$750,000	$2,694,776	$-	$-	$-	$-	$3,444,776
Priority B	$-	$475,000	$-	$-	$-	$-	$475,000
Priority C	$-	$-	$1,750,000	$-	$-	$-	$1,750,000
Priority D	$-	$-	$-	$1,070,000	$-	$-	$1,070,000
Priority E	$-	$340,000	$2,245,000	$2,565,000	$1,840,000	$1,840,000	$8,830,000
Total	**$750,000**	**$3,509,776**	**$3,995,000**	**$3,635,000**	**$1,840,000**	**$1,840,000**	**$15,569,776**

The total estimated program cost of $15,500,000 (including SCADA improvements) to operate and manage new water supplies is approximately one percent of the infrastructure investment Tampa Bay Water has committed.

Funding Options

Because of the magnitude of this program, development of a comprehensive funding strategy will be essential. Such a strategy will include, but may not be limited to:

- Specifying which projects can be funded from Tampa Bay Water operating budgets, which are allocated on a fiscal year basis.
- Defining which projects qualify for funding through the sale of bonds, the estimated dollar amount required and timing in which bond funds need to be made available
- Identifying possible outside agencies that fund such programs through grants, cooperative, projects, direct appropriations or other means

Development and implementation of this strategy and efforts to secure outside funds will be ongoing processes, and will evolve as various phases of implementation take place.

STRATEGIC WATER RESOURCE MANAGEMENT AND WATER RESOURCE ASSESSMENT

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ABSTRACT

Water resource development is one of the key sectors for sustainable development as well as for the removal of poverty and hunger, specifically in the developing countries. The paper initially provides a brief outline of the international events that took place and the outcomes received from them, related to water resources. Later it elaborates on the significant challenges faced by the international community. The data related to water resource assessment, specifically for the APO member countries are provided. Then, the strategic approaches that are derived after long deliberations are mentioned. At the end, the activities that could be undertaken are suggested.

> "Water is likely to become a growing source of tension and fierce competition between nations if present trend continues, but it can also be a catalyst for co-operation"
>
> ……………………………………………………….UNITED NATIONS

INTRODUCTION

The issues related to Water Resource are becoming more and more severe. It can be observed that in the last decade, even on the international agenda, the Water Resource Management is getting more and more prominence. If we reviewed the international events in last 50 years it can be noticed that since the Earth Summit at Rio de Janeiro in 1992, the international community has awakened regarding the importance and threats related to Water Resources.

Water is elixir of life. Not only the humanity but also the existence of the whole ecosystem is dependant on availability of Water Resource. Out of the total water resources available on the globe, the Freshwater resources are finite and limited. Of the total water resource available hardly 0.3% of it is fresh water. As the human population is growing day by day, the per capita availability of water is decreasing. Already, in about 45 countries spread across the world, the fresh water availability has gone below the minimum per capita requirement of 1700 cubic meter per year. The finite freshwater resource and increasing population would further decrease the per capita availability that may lead to very challenging situations in times to come. We may witness the conflicts and tensions across the globe, if we do not act wisely. It is said that the prevention is better than the cure. It is directly applicable to the water resource. It's high time to act wisely or there is no dough that we would have to face the extremely conflicting situations.

THE MILESTONE: THE GLOBAL PERSPECTIVE

It is not that the international community has not taken cognizance of the worsening and degrading water resource situation across the continents. But one can say that the initiatives are not very old but are relatively fresh. If we examine the history, we could observe that it is only the last decade that the attention has been given to the issues related to water resources, prominently.

At international level, many events, conventions and summits were conducted that discussed the water related issues. Let us see some of them so that we would get a clear picture of what has happened around the world.

Conferences, Forums and Summits

The United Nations Conference on the Human Environment that was conducted at Stockholm in 1972 was the first common effort where issues related to development were discussed on the international platform. There was no separate reference to water resources but it was part of the environmental issues. In 1977, an United Nations Conference on Water was conducted at Mar del Plata where the issues related to Assessment of water resources, water use and efficient water use were discussed at length. That time hardly there was any authentic data available at international level. Nations use to neglect any processing and compilation of basic data related to water resources.

United Nations took a giant step and declared the decade 1981-90 as International Drinking Water and Sanitation decade. The goal of the decade was that, by end of 1990, all people should possess an adequate water supply and satisfactory means of excrete and sewage disposal. It was really an over ambitious goal. Unsurprisingly, the goals remained unfulfilled. The world community was far behind the declared goals.

In 1992 two international events took place that really changed the status of water resource development fundamentally. The first conference was conducted at Dublin, which was named as 'International Conference on Water and Environment'. Many issues like economic value of water, Women and Poverty issues, resolving conflicts, awareness etc. were discussed. The four fundamental principles were drawn out. This Dublin conference laid down the foundation stone for the conceptual principles of water resource development. In the same year, 1992, The United Nations Conference on Environment and Development, also popularly called as Earth Summit, took place at Rio de Janeiro. This conference was a major remarkable effort in establishing new and global partnerships. A complete road map for the 21st century was designed and documented in the report called 'Agenda 21'. In this agenda, the 18th chapter has elaborated outline of challenges related to water resources. This first Earth Summit could be described as the spectacular benchmark in the history of World Water Development.

As a fall out of the road map set out by the earth summit, half a dozen international conferences took place, successively. The first World Water Forum (WWF) was conducted at Marrakech, Morocco, Africa in 1997. The Second WWF took place at The Hague, Netherlands, Europe in year2000 where as the Third WWF was held this year at Kyoto, Japan. Also, the International Conference on Freshwater was conducted at Bonn. This conference discussed the vital issues like Water Governance, mobilizing financial resources, capacity building and sharing of knowledge. The Ministerial Declaration ratified by almost all the nations stated that combating poverty is the main challenge for achieving equitable and sustainable development, and water plays a vital role in relation to human health, livelihood, economic growth as well as sustaining ecosystems'. Last year the second earth summit was organized at Johannesburg, South Africa. The theme of this 'World Summit of Sustainable Development (WSSD) was WEHAB, where the 'W' stands for Water. Since the first summit at Rio, hardly any significant development took place around the globe. So, in the second World Summit, the major achievement was that the Plan of Implementation was prepared where the Heads of States committed time frame and financial resources to fulfill the Millennium Development Goals. The water issues took a center stage this year, when the United Nation declared the year 2003 as 'International Year of Freshwater; It expressed concern that this year could play a vital role in generating action needed - not only by the governments but by the civil societies, communities, the business sector and individuals all over the world.

These conferences and summits and international deliberations created a lot of database for the Water Resource Development and Management. Many important issues were identified, strategies defined, conflict areas located and challenges put forth. Let us take a consolidated review of all these efforts.

THE SIGNIFICANT CHALLENGES

When we are thinking of Sustainable Development, there are many issues that need to be considered. The issues of poverty, food security, environmental sustainability, water security, etc. are all important from different perspectives. The world community consolidated many of the issues and challenges concerned into the Millennium Development Declaration in the special Millennium Session of the United Nations General Assembly conducted in year 2000. The Heads of the States of the member countries of the United Nations participated in the session, which discussed the issues related to Sustainable Development for the 21st century. The goals were set and the specific targets were defined.

One of the most important targets of the Millennium Development Goals, set for the year 2015, states that, 'We resolve further to halve, by the year 2015, the proportion of the world's people whose income is less than one dollar a day and the proportion of people who suffer from hunger and, by the same date, to halve the proportion of people who are unable to reach or to afford safe drinking water'.

This resolution explicitly expresses the link between the poverty, hunger and water security. This link is significant in policy terms, as it defines for the international community, the overriding policy priority for water resource management.

Numbers of international conferences and summits have now explicitly defined global challenges that are related to water resource development and management. Initially, in the past, there was a tendency to regard water problems as being local or regional in nature. But now, there is a growing recognition that the increasingly widespread occurrence of water related challenges has now identified water as a global crisis. Water resource challenges have global stresses and water is considered a key resource for sustainable development.

The significant challenges related to water resource are explained in brief.

1. **Meeting the Basic Needs:** It is recognized at international platforms that access to safe and sufficient water and sanitation are basic human needs. Yet, more than a billion populations do not get safe drinking water where as more than two billion populations is not provided with sanitation facility.
2. **Securing the Food Supply:** This aspect refers to the Food Security across the globe. Particularly, the poor and vulnerable people should be secured with the food. More efficient mobilization and use of water and more equitable allocation of water for food production should be achieved. Considering $1 a day consumption poverty line, in 1999 there were 490 million people living in extreme poverty in South Asia, 260 million in East Asia and 300 million in Sub - Saharan Africa.
3. **Protecting Ecosystem:** The water resource management should be sustainable and should assure integrity of ecosystem. Poor rural households often derive a large share of their incomes from natural resources. Thus poor people are more affected by natural resource degradation because of their limited assets and their greater dependency on common property resources for their livelihood.
4. **Managing Risks:** Society should be protected from floods, droughts, pollution and other water related hazards. Resource mismanagement and environmental degradation increases the frequency and impact of natural hazards. Poor people often live in ecological fragile areas, making them vulnerable to environmental shocks and stresses.
5. **Sharing Water Resources:** Should promote peaceful cooperation and developing synergies between different uses of water at all levels. Whenever possible within the boundary or in case of boundary or Trans-boundary water resources between concerns states, cooperation should be obtained through sustainable river basin management.
6. **Valuing Water:** Water should be managed in such a way that its economical, social, environmental, and cultural values should be reflected while pricing the water services. One should not miss out the equity aspect and the poor and vulnerable people.
7. **Governing Water Wisely:** Should include good water governance so that the involvement of the public and the interests of all stakeholders are included in the management of water resource.
8. **Water and cities:** One should acknowledge that the urban areas are increasing. The human settlement and economic activities of the societies are increasing day by day. Water management for urban areas is also one of the major issues.
9. **Water and Industry:** The industry needs should also be focused. The water quality issues should be properly responded. The needs of different sectors for water use should be honored.
10. **Water and Energy:** It is well recognized that water is vital for all forms of energy production. There is a need to ensure that the energy requirements are met in sustainable manner.

11. **Ensuring the Knowledge Base:** It is well understood that good water policies and management of water resources are dependent upon the quality of knowledge base available to the decision makers.

These are the significant challenges faced by the international community across the globe. There are many more challenges that are not mentioned here. The challenges need to be overcome. Systematic approaches could lead to the solution of the problems. Before going into the details of the strategies for implementation, let us see the status of the Water Resource within the countries. Here, as our priority area is the Asian continent, the factual status of water resource development and management for the APO member countries is worked out. After studying the status quo of water resources of these countries, later the strategic approaches could be worked out.

WATER RESOURCE ASSESSMENT

Since decades, the countries over world were divided into different themes or different philosophies, e.g. the capitalist and socialistic countries, the developed and developing countries, the poor countries and rich countries, etc. Now, the new definition has been added to these different characteristics that defines the status of the countries according to 'Water Index'. The index defines the status of each country and distributes them into Water Rich Country and Water Poor Country. As we are more concerned over the Water Resources, this index would be very important for us.

Recently, this year, the 23 agencies of United Nations and some International Institutions, which are working in some way or the other related to water resources, jointly published the First World Water Development Report as a part of World Water Assessment Program. This exclusive report has formed the basis for the informed discussions.

The 576-page report elaborately details out the status quo of the water resources of all the 182 countries in the world. The data related to fresh water resources, resource challenges and management challenges, some pilot case studies and probable path finding solutions are documented in the report. Water resources of each country are mentioned in the report, which takes into account the Groundwater Produced Internally; Surface Water Produced Internally and Total Internal Renewable Water Resources along with external waters. It also takes into account the Population as in the year 2000 and the Per Capita Availability of Water per year. As many rivers have trans-boundary basins, the index also takes into account the dependency ratio of water resources. It provides the data that how much percentage of renewable water resources of the country are dependent on water from across the borders. It is observed that the shortages of resources and inequitable sharing of resources may get transformed into the conflicting situation; the trans-boundary distribution of river basins presents the potential areas of conflicts over the sharing of water resources within nations.

For the APO member countries, the status of water resources is as follows,

Table 1 Freshwater Availability

Sr. No.	Name of the Country	Global Country Rank (Water Index)	Total Renewable Water Resource (km^3/year)	Water Resources Total Renewable (m^3/capita year)
1	**Bangladesh**	76	1210	8809
2	**Taiwan**	111	67	3021
3	**Fiji**	32	28	35074
4	**Hong Kong**	-	-	-
5	**India**	133	1896	1880
6	**Indonesia**	58	2838	13381
7	**Iran**	131	137	1955
8	**Japan**	106	430	3383
9	**Korea**	146	69	1491
10	**Laos**	18	333	63184
11	**Malaysia**	37	580	26105
12	**Mongolia**	56	34	13739
13	**Nepal**	74	210	9122
14	**Pakistan**	114	418	2961
15	**Philippines**	86	479	6332
16	**Singapore**	171	0.6	149
17	**Sri Lanka**	122	50	2642
18	**Thailand**	85	409	6527
19	**Viet Nam**	62	891	11406

Table 2 Dependency Ratio

Sr. No.	Name of the Country	Total Renewable Water Resource (km^3/year)	Dependency Ratio (%)
1	**Bangladesh**	1210	91
2	**Taiwan**	67	0
3	**Fiji**	28	0
4	**Hong Kong**	-	-
5	**India**	1896	34
6	**Indonesia**	2838	0
7	**Iran**	137	7
8	**Japan**	430	0
9	**Korea**	69	7
10	**Laos**	333	43
11	**Malaysia**	580	0
12	**Mongolia**	34	0
13	**Nepal**	210	6
14	**Pakistan**	418	41
15	**Philippines**	479	0
16	**Singapore**	0.6	-
17	**Sri Lanka**	50	0
18	**Thailand**	409	49
19	**Viet Nam**	891	59

Table 3 Water for Sanitation and Health

Name of the Country	Total Population (Millions) 2000	Annual Population Growth Rate (%) Up to 2000	Population Using Adequate Sanitation Facilities (%)	Population Using Improved Water Resources (%)
Bangladesh	137.4	2.4	53	97
Taiwan	22.1	-	-	-
Fiji	0.8	1.4	43	47
Hong Kong	6.9	1.8	-	-
India	1008.9	1.9	31	88
Indonesia	212.1	1.8	66	76
Iran	70.3	3.0	81	95
Japan	127.1	0.5	-	-
Korea	46.7	1.1	63	92
Laos	5.3	2.2	46	90
Malaysia	22.2	2.4	-	-
Mongolia	2.5	2.2	30	60
Nepal	23.0	2.2	27	81
Pakistan	141.3	2.8	61	88
Philippines	75.7	2.4	83	87
Singapore	4.0	2.3	100	100
Sri Lanka	18.9	1.3	83	83
Thailand	62.8	1.7	96	80
Viet Nam	78.1	2.0	73	56

An international standard is set that if the water available per capita per year falls below 1700 cum, then the water scarcity situation would arise. If the availability falls below 1000 cum per capita per year, then a very severe scarcity situation could arise. If we observe the data stated above, and project the demographic situation for what would happen after population increases over some decades, then we find that Korea, Singapore, India and Iran may have to face the challenging situation in years to come.

Some countries have sufficient water resources but substantial volume of water is coming from across the borders. The dependency ratio is very high. This may cause the conflicting situations if the understanding regarding the sharing of water between nations is not properly maintained. The member countries India, Pakistan, Laos, Thailand, Viet Nam and Bangladesh fall in this category.

Let us consider some other parameters that would elaborate on Water Security and Sanitation aspects.

If we analyzed the data we would observe that the situation of population using improved water resources for domestic purpose is better than the population using adequate sanitation facility.

The world community has expressed the commitment of reducing to halve the population living without sanitation facility by the year 2015. The commitment was expressed in first Earth Summit at Rio in 1992 and reiterated in 2002 at Johannesburg. Still, unfortunately, very less improvement is seen on this aspect. The APO member countries, Nepal, Mongolia, India, Fiji and Bangladesh have to travel a long distance to achieve the said goals.

Let us analyze the ‘Food Security’ aspect for the APO member countries.

Food Security and Water Security are the main pillars of development. Unless the countries achieve this, no further development would be possible. This is particularly true for the developing countries. The last indicator, the percentage of people under nourished shows that the APO member countries have to design policies and implement them in proper manner so that the basic need of human being would be resolved. The countries Mongolia, Bangladesh, Laos, Philippines, India, Sri Lanka and Thailand need to improve the situation substantially.

Here, very briefly the situation of water resource development of APO countries is analyzed. But an elaborate understanding and the detail analysis of the status would be required. Although all the APO member countries are located adjacent to each other, the water resource situation is very different for different country. Each member country needs a separate attention. The challenges faced by each country are of different nature. A question would come in mind that what should be different ways of handling the situation? How to face the challenges? What are the possible solutions? Let us understand the different flavors of strategic approaches.

Table 4 Water and Food Security

Sr. No.	Name of the Country	Total Area Km^2	Cultivated Land Area $(1,000)^2$	Irrigated Land as % of Culti. Area	Under - Nourished (As % of total population)
1	**Bangladesh**	144000	8332	46	33
2	**Taiwan**	35960	-	-	-
3	**Fiji**	18270	285	1	-
4	**Hong Kong**	-	-	-	-
5	**India**	3287260	169650	34	23
6	**Indonesia**	1904570	30987	16	6
7	**Iran**	1633190	18803	40	5
8	**Japan**	377800	4905	55	-
9	**Korea**	99260	1910	61	0
10	**Laos**	236800	940	18	28
11	**Malaysia**	329750	7605	5	0
12	**Mongolia**	1566500	1322	6	42
13	**Nepal**	147180	2968	38	23
14	**Pakistan**	796100	21970	82	18
15	**Philippines**	300000	10000	16	24
16	**Singapore**	620	1	0	-
17	**Sri Lanka**	65610	1889	34	23
18	**Thailand**	513120	18297	26	21
19	**Viet Nam**	331690	7250	41	19

THE STRATEGIC APPROACHES OF WATER MANAGEMENT

In many international events, the principles of water management were discussed in detail. The results were again and again negotiated so as to generalize the approaches and principles so that they are applicable worldwide.

One of such initial attempt was done at Dublin in the year 1992, just before the Earth Summit. In Dublin, lot of discussion took place and at the end of it four principles, called Dublin Principles were declared. These principles have become the cornerstone of much debate on international approaches to water policies. The principles are as follows:

1. Freshwater is a finite and vulnerable resource, essential to sustain life, development and the environment.
2. Water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels.
3. Women play a central part in the provision, management and safeguarding of water.
4. Water has an economic value in all its competing uses and should be recognized as an economic good.

The focus of these principles, and of the action plan, on issues of environment, gender, governance and sustainability are still relevant. The Chapter 18 of Agenda 21 has further stated that, 'The holistic management of freshwater as a finite and vulnerable resource, and the integration of sectoral water plans and programs within the framework of national economic and social policy, are of paramount importance for action'.

The elaborate discussions laid down some strategic program areas for action at the national and international level. The seven strategic action points are as follows:

1. Integrated Water Resource Development and Management:

Integrated water resource management is based on the perception of water as an integral part of ecosystem, a natural resource and a social and economic good, whose quantity and quality determine the nature of its utilization. Integrated water resource management including the integration of land and water related aspects, should be carried out at the level of the catchment basin or sub basin.

2. Water Resource Assessment:

Water resource assessment, including the identification of potential sources of fresh water supply, comprises the continuing determination of sources, extent, dependability and quality of water resources and of the human activities that affect those resources. Such assessment constitutes the practical basis for their sustainable management and pre requisite for evaluation of possibilities for their development. Many activities like formation of institutional networks, data management systems, data dissemination systems and emphasis on research and development are expected.

3. **Protection of Water Resources, Water Quality and Aquatic Ecosystem:**

   Long-term development of global freshwater requires holistic management of resources and recognition of the interconnectedness of the elements related to freshwater and freshwater quality. Major problems affecting the water quality of rivers and lakes arise, from inadequately treated domestic sewage, inadequate control on the discharge of industrial waste, loss or destruction of catchment areas, deforestation, uncontrolled shifting cultivation and poor agriculture practices. Overall, the aquatic ecosystems are disturbed and freshwater resources are threatened.

4. **Drinking Water Supply and Sanitation:**

   All people, whatever their stage of development and their social and economic conditions, have the right to have access to drinking water in quantity and quality. The safe water supplies and environmental sanitation are vital for protecting the environment, improving health, and alleviating poverty. It is estimated that 80 percent of all diseases and over one third of deaths in developing countries are caused by consumption of contaminated water.

5. **Water and Sustainable Urban Development:**

   Today, nearly half of the world population is living in urban areas. Rapid urban population growth and industrialization are putting severe strains on the water resources and environmental protection capabilities of many cities. Special attention needs to be given to growing effects of urbanization on water demands and usage and to the critical role played by local authorities in managing supply, use and overall treatment of water, particularly in developing countries.

6. **Water for Sustainable Food Production and Rural Development:**

   Sustainability of food production increasingly depends on sound and efficient water use and conservation practices consisting of irrigation development and management, including water management of rain fed areas, livestock water supply, inland fisheries and agro forestry. Achieving food security is on high priority in many countries and agriculture must not only provide food security but should also save water for other uses. The rural population should also have better access to potable water supply and to sanitation services.

7. **Impacts of Climate Change on Water Resources:**

   There is uncertainty with respect to the prediction of climate change at the global level. The uncertainty increases greatly at regional, national and local levels. Higher temperatures and decreased precipitation would lead to decreased water supplies and increased water demands. They might cause deterioration in the quality of freshwater bodies, putting strains on the already fragile balance between supply and demand in many countries.

The principles and approaches explained above are nothing but the guiding directives. Irrespective of any country and challenges, the basic principles and approaches are quite universal. We have to understand them and use them appropriately.

THE WAY AHEAD: CONCLUSIONS

In this brief paper, initially some light is shade on the Global Perspectives in water resources. Some issues of significant challenges in water resources and water resource assessment were discussed later. It can be seen that the international community has been awakened regarding the challenges concerning water resource. The political leadership has expressed commitment over resolving the issues. But, unfortunately there is a lot of gap between the sip and the lip.

Considering the seriousness of the situation, it's high time that we must act. The APO countries should come together and create an environment that would assist in resolving the water crisis situation, ahead of time.

The Millennium Development Goals have set the minimum common agenda for the world community. In reality, the agenda is specifically applicable to the developing countries. Many of the APO member countries are still in the development stage. Many people are deprived of the basic minimum necessities of life. The food security and water security is still an unresolved problem.

Asia Productivity Organization can take up some key strategic activities that would be very helpful to APO member countries. Some of the activities could be as,

a. **Setting the Platform for Continuous Monitoring:** APO can set a platform for continuous monitoring of the development process, specifically relevant to Millennium Development Goals. APO not only should monitor the process but also contribute in setting the right direction. The platform could be virtual, a well-defined web portal. Critical aspects of each country should be identified that needs to be monitored.

b. **Capacity Building of Stakeholders:** Preparation of Resource Material, Documentation of Success and Failure Stories, Training of Selected Stakeholders, Comparative documentation of progress over Millennium Development Goals, arranging specialized training e.g. Integrated River Basin Management, Application of GIS and Latest technologies, etc.

c. **Water Governance:** Policy Advocacy, Policy Monitoring, Capacity building of Elected Representatives, Multi stakeholder Dialogue.

These are some of the examples but many such action points could be evolved. It is the fact that on the international platforms, the African and South East Asian countries are amongst the least developed countries in the world. It is very appropriate that APO has taken the initiative in finding the solutions to the water problems for the region. Water is one of the key resources for sustainable development as well as for eradication of poverty and hunger. It is said that 'Words make noise and actions speak'. The proper understanding of water resource and immediate implementation of the action program would only lead to more healthy and prosperous life.

REFERENCES

Human Development Report. (2002). "*Deepening Democracy in a fragmented world*", Published for UNDP, Oxford University Press, New Delhi, India.

Review of World Water Resources by Country. (2003). 23 Water Reports, Food and Agriculture Organisation of The United Nations, Rome.

The United Nations Conference on Environment and Development. (1992). "*Earth Summit*' 92" Rio de Janeiro.

The United Nations World Water Development Report. (2003). "Water for People, Water for Life", World Water Assessment Program (WWAP).

Panel Discussion I for Track 1, Part 1

Moderator: • **Joo Hwa Tay,** Nanyang Technological University, Singapore

Panelists: • **Wendy Nero,** CH2M HILL, Tampa, Florida, USA

• **Santosh Gondhalekar,** Gangotree, India

Moderator: Good morning, the format of this panel discussion is more like an open discussion rather than just limited to the presentation material. This morning we are very fortunate to have two presentations from our speakers on different topics: one is more on sort of project basis, and the other one is more on global aspects.

Mr. Santosh mentioned about new terms of water rich and water poor country. I am very glad to hear that, although there are always conflict between India and Pakistan, the water treaty between the two countries is still intact because both countries still honor the treaty; whereas for other countries like Malaysia and Singapore, there are frequent arguments between the two countries on water issues. Until today the problem is not solved and I don't believe it can be solved in the near future.

Some pessimistic scientists even predicted that by the year 2030 if we carry on our current water resources management practices, the 3rd world war will be ignited because of water issues, not other issues. Countries will fight among themselves because of water right, There is only 1% of the earth water accessible to us, the world population is currently stand at 6 billions and half of it is in Asia. The amount of water that is accessible by the Asian population is far below 1%, or even far below 0.5%. This is a very pressing problem.

I'm fortunate enough to gather all the experts in this room to share our experiences and exchange our ideas on this issue. Every country is unique, so I wish you could raise your questions to the two experts here. They may be able to help to solve the problem. Wendy is very humble by saying that she learns something from Singapore as she didn't realize that Singapore has been fighting very hard to survive on water issues for the last 15 years. Currently we still have a lot of water issues to be solved. Minister Lim mentioned about four major water sources, which I think are unique in the world: from the sea, from the heaven, from the surface water and for the used water. In Singapore, we are not tempting into any groundwater sources because of a certain specific reasons. But in the region, majority of the water comes from the ground.

Now, I'd like to invite the experts in this room to ask the first question. Please mention your name and the country where you come from. Thank you.

Question: I am from India and I have a few questions for Ms. Nero. She seems to have a strong confidence in groundwater. She must have studied and done enough assessment on the environmental impacts it might cause. I would like to know what was the most significant environmental impact (of using groundwater) that she has noticed. Ms. Nero also mentioned about drought management in her presentation. In fact, there are many aspects in environmental management plan, particularly in drought management plan. So, what are those aspects, other than water, that should be taken into account when deriving a water management plan? What will be the first action you take for replenishing the groundwater and, have you taken any water harvesting measures for conserving the water?

These are the questions I would like to ask and probably after your answer we can discuss it further. Thanks.

Wendy Nero: I hope I get the question well, first of all. If I don't, please ask me again.

The significant environmental impacts that we saw from groundwater use in South West Florida: - in that particular area, there is a very high level of connectivity between surface water system and the ground aquatic system:- the shallow, intermediate and deep aquifers, so we have very high level of recharge with rainfall. Hence, protecting the watershed, keeping the recharge area open and free from pavement, so that we can have recharge as oppose to run off, is a critical component of replenishing strategies. Understanding the connection between rainfall, recharge, pumpage and drought are really very important.

The significant environmental impact that we saw were primarily lakes and wetland drying up, which create not only environmental impacts but economic impacts. When somebody has waterfront property and a boat or have a finishing camp that the water is essentially gone, that is an economic impact for sure. We saw changes in stream flow in terms of total quantity of stream flow; we saw changes in terms of the water quality parameters. With fewer streams flow into the salt-water interface of the Tampa Bay area, we began to see the salt water profile changing. In that part of the state, we don't get significant groundwater quality change from over pumping, like inducing salt-water flow either laterally or upcoming from underground, but we do get more changes in groundwater quality for the south of the Tampa Bay area. Most of the impacts are on the surface water system:- lakes and wetlands impacts. Significant wetland impacts in terms of speciation, tree fall down, and changes from a wetland to a more upland-kind of habitat were definitely the typical environment impacts we have seen.

Now talk about drought management planning. What do we do beside water? Not quite sure I fully understand the question. I will describe the drought mitigation plan instead.

Up until now, the State of the Florida and the Water Management District have the responsibility for drought management planning. They declare that we react according what they refer to "water shortage". Yet they never link the climatic conditions to actual water supply. In Tampa Bay Water's view, that was considered to be a major gap. It didn't link if you have certain amount of rainfall and therefore we use 10 inches on the running annual average as deviation from normal, we get 52 inches of rainfall of a year, which is about a meter and half. That is a significant deviation because it begins to significantly affect surface water availability. With the current trend towards increasingly dependent on surface water, it made a lot of sense to link rainfall with surface water availability using rainfall as a very simple measure, which is easily understood by public, to trigger or declare different level of water shortage.

We had water shortage alert, water shortage and severe water shortage or water crisis. Those were three levels of severity that we defined in our drought mitigation plans. With each, there will be different kinds of action. At the first level, it was more about public attention, they called (the public) to say: "we are beginning to face water shortage problem, please help us with voluntarily reducing the water use..." Unlike this part of the world, we have very significant demands for landscape watering. Even though we get more than 52 inches rainfall a year, a lot of it either evaporates or runs off and is not available for landscape use, especially in the spring time when we have drought and a lot of grow, a lot of plants needs. So the primary action with drought mitigation plans was to limit water use in the landscape. Again there are economic consequence of that, because it wasn't just residential landscape, it was golf courses, it was commercial property and recreation areas, it was agriculture use, it was nursery and greenhouses, all face curtailment. So it wasn't just residents, it went across many different user classes.

We've identified a couple of alternative sources in emergency, interconnected with different utilities that wouldn't be affected by the surface water availability. We've also identified a short-term or temporary supply from a groundwater source that will only be used for a period time during drought season.

Finally, the management of groundwater recharge and water harvesting. We did so by simply cutting back the pumpage. By the return of normal rainfall, we are beginning to see the recovery. We are now working on project with Tampa Bay Water to statistically measure and demonstrate the relationship between groundwater pumpage reduction, the recovery of surface shallow aquatic system and surface water system. In terms of water harvesting, one of the things we do is capturing in a series. We have a number of offline reservoirs surrounding the Tampa Bay area. The Tampa Bay Project is about developing some above-ground reservoirs. That is one way to capture high water flows as you can never capture all the water and store it in the offline reservoirs for later use. When flows are low, these reservoirs need to be protected. A regulatory measure that the State has now taken on is called "the minimal flows levels", by which all the wetlands, lakes, steams and rivers, as well as groundwater evaluation now have to find ranges of the minimum that they can drop to, but no below, before there are regulatory penalty.

Moderator: Thank you. Groundwater seems to be a very interesting topic. Singapore is no using groundwater for taping, but in the region, at least seventy out of the ninety member countries are using groundwater as one of their water sources. Some countries even have groundwater as their major water sources.

In Asia, traditionally, groundwater is free of charge. If you go to the rural areas where tap water is not accessible, you can see wells everywhere. Nowadays, with the advancement of technology, you may not see the open wells but pumping facilities. People pump water from as deep as 15 meters down from the surface. Such practice comes with a lot of problems. Few countries, including China, are experiencing land subsiding because of over withdrawal. A big island in China - Hainan Island, is a major city where the land is slowly sinking. Not to mention about Bangkok. Bangkok is trying to stop the land subsiding. This is one of the major problems. Salt-water intrusion is another obvious problem, so as pollution. Toxic chemicals or components were found in some groundwater samples. It is quite a common problem in this part of world.

So, I would like to ask the experts in this room: how do you actually manage the groundwater resources? For example, is that any permit being issued in order to use groundwater? A few countries had started using some sort of permits to control groundwater extraction, some even charge US 10 cents for every cubic meter of water withdrew from the ground. Among the APO member countries, is this commonly practiced? This is the first question that I would like to ask our experts. Second, how can we actually control the withdrawal? Wendy mentioned about reducing the 150 million gallons per day withdrawal limit to 90. That is a policy and there are certain strategies. In Asia, do we have this kind of strategy? And, do we have this kind of control? My third question is: how we prevent groundwater from pollution and how we recharge the groundwater reserve? How do we practice these in this part of the world (Asia)? Can I have the opinions from somebody from the floor before I ask Santosh comments on in this issue? Anyone like to share with us his or her experience on groundwater management?

Comment: In India we have a permit system and Environmental Protection Act for the groundwater management, although it is not that effective. But we have the permit system for the groundwater in the Groundwater Board. Mr. Santosh must know about it. That permit system control the groundwater extraction from the individual society and the agencies, hence it has some control on the quality and quantity of groundwater. With regards to the quality of groundwater, the Pollution Control Broad, where I come from, has kept it tight on the quality of the groundwater. In the Central Pollution Control Broad, we have the groundwater quality statistics data, which we publish the data regularly. These data are also available on our website. Based on these groundwater quality data, we derived our management plan. This in turn take care of the quality and quantity aspects of groundwater in each of the state.

I have listened to Ms. Nero's comments on drought management plan. What I am interested in is not the water management aspect. Water management is very important to drought management, but there are other aspects, which are necessary for the management of drought as well, like deforestation, changing of the ground patterns, and things like that. I am interested to know what are the management strategies you have with regards to these aspects?

Moderator: Do you mean the control measures?

Question: No, I mean management strategies for other aspects other than water. Have you understood my question?

Wendy Nero: No, I didn't.

Question: Actually, there should be strategies for different aspects in a drought management plan; water management is one of them. There is also agriculture, ground patterns, control of pesticide and insecticide, quality and quantity as well as type of soils. Like you have green area - the forest that manage drought very well. Which of these drought management strategies you undertook?

Wendy Nero: Actually we didn't undertake that plan, because we look at different definition of drought and focus on water supply drought, not just climatic drought, which is because of shortfall of rain. Because it is a very urban area, and it is predominantly public uses, domestic uses and business uses, especially with Tampa Bay Water, the client we were working with. We do not really address the agriculture uses. Now the State has done that to some extent, but not to great extent. In fact there is an ongoing debate right now between the State and US government to look at who is responsible for drought management.

Moderator: Thank you. May I request the Thailand expert to share with us some of their groundwater management strategies? I understand that a few years ago, Thailand was charging 3.5 Baht for cubic meter of groundwater extracted. Can you share with us your experiences on this, please?

Comment: I am from Thailand. We have some problems with the groundwater in Bangkok some years ago. We over withdrew our groundwater. It caused subsiding in Bangkok. So now we limit some areas from extracting groundwater. We have an agency to control the groundwater, which is named Mineral Resource Departments. This department controls mineral resources and groundwater. If we would like to use groundwater, we have to get the permission from this agency. We have to pay for the water pumped. However, we are now limiting the permission for pumping water from the ground. Thank you!

Moderator: Thank you! A few countries have already discovered that some of the groundwater resources in this part of the world have been contaminated. I would like to know whether our Malaysian delegate could share with us some of their experiences? I remember that they found some groundwater contains radioactive materials, as a result of there is a dumping ground of radioactive material in the area nearby. Our Malaysian delegate, will it be possible for you to share with us on what is your strategies to prevent groundwater pollution? Ok, if it is not appropriate, Groundwater is a very important issue, I believe that countries are facing a lot of similar problems, such as over withdrawal, pollution, as well as not meeting our demands.

Let's move on another topic that Wendy presented on water demand. The water usage in every country is increasing steadily. Some may say that it is because of population increase. However, it is not only the total quantity, but also the per capital usage are increasing tremendously. For example, our Minister, Mr. Lim, mentioned that Singapore has per capital consumption rate of 160-170L/capital.day, but this is only the case in Singapore. If you look around the region, for example, China. Most of the cities in China have a per capital consumption rate ranging from 300-400L/capital.day. This rate is increasing with a rate of as high as 10%. So, how we going to reduce the water demand? Most of the time, it could be due to the leakage, or poor management. I believe every country has its own experiences. In Singapore, the water wastage is about 5%, whereas in some countries the wastage can be as high as 15%. I would like to hear from the floor that, how is your country controlling or tabling the water demand in your country? If we allow such an escalating of increase in demand, soon every country will be fighting for water.

Before we ask Wendy and Santosh to comment, I'd like to hear from the floor: what is your experience? Any volunteer, please? The question is: How to control the increasing water demand? Any strategy or planning from each country?

Question: This is J.G. from Korea. First of all, I feel like we are being questioned rather than questioning. You (moderator) like to post questions on us. I would like to question first, and then be questioned.(laughing) Thank you!

Wendy, I would like to draw five points from your presentation. First, from 1999 to 2003, your actual annual demand was reduced, but your prediction kept going up till 2025. I calculated quickly and that is 25% increase in demand from 2003, this huge increase of demand is not allowable, I believe, especially in this conference, when we are talking about green productivity. As a matter of fact, the domestic consumption in my country has been reduced for the past few years. Therefore, I believe we should control water demand rather than increase water supply. This is why we are here today, one part of it. We should go for reducing the consumption by means of using water-conserving devices, such as water forceps, showerhead, and low flush toilet etc. This morning, Minister Lim mentioned that we have to pay attention to drop by drop (of water). Every human activity can save water; every small activity can make a big difference. So, Wendy, I would like to question on your prediction of 25% increase in demand despite of the decrease of demand for the past few years.. I noticed that Tampa Bay area is very famous in water reuse, particularly in terms of using treated water for irrigation. Thank you!

Moderator: Thank you for you question. I was just trying to generate more discussion.

Wendy Nero: I like the latter - we asked your questions (laughing). No, I am happy to answer the question. It is a very good observation. In fact, that posed a dilemma to forecast the future use.

There are two reasons why the water usage was declining in the past few years. At the beginning of that downward trend we were at the peak of a very severe drought. Do you remember what I said that in Florida we have very significant irrigation uses for landscapes, publicly supplied water, outdoor uses, fountains, cleaning and things like that? So during that period of time, we had severe water shortage restrictions where our customers can only use water on very limited basis. So the demand actually dropped by about 15 %, as the result of legislative enforcement and issuing fines to curtail water uses. That is one of the reasons. The second reason was, immediately following the severe drought, in Florida we see the difference between a drought and a flood is hurricane, now it is called *El-Niño*.; we had above normal rainfall for about eighteen months. Because the demand is largely irrigation-driven, the combination of irrigation restriction and enforcement, together with huge and abnormally high rainfall, there was virtually no outdoor water use going on by then. These are the two reasons why it (the demand) declined.

Then, why we continue to see the trend upward? As pointed out by Professor. Tay just now, when you increase effluent or developed, the per capital water use tends to increase as well. This is one reason. Even though we have a number of water efficient measurements in USA, newer households use more water than older households, as results again of the landscapes, there are more water using fixtures and appliances in the house. So, even though each toilet uses less water, there are more of them (toilets), people are using and flushing them more often, we all have SPA tubs and different fixtures. One of the biggest contributor to the growth we projected is the new population moving in.

So, in terms of being sustainable, we have a long way to go. We are not doing a very good job especially giving the definition by Santosh this morning. We have to do a better job of recycling for portable use and consumption, as well as for landscapes. There are some very notable landscape irrigation programs and in that community their demands have flatten off, because they are using about 30% of reclaimed water or reused water for their landscape irrigation purpose. We are investing heavily in reclaiming water programs in the Tampa Bay area, but it is mainly the shear number of people moving there that is driving the growth of demand. We need to do a better job and we need to do a much better job.

Santosh Gondhalekar: I would like to add some figures especially where the demand of water is concerned. What we were talking about just now is the urban demand. In

Singapore, it is about 145-155L/capital.day and in some developed countries, it is about 250-300L/capital.day. As I mentioned previously, the water poverty index, or water poverty line, which states $1700m^3$/ year. If we converted that figure into daily consumption rate, the water poverty line is about 4000L/capital.day, out of this, 2500L/capital.day is required to produce food. There is a huge difference between urban demand and water requirement for agriculture. Basically, as far as domestic water requirement is concerned, the demand for urban area is hardly 5% of the total requirement of water, which included producing food, sanitation and all other things. If we assumed a demand of 250L/capital.day, multiply by 400days/year, it comes to about $100m^3$/year only. Therefore, out of the $1700m^3$, only 100 m^3 of water is used as domestic water in the urban area, how much can we are saved from this? it is merely one of 17 of the total demand. So the real challenge for the developing countries, especially for Asian countries, is not the domestic water demand for urban area but the irrigation water demand for agriculture. We should know some of these figures and understand what is the water requirement for domestic drinking water and sanitation, and what is the water requirement for agriculture. This is my opinion.

Question: I am from Pakistan. I have a few comments to make on how we can reduce the demand, which is the major issue then I have a question for Wendy.

As Mr. Santosh has mentioned, the major use of water in most of the developing countries is agriculture. Like in Pakistan, 97% of water is used in agriculture and only 3% is used in domestic and industrial purposes. You can see where the majority of water is going to. Therefore, agriculture is the sector where the smart invention can make a big difference in terms of water saving. There are two to three areas where we can really make a difference. One is the method of water application. In many developing counties, some very wasteful water application methods are still being used. For example, flood irrigation is still the main water application method in some countries. We conducted a study whereby we applied water back and forth and that can save up to 35% of the water used. This is again a flood irrigation method but it is a refine version of flood irrigation method.

My second example is to grow crops in zones where give you more production. For instance, if growing rice in one zone gives you 13 amounts of rice, and in another zone it gives you 17 amounts of rice, both using same amount of water, then you should grow proper crops in proper zones. Just like the case of sugar. In the southern area you can grow one hectare of sugar cane with less water and more yield. Crop zoning is very important in reducing the water demand.

The third example is we need to include what Mr. Santosh has pointed out: crops that have short duration may consume less water. When the production period of certain crop is reduced, says, instead of three months, it is reduced to two and a half month, we are going to save a lot of water. We have tried and we can grow rice on spring irrigation. The rice is normally grown by flood irrigation, where you make the water stand thereat about 10 inches to one foot. But we found that you can growth the rice equally good with spring irrigation. These are the area you can reduce the demand. These are the things that we can apply in large scale, and they can definitely reduce the demand in the agricultural sector.

My question to Wendy is on the drought management. Drought has a major impact on water sources. It takes much longer than you expected to get rid of these impacts. In Pakistan, we were in drought for the last four years. During these years, most of the areas as the water table went down as much as 20 feet. Out of some 560,000 (m^3 of groundwater) that was pumped through the entire basin, 70% of it was saline water. We can see that when the water table goes down, it inferences the quality of the water as well.

So, my question to Wendy is that we are having hard time for drought forecasting. We have look at our data the previous 50 years or so, and we are not able to draw any consistent trend. It could be a drought every ten years, fifteen years or twenty years but the data doesn't show that. Is there any other than modeling, or some better modeling which can tell us when the drought is coming so that we can get prepared? If you have any experience, it will be very appreciated. Thanks!

Wendy Nero: That is a very tough question. If I could give you that experience and had that answer, I would be one of the wisest women in this world. When we do our forecast, we don't have 50 years historical data, we have about 25 years of pretty good data that in the climatologically sense. So it doesn't surprise that we have very difficult time forecasting future conditions. When we come to weather forecasting, we can't even get tomorrow right. We did see some patterns in our data. But there is no easy way to forecast the certain weather in the future based on the past data. Even we did a probabilities forecast, we used modeling techniques, but we still don't know whether or not it will right in our forecast for another 26 years. One thing for sure is we can improve our forecasting methodology, but whatever we predict that will happen tomorrow could be wrong to some degree, it just a matter of what degree we could accept and plan around. Unfortunately I don't have a very good answer. Sorry.

Moderator: Thank you! I would like Dr Chizuru to comment on current water resources management practice, especially on the demand control management rather than increase supply. One mechanism that some countries use is pricing of the water supply. There are different comments from different country on pricing water supply. Some countries found it very successful, while the other countries found it is only successful at the beginning, after the consumers get used to the pricing, the demand growth is escalating again. Any question on this aspect that you like to ask our two experts here? In Singapore, our water is the second most expensive in the world, it priced at more than S$1.50/$m^3$; around the region, some of the countries only sell their water at less than 20 cents..

Question: I am from Iran; I have a question for Ms. Nero. As you may know that we have been facing some major problems in Middle East, major political problems. I would like to have your idea on how can we apply political issues in decision support systems to achieve integrated water resource management. For example, now we have an integrated water resource management projects in one of our catchments in Iran, where we have the most severe problems in water scarcity. The catchment is at the downstream and the upper catchment is in Afghanistan. About 99.5% of that area is in Afghanistan and just 5% is in Iran. Political issues are the most important issues in this kind of projects. I would like to have your idea on how we can apply these issues in the project. My second question is: you mentioned that in Florida State, you cannot transfer water from one watershed to another.. We have some major projects in Iran to transfer water from one watershed to another, these are very big projects which need huge resources- financial resources. Would you please explain the reasons why it is not allowed to transfer water from one watershed to another? Thank you!

Wendy Nero: I think with political issues, yours are huge and ours is a very small scale. Of the three counties area of Tampa Bay Water, we faced intrastate between, for example, Florida and Georgia, right now having along Alabama Water Wall; and international between United State and Canada along the whole Great Lake region. In these areas, some of the things that worked well for us is to integrate the science and the analytical part of decision making process with the policy and political aspect of the decision making. We developed some processes to bring those together that seem to help quite a bit. On the political side, it is understanding that who is concerned about and impacted by decision. Clearly, because you got 95% of the resource coming from another country that will benefit a receiving country that have 5% of resource, that is the huge issue. So I think getting the decision makers into the room early in the process if you can is very helpful. Try to understand what are their primary concerns, what do they need, what objectives do their need to achieve as a result. For example, it may be an economic gain if they transfer the water from one country to another. How do you measure that? How do you know that it is important? By being able to identify those issues very early in the process has been very important. In a very small scale of Tampa Bay area, one county said that we must have our environment restored because they will be the next supplier to another county. So, they said: "you can develop additional water resources, we are going to share the cost equally, and you will restore my environment". So we understood from the beginning what their objectives were. Then we looked at different resources scenarios and measured how well they perform against the State policies and their objectives. So the key is to understand what the objectives are. It is clear that the scale will change when we start talking about international transfers.

To your second question, that is the Florida State Water Law, the State Water Policy. In other parts of the United States, there can be very different. California is a very good example-the Rocky Mountain, we are transferring significant amounts of water from the Colorado river from the basin in which it is generated to other basins; from northern California to southern California. When Florida Water Law came into being, they wanted to avoid sort of the mass transfer, to allow us going back to the sustainable definition to have the area that supplies water only use whatever available to them, so that you don't get water-mining kind of development strategy. Will that work for a long term? I don't know. There are also different areas which are going into much higher cost alternative, so that they will only use local sources first. There is greater and greater need for the entire States to share the cost of the higher resources in one area, if in fact we are going to apply the State Water Policy. Therefore, it has to be both the policy plus the economic means to share the benefits of that policy across the entire population of the State.

Moderator: The clock is tingling very fast; we may allow one last question.

Comment: Thank you, Mr. chairman. I am from PUB, Singapore. I will switch of the topic a bit. I am not going to talk about demand but I would like to mention what Mr. Santosh's stated in his paper about the index. I think he mentioned about an index of 1700 m^3/capital.year, for a country to define whether it is water rich or water poor, and the other indice of 1000m^3/capita.year, for whether a country is water stress. If you look into the context of these indices, they are proposed by a Think Tank group. The way in which the indices for water rich/water poor is calculated was based on the total rainfall minus net losses, and divided by the population. If you take Singapore as an example, 600 square km, multiply the average annual rainfall of about 2.2 meters, over the population of four million we get about a hundred and fifty cubic meter per year per capital. This is much lower than the 1,700m^3/capital.year. We are not only water-poor, we are very water-stress based on that definition. I just want to comments that we should put in a lot of thoughts then we consider using the index. Whether we are water-stress, water-rich or water-poor, it all depends on how you manage your resources. Singapore is very water-stress, or water-poor, but we have managed it. In other words, that index does not really capture the state in which you manage your water resource. It does not take into account how you use technology, for example, to reclaim water. It doesn't take into account how the country manager is supplying it, in terms of whether you are desalting or etc. So when we use that index, bear in mind the other factors that we have to taken in. When you suggested that in the future, we divided the countries into the water poor or water rich, I left it for the audients to weigh by themselves whether it does make any sense, does it reflect the way in which the resources are managed in that country.

Santosh Gondhalekar: I think there are exceptions to every rule. But what I want to add is if a country is to be water secured and food secured within itself, then the index would be required. If Singapore wants to grow its' own food, then that amount of water would be required. If a country, like Singapore, is importing foods from outside, the 1700 or 1000m^3/capital.year of water that is required to generate food, food grains etc, should be made available from somewhere else for a given capital. That index is specifically for per capital, it can be anywhere in the world. If Singapore decided to generate their own foods through agriculture, it will be very difficult for them to generate that food. But if Singapore is importing that food, then you are importing 1000 m^3/capital.year of water from somewhere else. It is not that you have to own that amount of water resource, but you have to manage to get it. For pure water security, or domestic purpose, what I said is 100 cubic meter is required, or 150 (cubic meter). Definitely Singapore would be self sufficient permanently as far as only domestic water is considered. But if food grains are included, it has to import 1000m^3/year.capital from some other countries. That is the difference. It is not that 1700m^3 is required for only drinking, domestic and sanitation purposes, and so on.

Question: Could you please give the source of the citation?

Santosh Gondhalekar: The sources? World Water Development Report. I have the report here. There is a lot of this split between 1700 m^3. How much water would be required for food security? How much for the other purposes like drinking, domestic uses, hydraulic power generation? All water uses are considered together and this figure was derived. I have the detail report here, we can discuss later.

Moderator: There have been more discussion on the second half of the one hour discussion. I have to stop this discussion now. If you have any more questions, you can approach our two speakers, Santosh and Wendy to carry on the discussion. I would like to thank our two speakers, Wendy and Santosh for their excellent discussion and presentation.

WATERSHED MANAGEMENT

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OVERVIEW

Source water is a finite resource that needs to be protected for the long-term benefit of human health. The current approach for protection of source water is two-fold: assessment of existing vulnerability of a source water watershed to contamination and development of a protection plan. The US Environmental Protection Agency (USEPA) and Georgia Department of Natural Resources Environmental Protection Division (GAEPD) have provided extensive guidance on how to conduct a source water assessment; however, relatively little guidance exists on how to prepare and implement a protection plan. Source Water Assessment Plans (SWAPs) for twenty-eight Metro-Atlanta water supply intakes were completed in 2001 by the Atlanta Regional Commission (ARC) [Atlanta Regional Commission, 2001]. These Assessments indicate that some intakes have a potentially high susceptibility to pollution due to the density of contaminant point sources and high amounts of impervious surface (indicator of nonpoint source impacts). The source water protection strategies described herein outline a framework for local protection plans and provide a number of strategies that are appropriate for source water watersheds of different sizes and levels of impact. The recommendations in this document include programmatic recommendations that would be applied in each of the jurisdictions as well as pollution source specific strategies. Programmatic strategies include implementation of the Metropolitan North Georgia Water Planning District Model Stormwater Management Ordinances adopted in October 2002 to address nonpoint source loadings, implementation of the GAEPD Environmental Planning Criteria to require set backs from streams in source water watersheds, better enforcement of existing regulations, and acquisition and preservation of land within source water watersheds. A number of unique challenges exist in the development of source water protection strategies, some of which overlap with recommendations from Total Maximum Daily Load (TMDL) implementation strategies being developed simultaneously. Implementation of effective nonpoint source/stormwater control measures will address many of the primary sources of pollution contributing to both water quality impairments associated with TMDL listings and potential source water contamination. In order to minimize costs, source water protection strategies should be combined, to the extent possible, with watershed protection and management programs.

BACKGROUD AND INTRODUCTION

In 1999, the GAEPD contracted the ARC to coordinate and facilitate the implementation of the Source Water Assessment Plans for 28 Metro Atlanta public drinking water intakes. ARC created a Technical Task Force made up of local water managers to develop and implement Source Water Assessments. The purpose of these Assessments was to delineate and map the watersheds, inventory potential sources of pollution (point and nonpoint) and provide a ranking of the intake's susceptibility to these potential pollutant sources.

CH2M HILL and ARC provided consultant and watershed planning assistance to local governments and also provided support to the Metropolitan North Georgia Water Planning District (MNGWPD). As a preemptive step in Source Water Protection Planning, CH2M HILL and ARC have been developing source water protection strategies for the Metro Atlanta water supply watersheds. Source water protection strategies are being developed to address specific pollutants of concern for the water supply intakes found throughout the Atlanta metropolitan area.

Recommended source water protection strategies included programmatic measures as well as potential source specific activities. Programmatic measures included activities that overlap existing or planned watershed and stormwater management measures as well as enforcement of existing programs. Pollution source specific measures were focused on working with individual sources to improve awareness and ensure proper site procedures were used to limit pollutant runoff and potential water contamination.

PROGRAMMATIC STRATEGIES

Implementation of Nonpoint Source Controls

Watershed assessments completed in the area have documented that much of the pollutant loads reaching water supply sources was related to nonpoint source runoff. Therefore, the primary strategy for addressing nonpoint source contributions will be implementation of the recommended MNGWPD Model Stormwater Management Ordinances (MNGWPD, 2002). Implementation of the essential recommendations in these ordinances will significantly decrease the amount of nonpoint source related pollutant loadings to source water watersheds.

Implementation of the State of Georgia Environmental Planning Criteria

These criteria included requirements for protection of wetlands, floodplains, and water supply watersheds. It should be recommended that each of the local governments with a water supply watershed within their jurisdiction be responsible for implementing the minimum criteria for large (or small) water supply watersheds (GA Code § 391-3-16-.01). This will require local governments to develop and implement an ordinance to require the minimum set backs from perennial streams. These set backs may be implemented through land purchases by the local government that could be incorporated into their local Greenspace program.

Enforcement of Existing Regulations

Existing programs for water pollution prevention, stormwater control, and water quality permitting address many of the potential pollution sources in the water supply watersheds. Unfortunately, the GAEPD programs have been under-funded and existing staff are not able to commit the level of effort required to fully enforce the current requirements. Similarly, at the local government level, often the sedimentation and erosion control programs and stormwater programs have been under-funded. Additional support at both state and local level will be needed.

Land Acquisition

One of the most effective source water protection strategies is to purchase significant portions of a watershed leading to the water supply source and protect it from further development or disturbance. Throughout most of the area, this alternative is not possible due to the level of existing development. However, as Greenspace alternatives are evaluated, acquisition of lands within water supply watersheds should be considered high priority areas for purchase.

Public Education and Awareness

As part of a source water protection plan, specific recommendations for public education and awareness programs should be identified. Specific programs should be recommended to assist with the education of the general public. Additional education materials should be developed to educate specific potential pollutant sources about pollution prevention and the need to protect the water supply watershed. A common set of materials can be developed for all the jurisdictions within the region.

POTENTIAL POLLUTANT SOURCE-SPECIFIC PROTECTION STRATEGIES

In addition to the programmatic strategies listed above, local governments need to include additional measures to address specific pollutant sources highlighted in the SWAPs. The Georgia guidance for the SWAPs outlines a number of potential pollutant sources that need to be evaluated in water supply watersheds. However, the results of the majority of the SWAPs for the Metro area found that several types of pollutant sources were found to be consistent issues. These sources included sediment and erosion from exposed land, large amounts of impervious surface area, oil and gas pipelines and railroads crossing streams, septic systems, sewer lift systems, large industries which utilize hazardous chemicals, and fuel facilities.

Sediment and Erosion

Although not distinctly outlined in the State guidance as a potential pollutant source, sediment and erosion was identified by the ARC SWAP participants as a major concern for the metro-Atlanta area. The percentage of land identified as “in transition” was determined from aerial photography. For some areas nearly 5% of the total land percentage of the watershed was found to be in transition. Much of these concerns regarding the sediment and erosions control will be addressed with the new State requirements in the revised Sedimentation and Erosion Control Act. However, additional emphasis on compliance will be required at the local government level. Adequate staffing will be required to assure that the new requirements are being met during construction.

Impervious Surface Area

As discussed above, it is clear that large amounts of impervious area can be detrimental to water bodies (Schueler, 1994). Although it can be difficult, if not impossible to transition back to a pervious land surface, limiting impervious surfaces on a larger watershed basis can be important to limiting overall pollutant loadings to a water supply. Land acquisition of the entire source water watershed (or at least major parts of it) is ideal for managing land uses and the associated potential contaminants. Ultimately the best way to control activities is to purchase the land and/or the development rights to the area. However, due to the high cost of purchasing property in much of the area, this recommendation relates primarily to newly planned water supply watersheds and those that will be entirely within a single jurisdiction. Another option for land acquisition is the purchase of conservation easements offered voluntarily by landowners. Each easement, which would limit development, becomes a permanent part of the property title that must be adhered to by future owners of the land. In return, landowners can receive significant reductions in property taxes because the easement is no longer assessed as developable real estate. For those areas with extensive agriculture, the use of Federal funding associated with the Environmental Quality Incentives Program (EQIP) can be used as an incentive to farmers not to actively cultivate the land, but rather set it aside for conservation.

Oil and Gas Pipelines/Railroads

There area a number of oil and gas pipelines and railroads within the area that cross existing water supply watersheds. These facilities are currently regulated by the Federal Energy Regulatory Commission (FERC), GA Department of Transportation, or the Federal Department of Transportation. Liquid transportation pipelines are required to have emergency spill plans in place and to conduct periodic training with staff. Information could be distributed to facility owners and railroad companies identifying that their lines cross a water supply watershed.

Septic Systems

Septic systems can have significant impacts in source water watersheds, primarily due to failing systems or lack of maintenance. Local governments need to consider transitioning those areas with high densities of septic tanks to sewer. For many source water concerns, local governments can provide the requirement for ordinance changes to support protection.

Lift Stations and Sewer Lines Crossing Streams

The Capacity, Management, Operations, and Maintenance (CMOM) program required by US EPA will address many of the potential concerns associated with sewer line crossings and lift stations in water supply watersheds.

Large Industries Which Utilize Hazardous Chemicals

The primary method for addressing industrial and commercial sites is through existing regulations. Existing regulatory programs emphasize industrial good housekeeping practices, including equipment operation and maintenance, product storage, use, and handling, and waste storage and disposal. Enforcement of the existing programs described above will be critical to the success of the source water protection strategies. GAEPD is responsible for this enforcement. However, due to limitations in staffing and other resources, this task often does not receive adequate attention. Educational materials that emphasize the need for spill prevention and containment in water supply areas should be developed and distributed to these facilities.

Fuel Facilities

In Georgia, the Underground Storage Tank (UST) program is the primary way that fuel facilities are monitored and tracked. Recent requirements included the identification of those areas where USTs may be failing by testing methods and standards. In addition, the program requires implementation of an early leak detection system for new USTs and some retrofit, based on the size of the tank. Containment verification methods were also outlined with existing UST program. Depending on the type of tank, those verification methods included the implementation of a monitoring well system, double walled tanks, cathodic protection, and electronic monitoring.

CONTINGENCY PLANNING

Despite the use of any or all of the source water protection strategies described above, it is possible that accidents or disasters may still occur. Water supply replacement strategies are therefore critical for ensuring that a safe drinking water supply is available for consumption. Generally, disruptions of the primary supply, either short- or long-term, occur as a result of the weather (e.g., drought or flood) or a contaminant (e.g., a chemical spilled into the primary source water that cannot be removed by the WTP due to either its concentration or type). The current approach for managing the water supply through GAEPD includes reservoir management, water conservation, and a drought contingency plan. The existing contingency plan should be supplemented by the following actions: 1) providing the emergency response organizations in the watershed with instructions to communicate to affected members of both local and State governments in the event of a contaminant spill and 2) providing all personnel with a review of emergency response procedures.

LINKAGE BETWEEN SOURCE WATER PROTECTION AND TMDL STRATEGIES

A number of unique challenges exist with development of TMDL implementation strategies and source water protection strategies. Many of these challenges are common to both concepts and need to be fully addressed prior to implementation and include consistent enforcement of existing regulations, funding concerns, public outreach and education, each of which are discussed below.

In order to maximize cost savings, source water protection efforts should be combined to the greatest extent possible with watershed protection and management efforts (currently required through the wastewater and water supply permitting process) and water conservation efforts. Most of the source water in the area is from surface water and ultimately protecting stream segments for recreational, as well drinking water, uses would be ideal.

Public education is the key to many aspects of source water protection, if not through direct mitigation of human health risk, then through support of regulatory changes. Continued emphasis on school-age children to make long-term changes in behavior should be a central part of this effort. In addition, public outreach should target other groups and behaviors that affect source water (i.e., homeowners and motor vehicle owners).

REFERENCES

Atlanta Regional Commission. (2001). Metro Atlanta Source Water Assessment Project Final Report.

Metropolitan North Georgia Water Planning District Model. (2002). Stormwater Management Ordinances, adopted October.

Rules for Environmental Planning Criteria. (1992). Georgia Department of Natural Resources, Environmental Planning Division, revised

Schueler, T. R. (1994). The Importance of Imperviousness. Watershed Protection Techniques 1(3):100-111

INTEGRATED URBAN WATER MANAGEMENT: MEETING THE GLOBAL CHALLENGE

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ABSTRACT

This paper presents the principles of the integrated urban water management (IUWM) approach. To highlight the need for the IUWM approach, various global challenges in the provision of water and sanitation, as well as factors that contribute to urban water scarcity, are summarized. The article also introduces the components of IUWM, including alternative water source identification, improving the supply and consumption efficiencies, partnership and participation, policy and strategies, as well as the importance of metering and revenue recovery. Activities undertaken by UNEP IETC to promote the IUWM concept are summarized.

URBAN WATER CHALLENGE

The world is facing an increasing challenge in providing access to water and sanitation, the two fundamental requirements for human well-being and dignity, to its inhabitants. Various statistics paint a daunting picture. Of approximately 6 billion people in the world today, 1.2 billion, almost a quarter, do not have access to clean drinking water. 2.5 billion people, almost half of the world's population, lack adequate sanitation. In the Asia and Pacific region, one quarter of urban households do not have water connections, and 55% live without sewer services (WHO-UNICEF, 2000). 80% of illnesses and deaths in developing countries are attributed to water, and a significant share of such incidences occurs in urban slums (United Nations, 2003).

The projected population growth and urbanization trends pose serious challenges in urban water management. The world's population is projected to increase to 8.3 billion by 2030. Over 90% of this growth will take place in urban areas in developing countries. With such projected growth, over 55% of the developing country population is projected to live in urban areas by 2030, whereas 40% lived in urban areas in 2000. Asia will experience significant urban population growth, and Asian cities will be home to approximately one-third of the global population by 2030 (United Nations Population Division, 2002). The number of cities with more than 1 million inhabitants is expected to rise to 650 by 2025, whereas less than 100 such cities existed in 1950 (WHO-UNICEF, 2000). Many of these urban areas already are unable to provide safe, clean water and adequate sanitation facilities for their citizens (UNEP, 2003).

In terms of access to water, 3 billion people are projected to live in countries that will have less than 1,700 m3 of water per capita, recognized level of water stress, by 2025

(Engelman et al., 2002). If the current level of demand growth continues, some projections indicate that the water demand will increase by 50% over the next 40 years.

Inadequate access to water also poses serious impediment for the poor from leading productive lives, thus undermining equitable socio-economic development. Women and girls in developing countries spend more than 10 million person-years in aggregate each year to fetch water. The number not only implies a significant loss of productivity to the society as a whole, but also alludes to hardship and lack of alternatives for women (WSSD, 2002).

There is a clear need to adopt a new approach to water resource management in the urban setting to overcome the current problems and to mitigate future problems. Integrated urban water management (IUWM) offers the potential to alleviate these negative impacts, and is increasingly becoming an important framework for policies to address the urban water challenge in a sustainable manner.

GLOBAL INITIATIVES ON WATER

Water has been a central issue for international dialogue and cooperation, since the 1977 United Nations Water Conference. Within the past decade, water and sanitation have increasingly emerged as a central component to achieve the sustainable development goal. The urgent need for water management was articulated in Agenda 21 (Chapter 18), which identified freshwater management guidelines to address the protection of the quality and supply of freshwater and the application of integrated water resource management. Furthermore, world leaders have recognized that water and sanitation are inextricably linked to poverty alleviation and achieving sustainable development, and have established clear goals and timelines for action. Of particular importance to the current global efforts is the Millennium Development Goals (MDG), which are a part of the road map for implementing the Millennium Declaration of 2000, which the member states of the United Nations adopted unanimously (United Nations, 2000). The MDG include the following major targets for water and sanitation:

- Halve the proportion of people without safe drinking water by 2015
- Half the number of people without access to sanitation by 2015
- Develop integrated water resource management and water efficiency plans by 2005
- Provide new and additional financial resources for water management

Appendix A summarizes other key decisions, events, and frameworks linked to water since the Rio summit. Many governments at the national, regional, and local levels have made substantial efforts to promote sustainable water management practices, in cooperation with various bi- and multi-lateral organizations, including UNEP.

CONTRIBUTING FACTORS TO URBAN WATER PROBLEMS

Water scarcity in urban areas is aggravated by many interlinked factors, including physical, political and institutional, and economic factors, as well as stemming from inefficient service and unsustainable consumption. These factors are described below.

Physical Factors

As discussed in the previous section, urban water scarcity is magnified by rapid population and urban growth, and associated increase in water demand from individuals, industry, and institutions. The infrastructure development is often unable to keep up with the pace of urban expansion.1 The quantity of available water has diminished due to one or more of the following anthropogenic, hydrologic, and climatic factors:

- Over-exploitation to meet demand that outstrips resource availability
- Seasonal fluctuations in water availability
- Urban expansion into areas with deficient water resources (i.e., arid areas)
- Persistent drought conditions

The quality of available water has also declined, due to effluents from industrial sources, non-point sources (urban run-off), sewage discharge, eutrophication from household and agricultural discharges, and effects of over-pumping of groundwater, such as salination and arsenic contamination.2

Policy and Institutional Limitations

Responsibilities for water resource planning and management are often fragmented among various ministries, agencies, as well as the private sector, at the national, regional, and local levels. Many countries lack comprehensive water policy that integrates economic development, resource protection, and meeting the basic needs of the poor. Furthermore, compliance and enforcement of water policy requirements is often limited, due to resource constraints or lack of political will. These limitations hamper coordination and integrated response to address the challenges in an efficient and timely manner.

Economic and Financial Constraints

Almost all governments and municipalities have limited resources and competing demands for their allocation. Revenue recovery may be limited, due to low water tariffs and inadequate tariff recovery mechanisms. Under such conditions, the installation and maintenance of basic water infrastructure systems may not receive adequate priority and financing to meet the existing needs. System expansion in anticipation of urban expansion and growing demand may be far beyond the means and considerations of cities that are struggling to meet the current demand.

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[1] In some urban areas where informal settlements from migration are rampant, government agencies are often reluctant to provide access to water and sanitation services in fear of legitimizing the settlement and thus fueling further migration.

[2] In Bangladesh and neighboring countries where groundwater contamination with arsenic has been documented, arsenic concentrations have been observed to be influenced by the change in water chemistry, which has been induced by pumping (Harvey et al, 2002).

The cost estimates for meeting the MDG goals of providing water and sanitation for all people are quite significant, ranging from US$9 billion per year for basic coverage to US$30 billion per year for universal coverage (World Bank, 2002). Such significant financial commitments require the mobilization of additional resources from public investment budgets, international development financing, private sector involvement, as well as community-based finance.

Inefficient Service Provision

Antiquated or poorly maintained distribution systems increase the percentage of water that goes unaccounted for in the system. Referred to as UFW, or unaccounted for water, physical losses of water can stem from supply leaks, in-house connections, overflow, and also from distribution tanks. In the Asia and Pacific region, approximately 35% of water distributed was unaccounted for in 1997, similar to the 1993 level. The UFW values in select Asian cities ranged from 44% in Manila, to 6% in Singapore, as summarized in Table 1(ADB, 1997).

Table 1 Percentage of Unaccounted for Water in Select Asian Cities (Source: ADB, 1997)

City and country	Percentage of UFW (%)	Survey year
Karachi, Pakistan	30	1995/96
Shanghai, China	14	1995
Manila, Philippines	44	1995
Bangkok, Thailand	38	1994/95
Tokyo, Japan	12	1990
Macao	11	1991
Singapore	6	1994
Regional average	35	

Furthermore, utilities in the region often do not have data on how much water is being consumed by a significant percentage of customers. According to ADB, 17% of all connections in Asia remained unmetered as of 1997. The regional averages of unmetered connections were as follows: 83% of public taps, 20% of commercial taps, 18% of household connections, 12% of institutional connections, and 3% of industrial connections. Of the metered connections, only 60% should be considered to have accurately functioning meters (ADB, 1997). The lack of reliable data on consumption volume hampers efforts for fee recovery and target setting for water conservation. Also, the level of basic service provision to the underserved population may not be analyzed and adjusted accurately, due to the high percentage of unmetered public taps.

In addition, service efficiency may not be optimized, as water service institutions may not have incentives to improve efficiency and reliability. Many utilities have been experiencing low degrees of cost recovery, due to the above-mentioned challenges, as well as other institutional factors such as inefficient tariff collection mechanisms and excessive size of workforce.

Unsustainable Consumption

According to WHO, the minimum volume of water usage for very basic health protection is 7.5 liters per day (WHO, 2003). Good health and cleanliness requires a daily supply of about 30 liters of water per person. In the Asia and Pacific region, the average per capita consumption in 1997 was approximately 160 liters per day (ADB, 1997). In contrast, Europeans consume approximately 230 liters of water each day, and Americans consume about 700 liters (GDRC, 2003). While the Asian average is less than European and American figures, water is still consumed inefficiently by those with access to it. For example, some urban rich in India consume 300 liters per day, about twice as much as an average Singaporean, while the Indian poor have been known to subsist on 15 liters per day (ADB, 2001).

There exists a wide range of technical options for improving consumption efficiency that have been implemented successfully for residential, industrial, and public-sector purposes around the world, often coupled with demand management policies. In addition, various water supply augmentation measures, such as rainwater harvesting and recycling and reuse of wastewater, are effective in curbing demand for additional freshwater supply. However, limitations in know-how, management capability, finances, and willingness hamper their wider acceptance.

In addition, water pricing that does not reflect the true economic cost and water usage sends wrong signals for water conservation. In some countries, stemming from historical practice, there may not be a consensus on who should pay for water and wastewater treatment. Individuals and organizations are less likely to conserve water and minimize wastewater generation if they do not, or feel that they should not, pay for such services. Finally, the lack of understanding on environmental and human health consequences of water scarcity often hampers efforts to provide access to the under-served, and does not compel those with access to conserve so that more people can access it.

More integrated approaches to water resources management are needed to overcome these problems, to alleviate poverty and to protect the environment.

INTEGRATED URBAN WATER MANAGEMENT

The integrated urban water management (IUWM) approach has emerged from the growing recognition that an integrated approach to water management at the urban level offers an appropriate framework for decision-making and tangible actions.

Definitions

IUWM is defined as the practice of managing freshwater, wastewater, and storm water as links within the resource management structure, using an urban area as the unit of analysis. The concept encompasses various aspects of water management, including environmental, economic, technical, political, and social impacts and implications. Specific components of IUWM are described in further detail in the following section.

Components of IUWM

Various complementary approaches are available to implement IUWM in urban areas. Any strategy for IUWM involves a combination of various components discussed below to accommodate the local circumstances and preferences.

Develop and Utilize Alternative Water Sources

There is an emerging consensus that increasing needs and demand for water cannot be met by relying solely on the development of new water sources. New sources will have to complement more efficient use of alternative water sources with sufficient water quality. Alternative water sources include reclaimed and treated waste water, desalination, rainwater, and reuse of water.

Reclamation and reuse of wastewater require technical skill and expertise, which are available and successfully implemented around the world. To establish a wastewater reuse program, an evaluation of infrastructure needs, economic and technical feasibility and possible alternatives is necessary. Adequate treatment should be provided to meet local reuse standards, or the WHO guidelines on microbial and viral removal requirements to protect human health and the environment.

Improve Water Supply and Consumption Efficiency

Improving the efficiency of water supply and consumption is another component of IUWM. By improving the supply and consumption efficiency, and by utilizing alternative water sources, it may be possible to delay, scale back, or sometimes eliminate investments for new water source developments.

On the supply side, losses during transmission and distribution, as described in section 3.4, can be minimized through leak detection programs, rehabilitation of pipes or pressure reduction projects. UFW can be reduced further by administrative measures, such developing an inventory of suspiciously low usage, compared to earlier records or neighbors, followed by inspection, improved meter reading and recording losses, and inspection for non-registered connections.

On the consumption side, increasing end-use efficiency can be achieved through the following:

- Water saving devices: such devices include low flush toilets, low flow showerheads and faucets, spay nozzles, adjustable flow valves, as well as good plumbing management to reduce leaks.
- Water recycling mechanisms: rainwater harvesting mechanisms can be installed, and collected water can be used for various purposes, such as toilet flushing and landscaping, after appropriate treatment. Greywater can be recycled for domestic, and industrial, and agricultural uses, such as for wash water in the laundry.
- Low water-use landscape: water usage from landscaping could be reduced by using native plants that consume less water, mulching to minimize evaporation, as well as xeriscaping.

Demand management also requires awareness raising programs, as well as price incentives and regulations, which are discussed in more detail below. Changing the public attitude towards water usage is the key to successful demand management.

Tools and systems are available to assess the water systems, and to evaluate various options. Water audits can be implemented at residential, industrial, or commercial units, or more comprehensive water budget analyses can be carried out at the urban or watershed level. Local knowledge and practices are often valuable sources for identifying potential options that meet the specific local needs.

Engage Community and Develop Partnerships

While a number of actions can be undertaken at the macro level (global, national, and sub-national levels) to mitigate the problem, the real challenge lies in taking actions needed at the micro level (households and industrial/commercial units) that have eventual and cumulative macro impacts. Citizens need to be engaged in conserving water as home and at workplace. Their participation in the local and regional planning processes can also ensure that local needs and priorities are reflected in the decision-making, and ensure transparency.

Establish and Implement Policy, Strategy, and Legislative Framework

Appropriate policies and strategies provide incentives for water efficiency improvements. National water policy can be developed to evaluate water demand based on projected change in population, industrial and agricultural outputs, and other factors. Such policy can assign responsibilities and mandates to various institutions at the national, regional, and local levels, and clarify accountability.

Standards for water-using fixtures and appliances can also be established. Economic instruments, such as rebates and incentive programs, may be effective in accelerating the replacement of less efficient water fixtures. Municipalities can also put in place water management plans for drought, flood, and other emergencies, including the authority to ban and enforce non-essential uses of water (World Bank, 2003a).

Improve Economic Efficiency of Services to Sustain Operations through Metering and Revenue Recovery

The economic efficiency of services must be maintained in order to sustain daily operations, and to secure investments to expand services to meet demand in a sustainable manner. This point is true whether the services are provided by the public sector, private firms, or through public-private partnerships. To do so, the service providers must strive to recover fees from all users, while ensuring to provide water to meet the basic human needs. 3 Tariff reform may be necessary to improve economic efficiency. Such reform, which must be carried out in a transparent manner, has been carried out in various Asian cities with varying results, supported with international technical assistance as needed.

Price incentives are often the central feature of inducing water conservation. Metering is essential to determine the actual usage in order to charge users. Water conservation results from metering efforts have been documented in various countries, as summarized in Table 3 (OECD, 1999).

Metering can be carried out at various levels for different conservation purposes. For example, source water metering is suitable for total water accounting by service providers, whereas service connection metering can be

[3] As stated earlier, water should be considered as fundamental requirement for human well-being and dignity. As such, basic access should be provided to the poor and under-serviced to protect human health and the environment.

used to inform users of the quantity of water consumed. Finally, public-use metering measures the amount of water provided free for public use.

Table 2 Water Savings Attributed to Improved Metering (OECD, 1999)

Location	Period	Savings from improved metering
New York City, USA	1991- 95	Annual: 7%
Leavenworth, Washington, USA	1988-91	Summer peak: 61%
Barcelona, Spain	Early 1990s	Annual: 13%
Portland, Oregon, USA	1993 –1994	Annual 10 – 12%

Links to Integrated Water Resource Management

The IUWM is closely linked to the integrated water resource management (IWRM) concept, and comprises similar components. The two concepts differ in the scope of analysis: IWRM is usually applied at the catchment or watershed level as the basic unit of analysis and management, whereas IUWM uses the urban area as the unit of analysis. Urban areas are appropriate as units of management, as specific problems and needs faced by cities may transcend the physical and scientific boundary embodies by more traditional units of management of catchments and watersheds (UNEP, 2003). IUWM can be pursued as a part of IWRM at the implementation level to address specific issues within the urban context (IWA, 2002, GDRC, 2003). While urban areas are dominant features in the catchments, care should be taken to link the priorities of urban concerns with non-urban concerns, such as rural water supply, agriculture, power generation, eco-system service provision, and downstream use.

Various definitions of IRWM reflect different perspectives of organizations that are active in the field of water resource management. Four representative definitions are presented in this section. First, the US AID defines the IWRM as a “participatory planning and implementation process, based on sound science, which bring together stakeholders to determine how to meet society’s long-term needs for water and coastal resources while maintaining essential ecological services and economic benefits” (Findley et al, 2001). The US AID defines the principal objectives as follows:

- Manage water resources, including land and water, upstream and downstream, as well as groundwater, surface water and coastal resources
- Optimize supply, through an assessment of supply from all sources, wastewater reuse, and environmental impacts of distribution and usage
- Incorporate demand management, including cost recovery strategies, water efficient technologies, and decentralized water management authorities
- Provide equitable access to water resources through participatory approach, transparent governance and management, including support for water user associations, involvement of marginalized groups, and consideration of gender issues
- Improve and integrate policy, regulatory and institutional frameworks, including the incorporation of the polluter-pays principle, water quality standards and market-based regulatory mechanisms

- Introduce inter-sectoral approach to decision-making, where responsible management of authority for water resource management is coupled with involvement of stakeholders in decision-making (USAID, 2003).

Second, the International Water and Sanitation Centre (IRC) states that the core message of IWRM is the integration across sectors, applications, groups in society and time. The eight principles of IWRM advocated by the IRC encompass the following:

- Water source and catchment conservation and protection are essential
- Water allocation should be agreed among stakeholders within a national framework
- Management needs to be addressed at the lowest appropriate level
- Capacity building is the key to sustainability
- Involvement of all stakeholders is required
- Efficient water use is essential and often an important "source" in itself
- Water should be treated as having an economic and social value
- Striking a gender balance is essential (IRC, 2003)

Asian Development Bank (ADB), on the other hand, stresses the resource management aspects by defining IWRM as "a process to improve the planning, conservation, development, and management of water, forest, land, and aquatic resources in a river basin context." ADB applies the concept to maximizing economic benefits and social welfare in an equitable manner without compromising the sustainability of vital environmental systems, and to addressing quantity and quality concerns for surface and ground water, and opportunities for their joint use (ADB, 2001).

Finally, the World Bank defines IWRM as an integrating concept for water sub-sectors, such as water supply and sanitation, irrigation and drainage, and hydropower. An integrated perspective, according to the World Bank, ensures that social, economic, environmental, and technical dimensions are taken into account in the management and development of water resources (World Bank, 2003b).

There are some key similarities between the IUWM and IWRM approaches. The fundamental principles of IUWM and IWRM cover the entire water cycle, as well as storage, distribution, treatment, recycling and disposal, and protection and conservation of water resources. Both concepts also address the importance of engaging the local communities to participate in the decision-making process to improve water and sanitation access. Finally, both concepts stress the need to conserve the quantity and quality of water, and to value the services provided by the eco-system.

Principles for Action

Options considered for IUWM should adopt the precautionary approach and embrace full cost accounting. The precautionary principle aims to minimize environmental and social impacts by incorporating ecological concerns into the planning and delivery of process, product, and services, and by establishing clear response mechanisms to address any environmental issues that may arise. Full cost accounting of technology and management options are necessary to internalize the negative and positive externalities. Services provided by the eco-systems, including their productive and regenerative capacities, as well as the need for their restoration, should also be included in the costing.

Implementation

IUWM is implemented through a strategic framework for evaluating urban water solutions and a process for assessing the environmental characteristics, benefits and risks associated with water-related technologies and infrastructure. While a full description of the assessment and implementation of IUWM is beyond the scope of this article, a brief introduction of the steps for assessment and implementation is warranted, as follows:

1. Define baseline conditions and scope of the problem to be addressed
2. Establish performance criteria and management procedure
3. Mobilize financial and human resources
4. Engage the stakeholders through partnership
5. Maintain and improve options

UNEP IETC'S APPROACH TO URBAN WATER MANAGEMENT

IETC's Focus

Since its inception in 1994, the UNEP International Environmental Technology Centre (IETC) has aimed to facilitate the adoption and implementation of environmentally sound technologies (ESTs), focusing on water and urban applications. In relation to urban water issues, IETC pays particular attention to water and wastewater treatment and the integrated management of urban watersheds. IETC works collaboratively with key partners and stakeholders to develop urban water management approaches that are socially acceptable, technically sound, environmentally responsible and economically feasible.

Current IETC Activities Related to IUWM

IETC has focused on improving access to water and wastewater ESTs and management approaches through the provision of information and knowledge management systems, complemented by capacity building activities to facilitate the implementation of sustainable urban water solutions.

For example, IETC has established an information system called SAFFIRE. 4 SAFFIRE, which stands for the Strategic Alliance for Freshwater Information, Resources, and Education, is an Internet-based system that brings together existing initiatives and websites of various organizations that are active in water management issues. It was established to respond to the need to provide access information on water issues from credible institutions. SAFFIRE is a gateway to explore the contents of the partner websites, with a consolidated search engine that searches the websites of partner institutions, and provides thematically clustered information. Users can utilize the system for the following purposes:

- Obtain information on policies, strategies, and tools on water management and related issues

[4] UNEP SAFFIRE can be accessed from the UNEP IETC homepage (www.unep.or.jp).

- Learn from case studies and illustrations
- Carry out research using the set of references
- Network with other water professionals using the mailing lists

In the field of capacity building, IETC has been developing a number of E-learning tools that are free and readily accessible from the IETC website, with complementary technical publications. These materials can be used by independent learners to gain knowledge on specific issues of their interest, and can be incorporated into a more structured learning environment, such as workshops and university courses. E-learning packages and technical manuals on some key topics of IUWM, such as water demand management, water audit process, wastewater reuse, and rainwater harvesting, are under development, and are scheduled to be available on-line by the middle of 2004.

Future Direction and Activities

IETC's ultimate goal in the promotion of IUWM is to identify successful approaches and factors from real examples, so that guidance on their replication can be provided. Building upon the current activities described above, IETC plans to move towards providing assistance in the demonstration and implementation of IUWM practices through the following activities:

- Enable local IUWM practices by developing strategic financing opportunities
- Demonstrate how IUWM can be implemented at the local level through a select number of demonstration projects
- Develop tools and guidance for technology and policy assessments and decision making for IUWM
- Provide training and awareness raising programs on IUWM to decision makers at the national and local levels, as well as communities as end-users
- Assist in policy and strategy development to facilitate the IUWM implementation at the national and local level.

Other Initiatives

In addition to UNEP, various international and regional organizations are active in the area of urban water management. Appendix B lists the coordinates of some of the major initiatives.

CONCLUSION

This article presented the principles of the integrated urban water management (IUWM) approach. The world faces a growing challenge in the provision of water and sanitation in the urban areas, compounded by population growth, urban expansion, and degradation in the quantity and quality of available water resources. The IUWM approach provides an appropriate framework for conserving and managing water by incorporating good governance, stakeholder involvement, and capacity building. UNEP is committed to promote this concept to achieve sustainable development, in partnership with stakeholders at the local, national, and international levels.

REFERENCES

ADB (1997). *Second Water Utilities Data Book, Asia and Pacific Region.* Manila: Asian Development Bank.

ADB (2001). *Water for All: The Water Policy of the Asian Development Bank.* Manila: Asian Development Bank.

Deverill, P., Herbertson, P., and Cotton, A. (2003). *Urban Water Management: Sustainable Approaches for Low Income Countries*. London and Loughborough: Water and Environmental Health (WELL).

Engelman, R., Cincotta, R., Dye, B., Gardner-Outlaw, T., Wisnewski, J. (2002). *People in the Balance: Population and Natural Resources at the Turn of the Millennium 2002 Update*. Washington, D.C.: Population Action International.

Findley, M., Israel, M., and Scott, C. (2001). Towards A Water Secure Future: The Role of USAD in Water Resources Management, *Water Resources Impact (Journal of American Water Resources Association)*, Volume 3, Number 4, pp.12 – 19.

Global Development Research Center (GDRC). *Integrated Urban Water Resource Management,* http://www.gdrc.org/uem/water/iwrm/

Harvey, C. F., Swartz, C. H., Badruzzman, B., Keon, N. E., Yu. W., Ali, A., Jay, J., Beckie, R., Niedan, V., Brabander, D, Oates, P., Ashfaque, K., Islam, S., Hemond, H.F., Ahmed, F. (2002). "Arsenic Mobility and Groundwater Extraction in Bangladesh," *Science*, 298.

International Water and Sanitation Center (IRC). (2003). *Community Integrated Water Resource Management: Accepting the Challenge*. Delft: IRC.

(http://www.irc.nl/themes/iwrm/index.html).

International Water Association (IWA). (2002). *Industry Sector Report for WSSD*, London: International Water Association; (referenced in http://www.gdrc.org/uem/water/iwrm/1pager-03.html).

Organisation for Economic Co-operation and Development (OECD). (1999). *Household Water Pricing in OECD Countries.* Paris: OECD.

United Nations. (2000). *Resolution Adopted by the General Assembly 55/2. United Nations Millennium Declaration,* 8th Plenary Meeting. New York: United Nations.

United Nations. (2003). *'Water-Related Diseases Responsible for 80 Per Cent of All Illnesses, Deaths in Developing World', Says Secretary General in Environment Day Message.* Press Release SG/SM/8707 OBV/348, New York: United Nations.

United Nations Environment Programme. (2003). *Integrate Urban Water Management (IUWM).* Osaka and Shiga: UNEP.

United Nations Population Division. (2002). *World Urbanization Prospects, The 2001 Revision Data Tables and Highlights*. ESA/P/WP.173. New York: United Nations.

United States Agency for International Development (USAID). (2003). *What is IWRM?* Washington, D.C.: US AID,

http://www.usaid.gov/our_work/environment/water/what_is_iwrm.html.

WHO. Domestic Water Quantity, Service Level and Health. (2003). WHO/'SDE/WSH/0.3.0.2, Geneva: WHO.

WHO and UNICEF. (2002). *Joint Monitoring Programme on Water Supply and Sanitation, Assessment, 2000 report*. Geneva: WHO-UNICEF; 2000.World Bank. *Reaching the MDGs to Cost $40 - $60 Billion Annually in Additional Aid, Says Bank:* DevNews Media Center Feature Story (21 February 2002), Washington, D.C.: World Bank.

http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:20035050~menuPK:34459~pagePK:64003015~piPK:64003012~theSitePK:4607,00.html

World Bank. (2003a). *Water Resources and Environment Technical Note F.1: Water Conservation: Urban Utilities*, Davis, R. and Hirji, R., eds. Washington, D.C.: World Bank.

World Bank. (2003b). *Water – a priority for responsible growth and poverty reduction: an agenda for investment and policy change: World Bank report # 25770,* Washington, D.C.: World Bank.

World Summit for Sustainable Development (WSSD). (2002). *Facts about Water: Press Release Fact Sheet*, Johannesburg: WSSD.

Appendix A: Global Frameworks and Decisions Related to Water

UN Conference on Environment and Development (UNCED) and Agenda 21

The urgent need for water management was articulated in Agenda 21 (Chapter 18), which identified freshwater management guidelines to address the protection of the quality and supply of freshwater and the application of integrated water resource management. Specifically, the guidelines have focused on the following: integrated water resources development and management; water resources assessment; protection of water resources, water quality, and aquatic eco-systems; drinking water supply and sanitation; water and sustainable urban development; water for sustainable food production and rural development; and impact of climate change on water resources.

UN Secretary General's Initiative on Water, Energy, Health, Agriculture and Biodiversity (WEHAB)

The UN Secretary General proposed the WEHAB (water, energy, health, agriculture and biodiversity) initiative, as a contribution to the process leading to the World Summit on Sustainable Development (WSSD) in Johannesburg. The initiative emphasizes the interrelationships between environmental protection and poverty alleviation, and highlights the critical role of water in all the priority areas. UNEP has participated in the WEHAB Working Group on Water, which has delineated necessary actions in areas such as capacity building and technological needs, access and availability, allocation and social issues.

Bonn International Conference on Freshwater

This Conference, organized in 2001 as a WSSD preparatory event for freshwater, was centered on the theme "Water – a key to sustainable development." The Ministerial Declarations confirmed the commitments of governments to reach the development targets agreed by the UN Millennium Summit. The Declarations also recommended actions to improve water governance, mobilizing financial resources for infrastructure, maintenance, research and capacity building, technology transfer for sustainable water management, as well as participatory approach to strengthen the role of women.

World Summit on Sustainable Development (WSSD)

One of the main outcomes of the WSSD in 2002 was the recognition that water and sanitation are inextricably linked to the eradication of poverty and to the achievement of sustainable development. The United Nations Millennium Development Goals (MDG), which was agreed upon at the Summit, includes the following major targets for water and sanitation:

- Halve the proportion of people without safe drinking water by 2015
- Half the number of people without access to sanitation by 2015
- Develop integrated water resource management and water efficiency plans by 2005;
- Provide new and additional financial resources for water management.

Third World Water Forum (WWF3)

The Third World Water Forum (WWF3) and its Ministerial Conference, which was held in Japan in 2003, resulted in a "Portfolio of Water Actions", which included 400 actions submitted by 36 countries and 16 international organizations. Most actions relate to water resources management and benefit sharing, and safe drinking water and sanitation. The Ministerial Declaration stressed the importance for each country to develop strategies to meet the Millennium Development Goals. It also called for the doubling of expenditures on water infrastructure in developing countries, public-private partnerships, and better legislative frameworks for resource protection and pollution prevention, mobilization of financial and technical resources, as well as knowledge and data sharing.

Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA)

The Global Programme of Action for the Protection of the Marine Environment from Land-based Activities was established in 1995 to strengthen regional and national efforts to protect the marine environment. The GPA sets the goals and priorities for UNEP activities in the management of the coastal and marine environment, focusing on the flow of chemicals, waste, and other pollutants into the sea. With the continuing development of the regional seas conventions and action plans, the GPA will be translated into national, regional and global objectives, with concrete activities to address the different pollutant source categories and physical degradation of coastal and marine eco-systems. The GPA provides the foundation for action in urban water issues that are of particular relevance for UNEP DTIE, including the promotion of cleaner production process to minimize treatment and water supply degradation, development and dissemination of EST to reduce demand and to increase supply in collaboration with other UN agencies, and support the GPA implementation through the development of Programmes of Action at the national, sub-regional, and regional levels.

International Year of Freshwater

Year 2003 is the International Year of Freshwater, and numerous activities have been undertaken to raise awareness on the importance of freshwater and its sound management.

Appendix B: Other Programmes and Initiatives

A list of selected international organizations involved in urban water issues:

American Water Works Association: http://www.awwa.org
Asian Development Bank, Water and Poverty Initiative (WPI): http://www.adb.org
European Commission, EuropeAid:
http://europa.eu.int/comm/external_relations/index.htm
Global Environment Facility: http://www.gefweb.org
Global Water Partnership: http://www.gwpforum.org
International Development Research Centre, Wastewater Treatment and Reuse for Food Security; Water Governance: http://www.idrc.ca
International Water Association: http://www.iwahq.org.uk
International Water Resources Association: http://www.iwra.siu.edu/
UN Development Programme, Public-Private Partnerships for the Urban Environment (PPPUE) Innovative Partnership Grant: http://www.undp.org/pppue/national/index.htm
UN Food and Agricultural Organisation: http://www.fao.org
UN University International Network for Water, Environment and Health (UNU/INWEH): http://www.inweh.unu.u
UNESCO: http://www.unesco.org/water/ihp
UN-HABITAT, Water for Asian Cities: http://www.unhabitat.org/
UNICEF, Water, Environment and Sanitation (WES):
http://www.unicef.org/programme/wes/
UNIDO: http://www.unido.org/
Water Environment Federation: http://www.wef.org/
Water Supply & Sanitation Collaborative Council: http://www.wsscc.org
WaterAid: http://www.wateraid.org.uk
World Bank: http://www.worldbank.org; Water and Sanitation Program (WSP): http://www.wsp.org; Bank-Netherlands Water Partnership Program (BNWPP): www1.worldbank.org/publicsector/civilservice/pospartner.htm
World Health Organisation: http://www.who.int
World Water Council: http://www.worldwatercouncil.org

Panel Discussion II for Track 1, Part 2

Moderator: • **Jing Yuan Wang,** Nanyang Technological University, Singapore

Panelists: • **Wendy Nero,** CH2M HILL, Tampa, Florida, USA

• **Chizuru Aoki,** United Nations Environment Program, Japan

Moderator: Good afternoon, ladies and Gentlemen. Thanks for joining this panel discussion II. We have heard about two excellent presentations from Ms Nero and Dr. Aoki. I think it is time to discuss further. Therefore, I would like you to raise your questions to these two experts now. This is not only limited to these two presentations, we can discuss other issues related to the whole day. So let us open the discussion for the floor, thank you! We have heard presentations about U.S experience, and United Nations experiences. I think it is good to listen to the experiences of other countries as well, including your local regional experiences.

Question: I attended Ms Wendy's beautiful presentation and lectures on watershed management. In urban areas, the population will increase as years moves, more people will migrate to the cities from other parts, and more activities are going to take place. So what is the better way? How can we go exist with the development of urban areas, more houses, more roads, things like that, and other concern is water quality. What is the best approach to follow?

Wendy Nero: I think this is the huge challenge, we know more now than we did certainly fifteen, twenty, thirty years ago. We know what the effects of urbanization are. We know how storm Aral changes as a result of paving over certain areas. We know how it changes the ability of recharging especially the areas like Florida. The other matter that we need to go now is, to be willing to properly evaluate and value the environmental system. And what it means in terms of quality of life, economy sustainability, and the value of preservation. I think we need to accurately value economic, I mean the environment as commodity if you will, especially in American, the capitalistic environment that we are within. If we cannot play value in dollar terms on the environment, it will never keep pace with other economic drivers. I think just now we are beginning to do that. So I think we are able to measure it, we need to have regulations in place when we can establish fair value for the environment. So, whether it is minimum percentage of the land, or land is a certain type, or restoration or medication, let's say, you develop a portion of watershed, where you created medicated areas or constructed areas that created equal value in environment protection else where. One of the other programs is that we are working with, in watershed area called pollution trading. For example, we have an industry that wants to come into a watershed, but we know that there are additional discharges that will exceed the total maximum daily load of that particular water body. Yet, we know upstream there is an agriculture area where a farmer was considering converting his land and selling to an urban developer. We had such a broken system we can identify what is the pollutant loading then ask the industry to pay the farmer very economical value for his land to preserved it as an environmental side site or as an open place to medicate the total impacts of the watershed. So clearly in America, the economic drivers and economic evaluations of environment have to be part of our solution. As does affected of planning and we consider the role of environment place in how we are developing our communities. So that is one way the world is approaching.

Question: I am from Bangladesh. Bangladesh is known as a developing country. We have 57kms boundary, 54 of which with India and 3 with Myanmar. Bangladesh watershed areas are 92% outside the country, so it is a unique problem. In the monsoon session, a huge water causing flood, while on the other side of dry season. As Bangladesh is an agriculture-based country, irrigation is one of the problems. So we have different problems. In this regard, what should we do?

Wendy Nero: Again it is not a question that I have an easy answer. I think everyone discusses so far in terms of range dealing with addressing transfer bound problem of shared water resource. So, I assume there is a good dialogue between the Bangladesh government and India on what you have done to come to an agreement, at least on how to manage, or how to come to the agreement on management of water resources. And I also understand my presentation is focused on water and drinking water issue and didn't touch on irrigation issue. But I understand there is a big issue on drinking water contamination in Bangladesh, which the primary reason for you to go into groundwater. Pumping was the major form of contamination of surface water, which was leading to water worm diseases. So to coordinate this case, there are situations where you try to address one situation in expecting to get the other problems. From new prospective, the government of Bangladesh has put together the technology verification and all the water irrigation programs, but into place with substantial funding from the World Bank. And I think they are also addressing the science and technology aspects, the effective pumping also for drinking water and irrigation. And what kinds of hydrological effects harm on your aquatic places? So, at least that kind of studies will provide you some information and technology on how to address this issue. I am sorry. I don't have a good answer.

Question: I am from Thailand. I would like to ask about the definition of some words. More than ten years ago I heard of the public participation, after that I heard public hearing, and today I heard of that the public involvement. I'd like to ask you whether these three words have the same meaning.

Wendy Nero: I would say public participation and public involvement are similar, maybe identical, but that is very different from public hearing. Public hearing has no much opportunity for real interaction, and development of knowledge and understanding. We have found that the most effective public hearing doesn't make sounds of casting. But if we have done a good job, involve the public to develop the program to development the project, then we get the time when we require the public hearing. If nobody showed up, we are addressing the concerns along the way. Public involvement, on the other hand, is very interactive, on going, exchange of information and ideas so that we can fully understand the issues and concerns of the stakeholders, whether they are directly affected stakeholders, interesting stakeholders or who believe themselves to be affected, so the involvement truly is engaging them in the discussion of, what is the objective in the mission of the program of the project? What are the goals we hope to achieving and the outcome and result? What are we will to pay to get it? What are the alternatives that can help us to meet the great point of the goals or objectives? What time frame do we want to have that accomplishment? How can public continuous to be involved participate in the decision making? These are the differences I see in those three areas.

Chizuru Aoki: Just one thing I would to make up to that, public involvement and participations, state holder has a pretty clear understanding the process in decision making and times. They are sign of clear responsibility to screw out the process that represents certain consistency or certain positions of a given group they were representing. Hearing maybe only part of the process but whoever shows up, the group voice of his opinion is only for one group of listeners. So the process based approach, which is embed the public involvement or participation is the more systematic way.

Question: Would you please recommend on successful public involvement process?

Wendy Nero: Clearly for successful public involvement program, it has to be linked to the decision that is going to be made on the given project; you have the right State code invited into the process. And we have decided to invite more people into the process and let themselves chose not to participate. Because if you resist their participation, that becomes their source of confutation, or that becomes the reason why they oppose e your answer. So link their involvement to decisions, invite more than you may need, let them participate, invite your biggest staff position because you can't be successful until you know their posing. Don't have the predetermination answer in mind, manage the expectations because if you have a predetermined answer, they can influence the outcome, then you position of selling your solution, which will work. If you can make a commitment to engage them, honor your commitments. So if say, you have a public meeting in three weeks, have it. If you have a citizen advise community, make sure they understand the role and responsibility. Make sure that the leadership of your organization of your country follows through and commits to the process. You don't want to start this and discontinuous because it comes confutation or uncomfortable. So you need to have a full commitment on the part of you leadership, your government or agencies to involve the public and carry through. The worst scenario you can have is to create next expectation of participation and involvement and then not carry at all. These are just some ideas on how we apply successfully on lots of different projects.

Chizuru Aoki: Just a couple of additions. You want to clarify the process of the decision making so everyone knows what the rules, the responses he or she or the organization has; you want to assign responsibilities, you are afraid what? And you want to share information, especially if the information is going to be used for the actual decision-making. These people is supposed to be involved in the decision making process, so the information should be shared and the process should be transparent. And also, you want to take an ample time and finally you don't necessarily or might not, and you definitely donnot want to make it to be political exercise. This is a more policy-making exercise, not a political exercise by itself.

Question: I worked in central India. Because of the interests by my friend from Thailand regarding the public participation, I thought I might share my experiences with you. In Bangladesh, in the last four years, public participation in irrigation management has been enforced by legislation. We have three criteria of irrigation management system: major projects, medium projects and minor projects. In major projects, we have Water User's Associations, Distribution Communities and Projects Communities. In medium projects, we have Water User's Associations and Projects Communities. And in minor projects, we have Water User's Associations. State holders elect their representatives, who manage the water resources themselves. They are empowered by legislation to manage water resources themselves. There is a provision for incorporating women representatives. That way in our State, during the last four years through the legislation process, empowerment of the public representative has taken place, this is a successful example. In case, if any one of the delegates is interested, I would be willing to share our experiences much more. Thanks you!

Moderator: Thank you, other than these negative involvement concerns, sometimes you might want to involve some professional engineer association, for example, U.S. American Society of Civil Engineers have been doing a lot of lobbying, if you can have a local chapter, they get involved to do a very active work and they might be positive. So, any other questions?

Question: Ms. Nero, I have a problem and maybe definitions. Recently in some European countries such as in Netherlands, a new approach is arising in flood management. They called it resilient strategies for sustainable flood management and used it very successful, and all the methods, all the strategies for flood control, they called old strategy are registered strategies. They say that, in the old strategy, the registered strategies, they resist floods. They prevent floods by, for example, be link depth. But in the new approach, they say that in resilient strategies for sustainable flood management, we do not prevent floods, but we learn how to live with floods. And so for achieving sustainable flood management, one should integrate that approaches. But as you state in your presentation, integrated approach not only deals consequences but eliminated the causes. Elimination flood means prevented. It seems it is a paradox between integrated approach and resilient approach. I want to have your idea about this paradox.

Wendy Nero: I think our intention was not to say that, it was resist or control the flood. But I think as we try to point it out is, to have the land use planning practices. For example making sure we can define the flood plain and then prohibiting any development in the flood plain. So when the flood does come and it will come, whether urbanize or do not, we do not have the same kind of consequences. I think in another application would be, to have the land uses where you can develop till to the steam bank but we have buffer zones and nature vegetation habitat along long stream bank, so I think perhaps to saying a more similar kind of approach strategy, then, you may have interpreted and I think the world might be different. But clearly our strategy recognized that, with urbanization you have increased drain off and you are going to increase the consequences result of that. But in the integrated approach, is to do as much prevention of impacts, not prevention of flooding. But prevention of impact of what we know be the flood vents to proper planning and proper practices. I would be curious to get your reference on the resilient approach from the Netherlands.

Moderator: Wendy, I have a question for you. I was listening to your presentation and it was on the watershed management. First is just recently in Taiwan, because there is an argument on how to conserve the watershed that cost the Minister to quit the job. And another thing is in the morning, our Minister mention about in Singapore, we are going to increase the watershed catchments from currently 50% to 67% in a few years time. In this case, would you give some free advice if Singapore is going to increase this catchments area to 2/3 of the whole land area. Because, as you mention, we have picked of those low fruits, so fifteen percent may be a maximum, or the more we increased, the more it is difficult. How to save money?

Wendy Nero: The question is getting harder today. It is not easier this time of the day. You know as your target, I don't have the quick solution other then I guess. I am curious to say if you have open space to increase the catchments for 15-16% added as it was said, and if do you have open space what environment impacts and trade of without of that. But I understand that the objective of having the ability to meet the demands locally with local supplies. But not knowing enough about the rest constriction and environmental consideration I can't answer that. I will have the answer by Friday. Ok, thanks!

Chizuru Aoki: May I have a question, is it permitted? What kind of relationship that is available in Singapore for rainwater harvesting?

Moderator: I will try to answer, but I may need my colleague from PUB to help. We have about 240 cm of the rainfall per year. I think you proposed household, we have about 14 or 15 reservoirs to catch rainwater, and this contribute to 50% of overall water use for Singapore, and the other half was imported from the neighbor country.

Comment: I am from PUB, Sorry I didn't get your question.

Chizuru Aoki: My question was, for example, countries like Japan or Korea, there are rainwater harvesting initiatives at major public buildings, for example, the household to collect rainwater for certain applications. And I was wondering because if those things were promoted, other countries perhaps have one of the options to complement your water balance.

Comment: Say in Singapore, we also try to catch as much rainfall as possible, that is why you see that presently about half of the land area are water catchments areas, meaning whatever drops of rainfall would get into reservoirs. The other half was left off more because the land uses itself. With that kind of land uses, the runoff to the reservoir, the quality may not suitable for treatment by conventional method. So we try to catch as much rain as possible. So inside the catchments itself, it is really not necessary to further catch within the building inside the catchments. In another wider scale, it is more cost effective to capture on the peaks of such of catchments, so we have skin slide storm water collection system, which is implemented in new housing estate. When during planning stage, a new town, we planning together with varies planning agencies such like Housing Board and the treatments departments when it was not part of PUB, such the drains under cover kind of conditions to a certain collections points system, where we then centrally pumping to reservoirs. That is the selective collection of the new town sort of runoff. And with that, we were able to sort off go into selectively cleaner catchments, but eventually, it still about half of the land area it catching. So we did not go into individual collection of new town because the characteristic of the rain is very short but it can be quite intense. Now with the advance of the technology of the water treatment, we could go into the membrane and all that, and therefore, we could look into now. That is why you heard from the Minister this morning, we are getting into the Marina, the Singapore river. Whether will be Temasek, you can have that area, that basin, that is behind them as catchments, additional catchments area. And other reservoirs altogether eventually will catch about 2/3 of the whole land area. Those areas presently are not catchments area, somebody wants to develop rainwater collection system, if it is economical for them to do so, we encourage.

But we don't force them in that sense, because, we know automatically we will come in with the catchments on a bigger scale. I hope I addresses.

Chizuru Aoki: Thank you!

Comment: Yes, that will subject to the detail study of the topography, where dam should be in the position, so that can catch whatever the catch area. It depends on the topography, where is the reach line? where is the catchments area? the storage, and you can play around to the storage to integration to maximize your yield. If it is economical, individual developer want to collect that, we will allow them within the catchments.

Moderator: There is another thirty minutes to go, so ask your question, please.

Question: I am from Korea. This morning, I gave some questions to Wendy so I'd like to skip Wendy. From Dr. Aoki, in your presentation, you give a global perspective of the water resource management, especially, in urban setting. From your presentation it is really whelming that our human activity, you know, smoking, ice cream and cortex consumes that much money. We can really improve the water quality and sanitation standards tremendously. But that again, it reminds me over the lunch I talked about the affluent to society. It is very difficult to differentiate between the necessity and luxury. That is human psychology. Another thing, I 'd like to make a comment is the percentage of UFW, which was some part of the city cross to 40%, which is very alarming. We should concerned about the quality too, not only quantity. When we lose that much of water, actually the system is not closed, it has a lot of chance too, outsides contaminants can get in. so that will be a lot of problem. Not only quantity but also quality problem. Another thing I want to make a comment is, in Asia, in some pacific region we use160L/day. I wonder whether this much of water is really appropriate quantity. But after all, when we talked about minimum water quantity, I think by UN statistics, 40L is the bare minimum to subsistence. If that is the case, 160 liter/day may be more than enough. For water, we still I think very limit, very generous, so we may go for some target, consumption, which is appropriate, whether it can be developed countries, developing countries. So we should utilize whether low technology or medium technology, rather than high technology. When they talk about the diminishing in town in your presentation, then we go for advance technology, When we meet that debate, such as rainwater catching, it is properly very low technology, but we can really make some difference. So I think we have to utilize all the options, low or medium technology first before we go for high technology. And then, the kind of thoughts for the some practical result, can you adapt that kind of resolution at the end of this conference to set some consumption target, or at least UNEP IETC member which is double to 800 by 2005 or by increase to 600 by 2010.

Chizuru Aoki: I saw it in your last comment. It would be lovely if we can double our staff members, double our budget and do more things. For all those things that I would request you talk to Minister about it when they come and meet in Feb. I think in Jeju-do Island in Korea, special governing session, they will come up with some resolutions to strengthen institution. We will very much welcome that, and I think if there have more additional funs we can do lot of more, thanks, no question about it.

In terms of your first comment on how human beings given the luxury, they will consume more, yes, you are absolutely in right of that. Having of that, I think especially, in developed countries, in certain European countries, probably not in U. S as much. The whole concept of the sustainable consumption limiting the volume of how much resource in raw material we can consume? And moving more towards focusing on the function on product of bodies. It is something that emerging. There is an awareness and opposition from developing countries to move quickly into sustainable consumption debate, because, you know the presumption that all the OECD countries, when they had water resources that they are turning out that we can use it anymore, so it is pretty sensitive political issue but we really have to incorporate more sustainable consumption those life style, that for sure. Use of low and medium technologies, I agree, I think Korea is one of a key country where the rainwater harvesting at the household and also municipal level, not moving more catching system. But having some system within the building, and using the water for cleaning for example, or for toilet if they have will. Korea is a very active clear area and I believe that the regional Rainwater Catchments Association is actually housed in South Korea. This is the area we hope to work more into to development easier to employment and easy to maintain program.

Moderator: I am talking about this technology. I think I will totally agree with you, which start from low, medium and high or even advance, especially, for these APO member countries. I think we need to development these kinds of more appropriate technology. I can share with you an experience; I recently visited the University of Technology in Harony, in Vietnam. I had a discussion with research institutes, and we talked about membrane. Say, how is the perspective using membrane, treating the drinking water in Vietnam? We both agree it is not sustainable, you can built up a beautiful RO, UF, MF system there, but after the consumption of the first piece of the membrane it might be dead, because the operating cost might be too high. So this kind of consideration of thinking should be developing in APO member countries. Appropriate technology, when we talk about advance, we are talking about economics, it is very expensive. But appropriate technology may be low, medium, high, but it could be high-tech that is cheaper. This is more appropriate. Thank you!

Question: I come from Eastern part of India, there was a lot of problem in water scarcity, and therefore we have a lot of water harvesting matters. Before we have derived water policies, we have also derived policies for urban development in environment. And in this, we have calculated the ideas of water harvesting. In all of these water policies, water management methods were almost concerned. Therefore, what we have done, we have taken it first, made by other departments (be the Irrigation Department, be the Public Engineering Department, Environment Department and Local Department). This integration has done a lot of good, a lot of positive effects on the water harvesting matters. And for almost all, which we have taken is, we have made it mandatory for all the building permissions given by local police to go for the water harvesting. That is being made mandatory. Needless to say that it spend almost for three years, this water resource policy is quite developed. And the water scarcity is feeling for sometime is dramatically reduced. So I think making water harvesting matters mandatory for building permission and other agencies probably be good for water management. Could I make the point?

Then regards to watershed management, Ms Wendy had talked about many things of water quality management. Basically, the water quality management not watershed management, because, watershed management has so many other aspects, which have to be taken care of. Anyway, in our India national context, properly watershed management is mainly the conservation of water. I mean the water, which is going to reverse and to the sea. We have to conserve it, we have to revert it, collect it and use it for the proper purposes. And watershed management, when we use this term, it is mainly conservation of water for varies purposes. Wendy talked about water quality management, is definitely one of the aspects of watershed management. There are so many other aspects. It is composite of very large area. Therefore, watershed management mainly by addressing towards the water quality management would not surprise properly. Particular in Asian context, our watershed management is more on water quantity than on other aspects.

Wendy Nero: Yes, I appreciate your comments. That is fine. I'd also like to say to that I took a piece from watershed management and focused on, but very straight, permanent requirements and watershed management policies, which do account for the water supply issues. I think the issue was raised here if you're catching or retaining every drop of water that fall in your given geographic area, what you're doing to preserve the down stream flows, and help the elsewhere near the shore waters. So when we look at watershed management, it takes into account what the nature watershed look like! How much you can capture and store on site? How much you can manage and what you need to manage to flood from the water quality perspective? Then, how much you need to allow the stream flows for overall water habitat in the environment protection? So is it the multi-approach and I think you are right that it does include many things about what I was talking this morning, and that is the area where I focused on. Yes, absolutely you have to manage the water resource.

Question: May I ask you another question? In your slide, you show 100 years floodplain, can you give us the criteria on how to select the data for different years for each area, for 50 years period something like that, for each area? Thank you!

Wendy Nero: You meancan I define establishing criteria for 100 years flood plain?

Comment: I mean that some area maybe important, why you choice 100 years flood plain in your presentation?

Wendy Nero: You know I am not sure about that, to be honest with you. That is typical default planning flood that you are measure and plan for. The probability of one in one hundred years event occurring, if it happened, what was the boundary of those flood water being on un-impact area? And that is based on historical rainfall trend limited, we have the historical data, and we know the flooding patterns to be given topographies environment.

Moderator: Any other questions, issues, comments? Ok, now I think it is time to close this session. And I hope you enjoy your staying in Singapore and see you tomorrow, thank you!

TRACK 2 : DEMAND MANAGEMENT

MANAGING SINGAPORE'S WATER DEMAND FOR SUSTAINABILITY

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Singapore

ABSTRACT

Singapore has to manage its growing water demand efficiently so as to stretch its limited water resources to the fullest. The efficient management of the demand must entail the implementation of water conservation measures and the proper handling of the transmission and distribution network to minimize losses.

For the past 5 years, Singapore per capita domestic water consumption has been about 165 litres/day – among the lowest compared to cities of the same density elsewhere. The UFW in Singapore has also reduced from about 10% in the early 1990's to about 5% in 2002, amongst the lowest in the world. These can be attributed to the effective measures taken under the water conservation plan as well as the implementation of comprehensive UFW control programs.

In recognition of PUB's achievement in the control of UFW, PUB was awarded the first IWSA-ASPAC (International Water Supply Association – Asia Pacific Group) Water Prize in 1996.

GROWING DEMAND

Growing Water Demand

Population increase coupled with rapid industrial, economic and social developments has resulted in an increase in water demand. In 1950, the population was slightly over a million and water demand was 142,000 cubic metres per day. Today, the population has increased 4 times to 4 million while water demand has grown some 10 fold to 1.36 million cubic metres a day.

Water Demand Management

The Public Utilities Board (PUB), the national water authority in Singapore, has always adopted a 2-pronged approach in the management of the national water supply for sustainability. The PUB endeavours to develop water sources to meet our needs on one hand, and places great emphasis on the need to control water demand on the other hand. While our water supply has been secured with the four National Taps – Water from local catchments, Johor Water, NEWater and Desalinated Water, we also have to manage the demand of water so as to stretch our supply sources and make them last.

Again, a 2-pronged approach is also adopted to effectively manage our water demand – by implementation of water conservation measures to keep potable water consumption in check and by the efficient management of the transmission and distribution system from water source to the customer tap to minimise the unaccounted-for water.

IMPLEMENTATION OF WATER CONSERVATION MEASURES

A comprehensive water conservation plan targeting both domestic and non-domestic customers is in place to ensure that water is used efficiently. This plan is regularly reviewed to ensure that our limited water resources are stretched and effectively utilised. The plan covers:

(a) Public Education and Publicity Programme;

(b) Mandatory Installation of Water Saving Devices;

(c) Fiscal Policy - Water Tariff;

(d) Legislative Measures;

(e) Water Recycling and Substitution;

(f) Water Audit;

(g) Water Efficient Homes Programme; and

(h) Best Practices

Public Education and Publicity Programme

The Board has an on-going public education and publicity program to educate the public on the importance of water conservation and the need to save water. The main objective of the program is to effect behavioral change in the way water is being used so that saving water becomes an ingrained habit. The various activities targeted both the domestic and non-domestic sectors. Some of the major activities carried out were:

Save Water Campaigns and Sustained Publicity Programmes

Month-long National Save Water Campaigns (SWCs) were held on the need basis, especially during the drier months, to remind the public of our scarce water resources and to use water wisely so as to avoid water rationing. It is also important to reinforce the water-saving message in between campaigns so as to sustain public commitment to the water conservation effort. In this respect, sustained publicity programs are carried out. Some of these activities are:

- Disseminating water conservation messages through the media;
- Conducting water interruption exercises;
- Distributing publicity materials such as water-saving leaflets, posters and stickers to customers;
- Setting up water-saving exhibitions at constituencies, hospitals, community centres, schools, shopping centres, hotels, etc;
- Posting water-saving tips and information on water saving devices on PUB website; and

- Conducting water conservation talks

Educating Our Young

The education system serves as a useful platform to educate the young, especially during their impressionable years, on the importance of saving water and the need to cultivate good water saving values. The numerous activities implemented include:

a) Inclusion of water conservation topics in school textbooks;

b) Set up of water conservation centre to educate and promote water conservation to students, the general public, community clubs and grassroots organizations as well as visitors from overseas.

c) Conduct of water conservation talks at schools;

d) Conduct of waterworks visit for schools;

e) Conduct of water conservation seminar for teachers;

f) Distribution of animated video cassette disc (VCD) on The Adventures of Captain H_2O to all primary and secondary schools. In the VCD, Captain H_2O, who is our champion for water conservation, leads the viewers to discover many ways in wise use of water. He also teaches that water is a precious and strategic resource and it is important to save water.

3P Partnership Involvement

Participation of community, including institutions, large customers and grassroots organizations, in water conservation is also part of our publicity and educational program. These community members have responded well by organising activities such as distribution of water-saving leaflets, signing the Save Water Pledge, conduct of essay and art competitions and organising water-saving exhibitions

We have also maintained close liaison and consultation with Government agencies and various industries such as the Singapore Hotel Association and the Singapore Confederation of Industries to promote the sharing of water conservation know-how through exhibitions, conferences and seminars. Institutions are also encouraged to further their research and development efforts in developing more economical water recycling technology. This would facilitate companies to recycle more water in their processes and hence reduce their water usage and water bills.

PUB also has regular dialogue sessions with the Singapore Plumbing Society and the Singapore Sanitary Wares Importers & Exporters Association on water fittings and plumbing standards and practices. The frequent dialogue is a good communication approach to obtain regular feedback as well as to establish good rapport and understanding with the various organizations.

In addition, PUB is also represented in the Singapore Environment Council's Environmental Awards Steering Committee. The awards give recognition to companies who have adopted a proactive approach towards environmental management in the areas of water conservation, waste minimisation and energy conservation.

Mandatory Installation of Water Saving Devices (WSD)

Installation of constant flow regulators and self-closing delayed action taps was made mandatory in all non-domestic premises and common areas of all private residential apartments and condominiums since 1983. The maximum allowable flow rate for all water fittings has also been revised downwards to 6 litres/min for basin taps, 8 litres/min for sink/kitchen/bib taps and 9 litres/min for all shower taps (except for hotels). This flow rate requirement was similarly extended to all water fittings in domestic premises.

Since 1992, low capacity flushing cisterns (LCFCs) that use not more than 4.5 litres of water per flush were installed in new public housing developments. These cisterns are an improvement over the dual flush cisterns that use 4.5 or 9 litres of water per flush. With effect from Apr 1997, installation of LCFCs was made mandatory for all new premises and on-going building projects, including all residential premises, hotels, commercial buildings and industrial establishments.

Other mandatory measures put in place include the installation of pre-treatment facilities for all boilers to reduce boiler blow-down and the recycling of water in any cooling system. Recycling facilities are also a requirement for any bath having a capacity exceeding 250 litres.

Fiscal Policy – Water Tariff

Pricing of water is an important and effective mechanism in encouraging customers to conserve water. Water should be treated as an economic good. The water is priced not only to recover the full cost of its production and supply, but also to reflect the scarcity of this precious resource and the high cost of water from developing additional sources.

Legislative Measures

Legislative measures have been put in place to deter water wastage. The relevant measures are covered under the Public Utilities Act, Public Utilities (Water Supply) Regulations and the Singapore Standard CP48: 1989, Code of Practice for Water Services. Punitive measures for non-compliance include fines and/or court prosecution.

The legislative measures are constantly being reviewed to keep abreast of the latest development in the area of water conservation.

Water Recycling and Substitution

All applications for water supply must be submitted to Water Department, PUB for approval. In evaluating the water requirements, PUB advises the applicants to adopt water conservation measures which include the recycling of process water and the substitution of potable water with NEWater, high grade industrial water, industrial water and sea water wherever feasible for their non-potable usage.

In Singapore, many industries, particularly the electronic and electroplating industries, have implemented various recycling systems to reuse their process water.

PUB also produces industrial water and NEWater for non-potable use. NEWater is high grade reclaimed water that has undergone stringent purification and treatment process using advanced dual-membrane (microfiltration and reverse osmosis) and ultraviolet technologies. Since last year, PUB had approached building owners in the NEWater supply zone to substitute potable water with NEWater for use in cooling towers as well as process use. NEWater is now being used by some commercial premises for cooling towers and by wafer fabrication plants for process use. The supply of NEWater would be progressively extended to more industrial and commercial customers for their non-domestic usage. Industrial water is also being used in place of potable water for cooling, washing and process applications by more than 60 companies in Jurong and Tuas Industrial Estate, including Jurong Island. In addition, seawater is also being used by industries located near the seafront for cooling and general washing purposes.

Water Audit

As part of the Board's efforts to promote water conservation, regular water auditing is carried out by PUB officers for large customers (consumption more than 5000 m^3/month). The visits are part of a market-oriented program to obtain industries' feedback on our water supply and to work with customers on the implementation of water conservation measures within their premises. During the audits, customers are also advised to monitor their own water consumption, check for leaks regularly and ensure that the flow rate at the water fittings is not excessive.

Water Efficient Homes Programme

A 6-month long pilot project conducted by PUB in the second half of 2002 showed that a reduction of monthly water consumption per household could be achieved through the installation of water saving devices. In Feb 2003, PUB launched a new water conservation program, Water Efficient Homes. Together with its 3P partnership approach involving residents, grassroots and suppliers, residents are encouraged to run Water Efficient Homes by installing water saving devices and adopting good water saving habits. In this outreach program, do-it-yourself (DIY) water saving kits is distributed to the residents free-of-charge for self installation. Mobile exhibitions will also be held to brief and demonstrate to residents the effectiveness of the water saving devices and their installation procedure.

Best Practices

Another pilot project conducted by PUB showed that a flow rate of 2 litres/min at the wash basin taps in staff and public toilets is sufficient for normal washing purpose. Under the pilot project, the flow rates at the wash basin tap in the toilets of several major government, institutional, private and commercial buildings were reduced to 2 litres/min. Feedback from users revealed that they did not encounter undue inconvenience with the reduced flow rate.

Since then, the Board has sent circulars to large non-domestic customers to urge them to reduce the flow rate at the wash basin taps in all their staff and public toilets within their premises to 2 litres/min. The response has been encouraging. In addition, these customers they are also encouraged to conduct checks on the water fittings in their premises to ensure the flow rates are not excessive and to adopt best water conservation flow rates for the various water fittings as shown in the table below.

Table 1 Best Water Conservation Flow Rates for different taps

Area of Usage	Best Water Conservation Flow Rates (litres/min)
Basin tap & Self-Closing Delayed Action Basin tap	2 (toilets) 4 (others)
Sink/kitchen tap and wash area	6
Shower tap & Self-Closing Delayed Action Shower tap	7
Other areas	6

MEASURES IMPLEMENTED TO REDUCE UNACCOUNTED-FOR WATER (UFW)

UFW is the difference between the amount of water supplied from the waterworks as measured through its meters and the total amount of water accounted for. UFW effectively comprises:

(a) apparent water loss arising from meter inaccuracies and improper accounting of water used in the commissioning and filling of new mains, connections, service reservoirs and for cleaning and flushing of the water distribution system during maintenance; and

(b) actual water loss due to leaks and illegal draw-offs in the transmission and distribution system.

UFW is often taken as a measure of the efficiency of the water supply system. In Singapore where our water resources are scarce, measures taken to control UFW will, by reducing wastage, not only bring about a reduction in operating costs but also allow deferment of investment in capital works.

In the early 1990's, Singapore's UFW was about 10% of total output. This high percentage of UFW was viewed with concern and PUB thus intensifies its efforts to reduce its UFW by implementing various measures broadly categorized as:

(a) leakage control

(b) full and accurate metering policy

(c) proper accounting of water used

(d) strict legislation on illegal draw-offs

Leakage Control

Use of Better Quality Pipes and Fittings

The first step towards reducing UFW was to minimize the occurrence of leaks in the transmission and distribution network. This was done by introducing new and better quality corrosion-resistant materials for new pipelines and tightening supervision of pipelaying work to ensure high quality workmanship. The objective was to ensure that newly-laid pipelines are watertight.

Since 1980 the use of unlined cast iron and galvanized iron pipes have been prohibited. More durable and corrosion-resistant piping materials such as copper, stainless steel and ductile iron which are internally lined with cement mortar have been used. The use of such materials has helped to prevent leaks in the water distribution network.

Mains Replacement Programmes

PUB carried out a ten-year replacement program (1983 – 1993) for all unlined cast iron water mains and unlined galvanised iron connections. Under this program, all unlined cast iron water mains were replaced by cement-lined ductile iron pipes and all unlined galvanised iron connections were replaced by copper or stainless steel connections.

The replacement program is on-going and a computer based system is used to capture information on mains such as the location, type, size and age of mains, details of leaks and repair works. The data captured are used to plan the mains replacement program. Problem areas and potential problem areas are identified and prioritized for early replacement. Water mains that are more than 50 years old or having 3 leaks or more per km per year were identified for replacement.

Besides the mains replacement program, every opportunity is exploited to constantly review and upgrade the transmission and distribution system through the following measures:

- Replacing old pipeline systems with new ones in the areas undergoing redevelopments.
- Using better quality materials for water pipes and fittings to reduce leaks.
- Regular maintenance and servicing program for the transmission and distribution network.

These programs and measures have been effective in reducing the number of leaks in the transmission and distribution system. The number of reports on water main and connection leaks has decreased by half from 1991 to 2002.

Leak Detection Programme

To curb water wastage due to leaks in the transmission and distribution system, an intensive leak detection program is being carried out for all mains in the system throughout the year. Zones with older mains and leak prone areas are checked twice or even three times a year. It involves detecting leaks by visual inspection along all pipeline routes and by use of Acoustic Leak Localisers (ALLs) to quickly identify the potential areas of leakage along the distribution mains. Once the leak areas have been identified, the leak detection team will be mobilized to pinpoint the leaks using other precise leak detection equipment for follow up repair work.

Quick Response to Public Reports of Leaks and Rectification of Faults

The extent of water loss from a leaking main depends on the length of time between the occurrence of the leak and the isolation of the main. Here, public co-operation in reporting leaks is essential. To facilitate public reporting of leaks, PUB operates a 24-hour call centre, PUB-One, where the Board's customers can contact us through the 6 multi-channel contacts namely telephone, fax, emails, SMS, web-chat and voice-over-IP. The centre is also equipped with modern data recording and retrieval systems and communication system. Some 92% of urgent complaints received were attended to within 45 minutes.

Public Education and Publicity Programme

PUB has an on-going education and publicity program to raise the level of public awareness on the need and urgency to conserve water. The public is reminded constantly on the ways to conserve water and to report leaks immediately to facilitate quick repairs.

The public is also actively encouraged to read their water meters regularly to monitor their consumption. By doing so, unexplained high consumption due to leaks could be promptly detected and rectified.

Full and Accurate Metering Policy

In Singapore, the entire water supply system from waterworks to customers' premises is 100% metered. This is done for two main reasons, i.e. to account for usage and to bill customers. There are currently some 1.1 million customer accounts, of which 92.5% are domestic accounts and the remaining 7.5% are commercial and industrial accounts.

Types of Water Meters Used

The accuracy of waterworks output meters is of utmost importance as any error in registering the production output would grossly affect the water balance account. PUB has since 1985 replaced the waterworks output meters with electro-magnetic flow meters. These meters are highly reliable and accurate to within 1 % allowable error for flow rates from 0.5 to 1.0 m/s and 0.5% allowable error for flow rates above 1.0 m/sec. To ensure reliable and accurate flow measurement, the waterworks output meters are checked monthly based on volumetric measurements by using the draw-down of the clear water storage tanks in the waterworks.

Besides leaks in the water distribution system, under-registration of customers' consumption by water meters is also an important area when addressing UFW. PUB uses water meters of sizes 15 mm to 150 mm in diameter. The Board ensures that all meters in service are accurate to within 3% allowable error by:

- Purchase of purchasing good quality accurate meters; and
- Replacement of meters through bulk-changing programs.

For domestic consumption accounting, PUB uses 15mm meters complying with ISO 4064/1C standard. These meters are able to register more accurately at low flow rates.

The pattern of water consumption by large customers like factories and commercial complexes can be very complicated with a wide range of fluctuation in water demand from very low to very high flow rates. PUB has since 1985 purchased compound types 50 mm, 100 mm and 150 mm meters. Compound meters have main meters to register high flows and by-pass meters to register low flows and thus have better flow-capturing characteristics. The use of compound meters has ensured that customers' consumption is registered to within 3% allowable error. This has helped to reduce the UFW.

Meter Maintenance and Replacement Programmes

PUB operates a meter workshop for maintaining and testing meters. Since 1985, in-service testing of meters has been carried out periodically to check the accuracy of various meters in service. Meters randomly selected according to model, size, period in service and location are returned to the meter workshop for accuracy testing. The results obtained are useful in evaluating the effectiveness of particular meter models and deciding on the replacement or bulk-changing intervals and frequencies.

Domestic meters are bulk-changed with new meters on a ten-year cycle to ensure that meters function within their 3% allowable error. For larger meters, a seven-year replacement program is adopted to ensure that accuracy to within 3% is maintained. In addition, water meters serving very large customers are replaced within a shorter period of less than 2 years.

A computerized billing system which incorporates a check program is used to verify the readings taken from meters. Any abnormally high or low consumption case is automatically detected by the computer during the billing process and isolated for further investigation. This enables defective meters and leaks in the customers' reticulation systems to be identified and rectified early.

Proper Accounting of Water Used

Significant quantities of water are used for commissioning and filling new mains, connections, service reservoirs and for cleaning and flushing during the maintenance of the water distribution system as well as for fire fighting. As the improper accounting of the water used for such purposes will affect UFW, PUB has put in place a monthly reporting system which ensures the proper accounting of the water used. All personnel involved in such operations are continually made aware of the importance of accurate reporting of such usage.

Strict Legislation on Illegal Draw-offs

There have been very few cases of illegal or unauthorized draw-offs in Singapore. This can be attributed to legislation and stringent enforcement on illegal draw-offs. As a deterrent, anyone found responsible for carrying out an illegal draw-off is prosecuted in court under the Public Utilities Act.

CONCLUSION

Singapore has put in place a comprehensive water demand management program to ensure the efficient use of water by both domestic and non-domestic customers. The water conservation message has been successfully driven home through the public education and water efficient home program. Industries are encouraged to substitute potable water with NEWater, high grade industrial water and industrial water. These water conservation measures coupled with the comprehensive UFW control programs and the latest technology will increase the efficiency of water use and help to achieve water sustainability.

RESOURCE CONSERVATION USING GREEN PRODUCTIVITY APPROACH

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ABSTRACT

Green Productivity (GP) program, established by the Asian Productivity Organisation (APO) in 1994, was drawn from the integration of two important development strategies, i.e., productivity improvement and environmental protection. By implementing GP approach properly, less resource would be consumed because of the reuse, recycle, and recovery of input materials (e.g., using less water in the process). Natural resources can be saved because less waste (e.g., wastewater) would be discharged into the environment and hence less impacts to natural resources (e.g., watercourse and sea). This paper describes how natural resources can be conserved using green productivity approach.

RESOURCE DEPLETION AND CONSERVATION

Due to rapid industrialisation and urbanisation over the last two to three decades, many Asian countries have observed a significant quality deterioration of their natural resources. On the other hand, because of the increase of materials consumption (was often related to increasing living quality!), the demand of raw materials has been significantly increased. These two factors have been causing fast resource depletion directly or indirectly. There is a pressing need to develop a sustainable approach to better manage and use the existing resources including water, land, energy, and other invariable raw materials.

ESTABLISHEMENT OF GREEEN PRODUCTIVITY

Before 1950s, the common response to pollution was to ignore it. Pollution issue was never a problem because the extent of pollution was relatively small and the environmental awareness was not high. In the late 1960s, mainly because of the introduction of the National Environmental Protection Act (NEPA) by the US Congress in 1969, environmental issues started drawing public attention. However, the common approach to pollution remained at the stage that "best solution to pollution is dilution". Industries tended to disperse concentration of the pollutants, for instance, by building high stacks and extending pipelines into the sea to dilute their wastewater strengths. It was soon realized that many pollutants were toxic even at small concentrations and some chemicals retained their toxicity for a very long period of time. These pollutants accumulated in soil and water eventually caused reversible or non-reversible damages to natural resources.

In 1970s, because of environmental legislation and regulations, discharges from industries were required to treat before sent into the rivers and sea. Various treatment technologies or processes were developed and widely used. This was the origin of the so-called "end of pipe" approach. As the discharge standards became more stringent, the cost of such "end of pipe" treatment of wastes became more expensive and affected the economic viability of some industries.

Despite the high costs, the "end of pipe" treatment approach was found to be far from adequate. Pollutants were not eliminated but merely transferred from one medium to another (or one phase to another). The responses came in various forms maturing gradually from command and control regimes to the voluntary systems emphasizing prevention of pollution at its source, cleaner production and environmental management systems such as the ISO 14000 series. These voluntary systems were found to be more cost-effective than using a command and control approach alone. Consequently, the waste management concept has been shifted from "treatment" technologies to "prevention" techniques.

Recognising the new balance required between environmental protection and economic activities, the Asian Productivity Organization (APO) established a Green Productivity (GP) program in 1994. The GP concept was drawn from the integration of two important development strategies, i.e., productivity improvement and environmental protection.

GP is in fact a strategy for enhancing productivity and environmental performance for overall socio-economic development. It is the application of appropriate techniques, technologies and management systems to produce environmentally compatible goods and services. GP is applicable to not only the manufacturing sector, mainly small and medium-sized enterprises (SME), but also the agriculture and services sectors.

An attractive feature of GP is that it leads to gains in profitability through improvements in productivity and environmental performance. Excessive use of resources or generation of pollution is indicative of low productivity as well as poor environmental performance. In many ways these are manufacturing defects that need to be consistently set right. To improve the situation, GP pursues a strategy based on technical and managerial interventions. It is a process of continuous improvement.

- The first step in this process is to identify ways to prevent pollution or waste at its source as well as reduce the level of resource input by the process of rationalization and optimization. Possibilities of reuse, recovery and recycle are looked into to salvage the wastes generated.
- Next, opportunities for substituting toxic or hazardous substances are explored to reduce the life-cycle impact of the product. At this stage, the product itself is examined including packaging in the framework of design for the environment.
- Finally, the wastes in its residual forms are treated adequately to meet the regulatory requirements both from the perspectives of the workspace and the receiving environment. In order to ensure a continuous improvement in the productivity as well as in the level of environmental protection, a management system is developed, much on the lines of Environmental Management System of ISO 14000 series.

Throughout the above process, proven productivity and management tools are employed. This approach is important because it shows that GP is not a new set of skills to be learned, rather it is the application of well-known tools and skills to a new set of priorities. Also, it shows that GP can be implemented within an existing quality program, which is very important to business people who are reluctant to try implementing a new program because of the time and organizational resources required.

By implementing GP approach properly, it is expected that less resource would be consumed because of the reuse, recycle, and recovery of input materials. On the other hand, natural resources can be saved because less waste would be discharged into the environment and hence less impact to the natural resources.

GREEN PRODUCTIVITY APPROACH

Green productivity intends to lead to the maximum feasible reduction of a1l pollutants generated at production sites. It is a method of multimedia pollution control and management that focuses on reducing the generation and discharge of pollutants (gaseous, aqueous, and solid) at their sources to avoid subsequent handling, treatment, and disposal. It involves the judicious use of resources through source reduction, energy conservation, reuse of input materials during production, and reduces water consumption.

Green productivity encourages industry to reduce pollutants at the source and to recycle pollutants on-site rather than to treat and dispose of them into the air, sewers, waterways, groundwater, and land. This is the preferred strategy for dealing with pollutants; strategies are often referred to as the "environmental management options hierarchy". The highest priority is assigned to preventing pollution through source reduction and source elimination. Recycling and reuse are considered the next best way to handle pollutants. Effluents and emissions treatment (e.g., biological degradation of toxic industrial wastewaters, well controlled incineration of hazardous wastes, or removal by smokestack scrubbing of pollutants from air emissions) is next most important. Finally, legally permitted disposal, for example, putting waste-filled barrels in secured landfills, or disposing of chemical wastes in deep wells, is the least desirable waste management technique.

These approaches are grouped separately into the following three areas: source reduction, recycle and reuse, and designing environmentally compatible products (APO Resource Persons, 1999 and Chiu and Peters, 1994).

SOURCE REDUCTION

Source reduction includes practices that reduce the amount or toxicity of any waste, hazardous substance, pollutant, or contaminant entering a waste stream (or otherwise released to the environment) prior to external recycling, treatment, or disposal. Source reduction measures generally fall into three main categories: input material changes, process changes, and energy conservation.

Input Material Changes

Hazardous substances can be introduced into a process in the input materials used to manufacture a product. These hazardous materials can be present in both the primary (raw) materials used to manufacture a product (e.g., hydrocarbons used to make plastics) and the secondary materials. The latter are not a component of the product, but are used in the manufacturing process (e.g., solvents used in cleaning process equipment). Input material changes fall into two major categories: material substitution and material purification. Under material substitution, e.g., water-soluble cleaning agents can be used, in many cases, in place of organic solvents that may have to be disposed of as hazardous wastes or recycled off-site after they are used. Under material purification, higher-purity raw materials may be used to reduce the quantity of wastes generated.

Process Changes

Process changes are concerned with how the product is made. They include technology changes and improved operating practices. All such changes reduce worker exposure to pollutants during the manufacturing process. Process changes may be implemented more quickly than input materials changes. Typically, improved operating practices can also be implemented more quickly and at less expense than input material and technology changes.

Technology Changes

Modifying the technology used to produce a product is one of the most effective methods of preventing pollution generation. A company can prevent pollution and increase production capacity and yield; improve product quality; and reduce costs for raw materials, utilities, handling, etc. But because technology changes generally involve greater personnel and capital investments than do procedural changes, and because the results usually take longer time to realize, they are generally investigated after procedural changes have been implemented.

Although some technology changes may apply only to specific processes, the general categories are (1) process modifications, (2) operational adjustments, (3) equipment modifications, and (4) automation improvements.

- Process Modifications: Modifying a process to prevent pollution means developing an alternate process to obtain the same product specification, while generating less waste.
- Operational Adjustments: Operational adjustments are changes in the way process equipment operates, not in the actual process or equipment.
- Equipment Modification: Equipment modification can reduce pollutant generation by reducing equipment-related inefficiencies. The equipment is modified, while the process remains the same.
- Automation Improvements: An automated system monitors and adjusts process-operating parameters to maintain the most efficient conditions.

Improved Operating Procedures

Procedural aspects of a manufacturing operation include the management, organizationa1, and personnel functions of production. Improved operating practice can be implemented in all areas including production; maintenance; raw material, product and waste handling; and storage. Because good operating practices can often be implemented at low cost, they usually have a high return on investment. Furthermore, they usually produce positive results relatively quickly. The following practices should be eva1uated.

- Material Handling and Storage: All production facilities store raw materials, intermediates products, and industrial wastes and transfer these items from one area of the plant to another. Proper material handling, transfer, and storage minimises the possibility of spills, leaks, fire, and/or explosion, or any other losses that could result in waste.
- Scheduling Improvements: Batch production of a variety of products using common equipment plays an important role in generating pollutants.
- Spill and Leak Prevention: Spills or leaks of chemicals generate waste. Washdowns and mop-ups, using absorbent materials, create additional waste.
- Waste Stream Segregation: Hazardous waste that is normally hauled to off-site disposal facilities is often a combination of two or more waste stream types or one type of waste and water. Segregation at the source can reduce the quantity of disposal of hazardous wastes.
- Personnel Practices: Green productivity programs can vary from simply pollution awareness programs, where managers and employees are asked to identify ways of reducing the generation of waste, to complex programs that are independently staffed by corporate personnel and that extend to worldwide operations.

Energy Conservation

Production facilities consume energy basically in two different forms: electricity and process heat. Combustion of fossil fuels in primary heat sources such as boilers or fired heaters provides a major source of heat input to industrial processes. Nearly all energy used in most manufacturing facilities is generated by processes that consume materials and generate pollutants (gaseous, liquid, and Solid) that pollute the environment if released directly. Any action that conserves energy would reduce the quantity of pollutants from energy-generating processes. On the other hand, actions that reduce pollutants would lower the expenditure of energy for waste handling and treatment.

Combustion of fossil fuels in primary heat sources such as boilers or fired heaters provides a major source of heat input to industrial processes. Thermal energy can be conserved by taking care to prevent its loss during transport from the combustion site to the specific processes where it is used.

Other than the above 3 practices, a good housekeeping actually can make operational practices more resource efficient. For instance, preparation of recipes in right quantity to avoid surplus, efficient handling of materials, optimum storage procedures to avoid losses and material degradation during storage etc., are all illustrative examples of good housekeeping. It has been the experience that in small-scale industries, good housekeeping alone could lead to a reduction in waste generation up to 20-25%. A good housekeeping can be achieved by inventory management and inventory control.

RECYCLE AND REUSE

Recycling and reuse options rank in the environmental management hierarchy as the next most preferable methods following source reduction techniques. The general category of recycling is a broad one; encompassing options with varying degrees of transportation, handling, or processing. Often, these options are referred to by a variety of names: recycle, reuse, reclamation, or recovery. Whatever the name, this methodology is advantageous for a number of reasons: it conserves natural resources, avoids waste management options, such as treatment or land disposal, and reduces the need for raw materials to a process, thereby lowering costs. However, recycling and reuse options can incur somewhat increased risk and liability due to additional handling and management of materials.

Some recycling/reuse options are ranked in terms of generally decreasing preferability, based largely on risk or liability: (1) reuse in the same process, (2) off-site recovery, and (3) recovery of energy value.

Reuse in the Same Process

Waste material generated in a manufacturing process in many cases can be reused in the original process with or without treatment to remove impurities. For example, material containers (such as 55-gallon drums) can be reconditioned and reused with minimal efforts. If waste material cannot be directly reused in the original process because of potential contamination, it may be treated to remove contaminants. For example, organic solvents used in parts cleaning and pharmaceutical manufacturing processes are often collected, distilled, and reused in the original process. If reuse in the same process is not possible, an alternative use (with lower raw material specifications) within the plant may be found. For instance, contamination is a key concern in the electronics industry. Solvents used to clean circuit boards may contain very few contaminants and can be reused as cleaning agents in degreasing operations or as a thinner or ingredient in paints. In another case, an electroplater may have a customer who requires that a new electroplating solution be prepared just for his parts. Once these parts are finished, the electroplating solution still meets specifications for routine electroplating operations. Subsequently, this solution can be directly reused in another electroplating operation, thereby saving raw material and reducing costs. Again, this option avoids expensive treatment of discarded solution.

It may not always be feasible or economical to recover waste at the operating unit that generates it. If a plant has a number of different departments and processes generating waste solvents, a central distilling department within the plant may offer economic advantages. A single recovery operation may be less expensive from both a capital and operating labour standpoint. The disadvantages of this type of operation are the additional storage, segregation, and handling requirements, all of which increase the possibility of environmental incidents and liability. The overall economics of centralizing a recovery operation must be assessed on a case-by-case basis.

Off-site Recovery

If on-site recovery and reuse options are not feasible, the next step is to investigate contracting with off-site services. The recycled material could be either returned to generator for reuse at the generation site, or sold for use at other facilities. Again, the potential for liability increases somewhat with the move to an off-site waste management facility. A waste stream must be characterized (composition and generation rate) before it can be sent off-site. Recovery firms usually require fairly constant composition and relatively high generation rates. These requirements are becoming less restrictive as competition between recovery firms increases along with pressure to avoid using treatment and disposal. The basic recycling options vary depending on which party, either the generator or the recycler, gets the recycled material. In most cases, the recycler markets the recycled materials.

Selling or giving away waste products for off-site reuse is sometimes possible. The key is to match generator and potential end-users. Outlets for materials may be found through material exchanges, waste exchanges, waste brokers, commercial recyclers, or cooperative agreements. Large firms often have investment recovery operations that can help locate potential users. Routinely generated by-product or waste streams with consistent specifications may be sold through marketing organizations in many firms. These materials can be handled just like typical products.

Recovery of Energy Values

The last form of recovery is salvaging energy rather than raw materials. This option is preferable to destructive techniques, such as incineration or land disposal. The waste can be processed in a variety of ways; such as in cement kilns or asphalt plants, co-firing fossil-fuel-fired plants, or in incinerators equipped with an energy recovery system. Larger firms with their own power generation facilities may have the flexibility to co-fire moderate-to-high energy content wastes. Waste characteristics, such as chlorine content or ash compositions, may restrict their use as a fuel either because of regulatory requirements or concern for boiler corrosion. All firms have the option of blending commercial fuels. These fuel-blending programs are usually run in conjunction with treatment or incineration firms. Such firms blend a variety of high-Btu wastes with varying compositions, from a number of generators, to produce a fuel with particular specifications. These blended fuels are usually fired in cement kilns or asphalt plants. Waste generators considering such alternatives should perform site inspections and investigate the blending firm and the ultimate user of the fuels. Full regulatory and legal reviews should also be conducted.

Incineration is the last form of energy recovery. Some hazardous waste incinerators and many refuse incinerators are equipped with energy-recovery equipment. While some major facilities operate either or both types of incinerator, most firms must investigate off-site treatment recovery. These facilities should also be investigated from economic, regulatory, and operational standpoints. While these facilities reduce volume and generally toxicity, air pollutant generation and the final incinerator ash disposal must still be considered and may impact a generator's liability.

DESIGNING ENVIRONMENTALLY COMPATIBLE PRODUCTS

Environmentally compatible products minimize the adverse effects on the environment resulting from their manufacture, use, and disposal. The environmental impact of a product is to a large extent determined during its design phase. By taking environmental considerations into account during product, planning, design, and development, a company can minimize the negative impact of its products on the environment and help reduce the pressure for conserving the depleting natural resources.

Design changes made to prevent pollution should be implemented in such a manner that the quality or function of the product is not affected adversely. Design for the environment can be achieved by the people directly involved, within the framework of company policy and with support from company management, whether or not in response to incentive external to the company.

The product manufacturer with the purpose of reducing waste resulting from manufacture, use, or ultimate disposal of the products performs product changes. Product changes could include product conservation and product design changes.

Product Conservation: Product conservation refers to the way in which an end product is used. For example, better maintenance of process equipment and components by industry can decrease the frequency of equipment component replacement, which in turn reduces the waste generated by the used component. A manufacture can also alter a product to minimize the waste resulting from the product's end-use. For example, a manufacturer of lubricants could develop a product that lasts longer than conventional lubricants, thereby reducing the amount of waste lubricant generated.

Product Design Changes: Product design changes involve manufacturing a product with a lower composition of hazardous substances, or less toxic materials being formed, or changing the composition so that no hazardous substances are involved. For example, a manufacturer could use an active ingredient in a formulation with a non-hazardous solvent rather than a chlorinated solvent. Other examples include using mineral oil in electrical transformers instead of polychlorinated biphenyl (PCB) liquids or organic pigments in paints rather than heavy metal pigments.

When beginning to look at product design or redesign to make it environmentally compatible, the first step is to define the goals. When redesigning an existing product, goals will involve modifying those aspects of its performance that are judged environmentally unacceptable and that can be improved. Aspects that should be examined include whether it uses a scarce input material, contain hazardous substances, uses too much energy, or is not readily reused or recycled. These environmental criteria can be added to the initial program of requirements for the product, such as quality, customer acceptance, and production price.

The goals of new product design can be reformulation and a rearrangement of product requirements to incorporate environmental considerations. For example, the new product can be made out of renewable resources, have an energy-efficient manufacturing process, have a long life, be non-toxic, and be easy to reuse or recycle. In the design of a new product, these environmental considerations can become an integral part of the program of requirements.

In both the redesign of existing products and the design of new products, the methods applied and the procedure followed will be affected by additional environmental requirements. These new environmental criteria will be added to the list of traditional criteria.

SUMMARY

Due to rapid industrialisation and urbanisation over the last two to three decades, many Asian countries have observed a significant quality deterioration of their natural resources. On the other hand, because of the increase of materials consumption (was often related to increasing living quality!); the demand of raw materials has been significantly increased. These two factors have been causing fast resource depletion directly or indirectly.

This paper describes how natural resources can be conserved using APO's green productivity (GP) approach. By implementing GP approach properly, less resource would be consumed because of the reuse, recycle, and recovery of input materials (e.g., using less water in the process). Natural resources can be saved because less waste (e.g., wastewater) would be discharged into the environment and hence less impacts to natural resources (e.g., watercourse and sea). Three GP techniques: source reduction, recycle and reuse, and designing environmentally compatible products were discussed in details.

REFERENCES

APO Resource Persons. (1999). "Green Productivity Practices." APO, Japan.

Chiu, S.Y. and Peters, R. (1994). "Industrial Pollution Prevention." Asian Development Bank, Philippines.

WATER CONSERVATION AND EFFICICENT USE OF WATER

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OVERVIEW

Water conservation efforts in the United States began in earnest in the 1970s during record droughts in California. Since that time, water conservation has spread across the globe and is now embraced as an effective water management tool by utilities, businesses and government. During more than 20 years of implementing a variety of conservation practices, a number of lessons have been learned, data collected, and technologies developed. This paper discusses various conservation options, both indoors and outdoors, along with specific implementation strategies. The paper is organized as follows:

- Management, Policy and Education
- Water Conservation Opportunities for the Landscape
  - Maintenance and Repair
  - Irrigation Audits
  - Soil Moisture Devices and Rain Shut-Off Devices
  - Telemetry
  - Desert Scape
- Plumbing Fixtures
  - Maintenance and Leak Repair
  - Toilets and Urinals
  - Tank-Type Toilets
  - Flush-Valve or Commercial Toilets
  - Urinals
  - Showerheads
  - Faucets
- Appliances
  - Clothes Washers
  - Dish Washers; Domestic, Commercial

MANAGEMENT, POLICY AND EDUCATION

A number of studies have pointed to the importance of leadership, involvement and commitment of top management in conservation. In each study, the role of top management was emphasized and found to be directly related to potential water conservation.

Management actions important to maximizing potential savings include:

- Develop an understanding of water uses and potential areas for conservation
- Emphasize the importance of water conservation to employees and develop an employee involvement "system" to identify leaks, and other wasteful actions. Create opportunities for employee input and develop incentives to gain employee involvement. Once involved, recognize employee contributions and achievements in water use efficiency
- Establish measurable, clear goals and priorities for conservation
- Designate a "conservation manager," if one does not already exist, who is responsible for all aspects of conservation. If this is not possible, attempt to coordinate all functions directly related to water use under one area within the organization
- Prepare a conservation action plan, based upon the economic evaluation of the conservation measures considered as part of this assessment. Plan for future evaluation of conservation investments to ensure that savings are being realized and the program is modified if necessary
- Policy level management options include the following steps:
- Evaluate current policies and establish policies supporting efficient water management
- Make each organizational unit responsible for the costs of water, energy, and wastewater disposal, providing economic incentives to use water wisely
- Make it a maintenance policy to seek and fix leaks routinely, eliminate waste and prohibit unnecessary uses of water
- Publicize success of your efforts, not only to your employees but also to customers, the media, and decision bodies
- Employee education is also critical to conservation effectiveness and can include the following:
- Develop and deliver educational materials to provide background information about water use and the need to conserve
- Create audio-visual programs
- Print newsletter and paycheck stuffers to communicate ideas, announcements, progress reports, and news of special achievements
- Install conservation stickers in bathrooms, kitchens, and cafeterias

- Conduct workplace demonstrations/training
- Promote involvement and efficiency as an important opportunity to express environmental responsibility

WATER CONSERVATION OPPORTUNITIES FOR THE LANDSCAPE

Maintenance and Repair

Landscape maintenance is essential to ensuring water use efficiency for all irrigated properties. Maintenance efforts primarily focus on the irrigation system, but should also address mulching, pruning and fertilizing. Each of these elements plays an important role in the overall health and appearance of the landscape. Common problems related to irrigation include mixed sprinklers in the same zone, differing application rates and poor coverage.

Maintenance of the irrigation system should include a monthly inspection of all components including spray heads, time clocks, valves and soil moisture devices or rain-switches if present. When checking spray heads, make sure that turf or plants have not become overgrown causing interference with the proper function of the head. If heads are on risers or are pop-up heads, ensure that they are not cracked or broken. Heavy pedestrian traffic, vehicle traffic and lawn mowing equipment are notorious for breaking spray heads resulting in water losses due to leaks. Another consequence of broken or missing heads is the severe impact on distribution uniformity downstream from the break.

Another irrigation system maintenance requirement is to ensure that broken sprinkler heads are replaced with heads with matched precipitation rates as those in the same zone. Spray heads and rotors should not be mixed in the same zone, but often are.

Mulching, pruning and fertilizing are necessary to maintain healthy plants and grass. The following maintenance activities are recommended.

- Apply low nitrogen fertilizer to encourage root development and to replace essential nutrients.
- In all non-turf areas, the use of organic mulch is recommended. This will reduce evaporation, moderate soil temperatures, add nutrients to the soil and discourage weed growth. Mulches to consider include wood bark chips, wood grindings, pine straw, nut shells, small gravel, shredded landscape clippings and leaves.
- Turf areas should be periodically aerated, which is the removal of cores or plugs, from the lawn. Aerating increases water and air transfer to the root zone, which is vital for a healthy lawn. This is especially important in high pedestrian use areas and areas with poorly draining soils, such as clays. (Walker and Kah, 1995)

Irrigation Audits

Irrigation audits, or evaluations, are designed and performed to assess the efficiency of the irrigation system and watering schedule to ensure that sufficient water is being supplied for optimal plant growth, health and watering efficiency. Distribution uniformity (DU) is a key measure of efficiency when conducting irrigation audits and measures how evenly water is applied by the sprinklers. A DU of 70 percent is considered good. However, field studies show that DU is often much less than that. In addition to DU, irrigation scheduling is also critical to system efficiency, especially when it is common practice to over water as opposed to under-watering.

There are several ways in which the irrigation schedule can be modified to maximize effectiveness. These options include seasonal variations, variations by zone and frequency/duration of the irrigation event. Infrequent deep-watering is suggested to promote deep root growth, separate zones for shrubs and turf and seasonal variation to replace water lost to evapotranspiration are suggested.

Although similar to ongoing maintenance, an irrigation audit should be completed on a three year basis. Specifically, irrigation audits address the following irrigation system needs: 1) inspecting the irrigation system (includes looking for broken water lines, leaking or damaged heads, matched precipitation rates, proper head spacing, water pressure at each rotor, shrub or turf interference, alignment of heads, mix of sprays and rotors in each zone, separate zones for turf and shrubs, controller type and limitations, irrigation time for each zone, valve type (electric or hydraulic), 2) conducting a catch-can test to determine application rate and distribution uniformity, 3) determine soil type and root depth, 4) calculate total water use per cycle, 5) report results which should include recommendations to improve efficiency, suggested run time for each zone, estimated water savings (quantity and percent), suggested Best Management Practices (BMPs) for turf, and an estimate of the potential dollar savings associated with the changes.

Savings potential from irrigation audits vary, but commonly range from 20 - 30 percent. However, these savings tend to decrease over time. Audits would need to be performed every three years to maintain ultimate savings. The lack of persistence may be due to the need to frequently re-evaluate and tune an irrigation system, and changes in landscape personnel due to turnover. However, it is hoped that after several years of conducting these audits, the performance factors would become routine and ultimately practiced as part of regular maintenance.

Soil Moisture Devices and Rain Shut-Off Devices

Soil moisture devices and rain shut-off switches are designed to override the irrigation system, stopping an irrigation cycle when sufficient rainfall has occurred or when soil moisture is sufficient. In arid climates, rain shut-off switches have little application. Soil moisture devices, on the other hand, do offer potential savings in dry environment. Soil moisture devices vary in specification, but generally operate in a similar fashion. They are placed in the ground in an area that is typical of the area watered by that zone or sprinkler system, and are then wired to the time clock so that when a pre-set amount of soil moisture is present, they override the time clock and bypass the scheduled irrigation cycle. When the soil dries to a point below the pre-set amount, the timer automatically resumes its programd schedule.

Relatively little research has been performed on these devices. However, one study in Boulder, Colorado found that the amount of water which soil moisture sensors will save depends on the area irrigated and the weather patterns during the year. Based on the residential use data, "it is estimated that the average residential user will save between 30 and 50 thousand gallons per year by use of the sensors (Boulder, 1995, p.6)." This can be assumed to represent roughly an 18 -19 percent savings, compared to theoretical calculations.

Telemetry

Telemetry, or central irrigation control systems are gaining popularity as a means of improving efficiency and reducing water use. With a system such as this, all time clocks, valves and irrigation zones are linked, by wire or radio, and controlled by either a computer from a central location or radius in the field. The advantage to this approach, in addition to field labor savings, is the ability to monitor system performance on a real time basis. Additionally, irrigation amounts for each clock or zone are preset with some systems. If a line were to break and water supplied to that zone exceeded the preset amount, that zone could be automatically shut-down until field inspection could verify the break and arrange for repair. Another advantage of a telemetry system is that all schedule changes could take place in the central control room, allowing for easy modification to accommodate seasons, plant establishment or other needed schedule changes. Based on the use of a central irrigation system in Albuquerque, water savings of 12.5 percent were achieved.

Xeriscape

Xeriscape is a landscape technique that maximizes the use of native or drought tolerant plant materials and minimizes the use of turf. Other principles of Xeriscape address the use of micro-irrigation in plant beds, prohibits the run-off of irrigation onto paved areas, limits irrigation to the hours of midnight to 6:00 a.m. and prescribes preventive and efficient maintenance. There are seven commonly accepted principles of Xeriscape, which include planning and design; soil analysis; appropriate plant selection; practical turf areas; efficient irrigation; mulches, and proper maintenance. When compared to traditional landscapes, water conserving-type landscapes reduced water use from 30 - 60 percent. Actual savings depend upon the final landscape design and use of remaining plant materials. Savings potential is related to the amount and shape of turf in the landscape. The more turf removed, the greater the potential savings.

PLUMBING FIXTURES

Maintenance and Leak Repair

Leaky faucets and showerheads can waste considerable amounts of water. Based on an analysis of the Las Vegas Valley Water District, these leaks can account for as much as 3,600 gallons per day (gpd). The following table shows the amount of water wasted according the diameter of the drip.

Diameter of Drip/Stream	Gallons per day wasted
1/32”	170
1/16”	970
1/8”	3600

In addition to leaky faucets, a number of toilets also leak. In fact, a study found that the average toilet leaks approximately 4.1 gallons per capita per day (gpcd), which represents approximately five percent of indoor water use. Additionally, the absence of billing for personal water use leads to more water wastage due to leaks since their is no incentive to report or fix leaks. This was field verified in a study of a military installation in Arizona where two toilet households used more water per capita and per capita toilet water use above the national average.

Toilets and Urinals

Toilets are the number one water user in the home and account for the majority of water use in office buildings and institutional buildings (40+ percent) and a significant portion (27+ percent) of water used in restaurants. Toilets are often defined and classified according to their use (residential vs. commercial) or flushing mechanism. For purposes of this paper, they will be grouped as follows: 1) tank-type, gravity fed; 2) Commercial type equipped with a flush valve, and 3) urinals. For each of these classifications, there are conventional and water saving models available for installation.

Tank-Type Toilets

Tank-type toilets are what are normally installed in residential settings, with the exception being the occasional use of commercial types of fixtures in dormitories. Typically, toilets comprise approximately 28 percent of indoor water use in a non-conserving home or about 68 gpcd usage. Conventional tank-type, gravity fed toilets have an average flush volume of 3.8 gallons per flush (gpf), with the typical person flushing their household toilet 4 times per day (Anderson et al., 1993).

The National Energy Policy Act of 1992 (NEPA) was adopted and limits flush volumes for all toilets and flow rates for showerheads and faucets, nationwide. These new toilets, called Ultra-low Volume (ULV) which has been used in Europe for a number of years, were limited to 1.6 gpf. Prior to the adoption of the NEPA, a number of states and municipalities had already adopted 1.6 gpf ordinances and laws. Initially, there was considerable concern about the performance and actual water savings associated with the ULV fixtures. Numerous studies have addressed these concerns and have found savings that range from 30 - 46 gallons per household per day and customers are at least as or more satisfied with their ULV fixtures than with their conventional counterparts.

In multi-family replacements, the toilet savings are even greater, making toilet retrofits in multiple family complexes more cost-effective than retrofits in single family households . This is due to the fact that the average multi-family household has greater numbers of residents compared to single family homes. On the other hand, two toilet replacements do not necessarily mean that savings will double. Some toilets in the same household are used with more intensity than others and will, therefore, generate greater conservation.

Flush-Valve or Commercial Toilets

Commercial type toilets are often defined as flush-valve toilets and can be either wall hung or floor mounted. Commercial fixture replacement has only recently been performed. One study found that "on average, the replacement of pre-existing toilets saved approximately 76.8 gallons per toilet per day. However, considerable variation in savings was evident depending on the site analyzed. Variations in water savings followed some predictable patterns and were dependent upon the number of toilets, number of urinals, number of full-time employees and visitors, amount of time visitors spent at a particular site, and the number of hours per day, and the days per week the facility is operational." (Bamezai and Chestnutt, 1994, p. iv).

A second study also demonstrated significant savings when flush-valve type toilets were replaced in a junior high school. That study measured a 33 percent or 851 gallon per day savings.

Urinal

Urinals currently use between 1.5 - 2.0 gallons per flush. Water saving and waterless models are now available for use in commercial installations.

Waterless urinals have been in the U.S. marketplace for several years and are gaining acceptance as they are being tried and tested. According to one manufacturer, Waterless, Inc., waterless urinals were developed for the public sector in 1891. Improvements and use over the last 100 years have led to today's hygenic and odorless No-Flush (TM) urinal. The waterless urinals work on the following principle: the bowl is pre-coated with a urine and water repellent coating to prevent bacterial growth and encrustations, which often result in odor. A plastic trap insert is connected to the standard sewer line and is filled with a biodegradable liquid, Blue Seal (TM), which effectively forms the trap seal. This is possible because Blue Seal has a specific density lower than urine, allowing the heavier urine to quickly penetrate the seal. The trap liquid floats on the surface, sealing the trap and sewer, preventing odors from entering the atmosphere. One ounce of Blue Seal will provide an effective seal for up to 500 uses.

Showerheads

Water use in the shower is another major contributor to average daily water use. On a daily basis, showers comprise 22 percent of indoor water use and are equal to 16.5 gallons per capita per day. The average shower consumes approximately 15 gallons per shower. When replacing conventional model with 2.5 gallon per minute showerheads, water use can be reduced by 3.6 gpcd, and total shower volume reduced from 14.7 gallons to 8.9 gallons.

A number of years ago, early conservation measures attempted to install flow restrictors in existing showerheads, rather than replace them with an entirely new, redesigned low-flow model. Although the inserts were less expensive, user satisfaction was so low that they were removed, negating any potential water savings. Low volume showerheads are now available in a wide range of styles and have very high user acceptance.

Faucets

Compared to other household or process water uses, faucets comprise a minor amount of water use. Based on recent studies, faucets represented approximately 9 gallons per capita per day, or just 12 percent of indoor water use. However, replacement aerators, which reduce flow rates from 2.5 gallons per minute (gpm) to 1.5 gpm, are available and cost very little. A number of other water saving faucets are available for commercial use. These include spring loaded, timed or infrared activated faucets.

APPLIANCES

Since the widespread replacement of toilets with ULV models and the adoption of local, state and national standards, much of the future conservation initiatives are focusing on the next most significant water using technologies: appliances. Clothes washers and dishwashers represent 22 percent and 3 percent of indoor household water use, respectively. In commercial applications, the amount of water used by these machines varies considerably, according to the industry and age of the equipment.

Clothes Washers

Clothes washers are the second biggest water user in the home, behind toilets. On average, clothes washers consume approximately 18 gpcd. Additionally, clothes washers and related drying, use considerable amounts of energy. The Consortium for Energy Efficiency (CEE), established a number of efficiency standards on new washers. These standards include the following:

- Energy Factor (EF) - in accordance with USDOE test procedures and are expressed as cubic feet/kWh/cycle
- Water Use Factor (WUF) - total water used per unit of washer capacity, expressed at gallons/cubic foot
- Remaining Moisture Content (RMC) - as the RMC is lowered, the amount of energy needed to dry that laundry is lowered, almost proportionately. RMC is the weight of water specified in a test load after the spin cycle as a percent of the dry weight of the test load of clothes.

Several models are available and are often referred to as horizontal axis, or h-axis, which have been used successfully in Europe for many years. Water savings associated with the h-axis machines are reported to be as high as 60 percent, a 10 gpcd usage savings. Water used per washing cycle is reduced from 60 gallons per cycle (gpc) to 19 gpc with the h-axis machines.

In addition to the water and energy savings, it has been have determined that efficient clothes washers are significantly gentler on fabrics and have better rinsing and cleaning performance.

Dish Washers; Domestic, Commercial

In home water use by dishwashers is minimal, 2.4 gpcd or 3 percent indoor water use. However, the average life of a dishwasher is 15 years, and once replaced, water and energy savings will persist over time. The average dishwasher uses 9 gpc, with the typical household running the machine approximately 5 times per week. Efficient dishwashers will have gpc ratings of 5.6 - 6.0 gallons (Association of Home Appliance Manufacturers, 1994).

Commercial-use dishwashers, on the other hand, can comprise a large amount of water use when used in restaurants or cafeterias. Generally, commercial dishwashers fall into one of two categories: continuous flow of rinse water or periodic dumps of a wash tank. Some machines discard water from each rinse step, however, most modern machines re-circulate the water in a countercurrent fashion, and discharge only the water for final rinse.

In addition to water savings, energy savings are also achieved since the reused water is already heated.

Minimum standards for wash and rinse requirements for dishwashers is established by the National Sanitation Foundation (NSF). Typical requirements range from 4.5 - 6 gallons per cycle for sanitary rack machines using water for final rinse and approximately 2.5 - 3 gallons per cycle for similar machines using sanitizing agent. Water use flow rates in commercial dishwashers are typically from 2.5 - 8 gpm.

In addition to machine design and reusing rinse water for lower quality purposes, maintenance and operator habits can also improve efficiency. Regular maintenance should include routine checking for leaks and the establishment of a hotline or other procedure for reporting leaks. When reported, leaks should be repaired immediately.

Operator habits that should be encouraged and rewarded include:

- washing only full loads on the rack
- in conveyor-type machines, water should be allowed to flow only when dishes are actually passing through the dishwasher. If the operator cannot control this, most machines can be equipped with an "electric-eye" system that can "see" whether or not dishes are present and actuate the water flow accordingly
- install timers to automatically shut off unnecessary flows after hours
- install meters to quantify flows - evaluation, prioritizing future investments, effective management
- general maintenance and leak repair: seek and fix leaks routinely, eliminate waste and unnecessary uses

REFERENCES

Amezai. A and Chestnutt. T. W. (1994). *Water Savings From Non-Residential Toilet Retrofits: An Evaluation of the City of San Diego's Public Facilities Retrofit Program*. Report submitted to the Metropolitan Water District of Southern California. December.

Anderson. D. L. and Siegrist. R. L. (1989). "The Performance of Ultra-Low Volume Flush Toilets in Phoenix." *Journal of the American Water Works Association,* 81:3:52.

Anderson. D. L., Mulville-Friel. D. M., and Nero. W. L. (1993). The Impact of Water Conserving Plumbing Fixtures on Residential Water Use Characteristics in Tampa, Florida. *Proceedings of Conserv93*. Las Vegas, Nevada. December 12-16.

Association of Home Appliance Manufacturers Presentation at meeting. (1994). Washington, D.C. November 10-11.

Black and Veatch, Inc. *A Guide to Commercial/Industrial Water Conservation*. Prepared for the City of Los Angeles, Department of Water and Power.

Breckinridge. C. (1992). *Detailed Technical Evaluation of Conservation Programs for Seattle Water Department*. Seattle, Washington: Synergic Resources Corporation. March.

Chestnutt. T.W., Bamezai. A., and McSpadden. C. (1992). *The Conserving Effect of Ultra Low Flush Toilet Rebate Programs*. Report Submitted to the Metropolitan Water District of Southern California. Los Angeles, California.

Chestnutt. T. W., Moynahan. M., and Bamezai. A. (1992). "Ultra-Low-Flush Toilet Rebate Programs in Southern California." *Lessons for Water Managers and Planners*. June.

City of Phoenix Water Conservation and Resources Division. (1990). *Water Conservation Guide for Buildings and Facilities Management*. Phoenix, Arizona.

City of Phoenix Water Conservation and Resources Division. (1990). *Water Conservation Guide for Hotels and Motels*. Phoenix, Arizona.

City of Phoenix Water Conservation and Resources Division. (1990). *Water Conservation Planning Guide*. Phoenix, Arizona.

Consortium for Energy Efficiency. (1995). *High Efficiency Clothes Washer Initiative Program Description*. Consortium for Energy Efficiency (CEE). December.

Dietemann. A. (1994). Seattle Water Department. *Energy and Water Efficient Clothes Washers.*

Dziegielewski. B. *Reliability of the Estimates of Water Conservation Savings*. Carbondale, Illinois: Department of Geography, Southern Illinois University.

Helping Businesses Manage Water Use: A Guide for Water Utilities. (1993). Denver, Colorado: American Water Works Association. December.

Hetrick. L., of Briggs Industries. (1996). Personal communication. February.

Karpiscak. M. M., Scholze. R. J., and France. G. W. (1996). A Study of Residential Toilet Water Use at a Military Reservation. *Proceedings of Conserv96.* Orlando, Florida. January.

Kiefer. J. C., Opitz. E. M., and Brown. R. (1993). Estimated Water Savings from a Plumbing Retrofit Program. Presented at Conser93. Las Vegas, Nevada. December.

Kiefer. J. C. (1991). *Tampa Residential Retrofit Evaluation: Analysis of Pilot Program*. William & Davis. August.

Konen. T. P. (1991). *East Bay Municipal Utility District Water Conservation Study.* Report No. R219. Hoboken, New Jersey: Stevens Institute of Technology.

Macy. P. P., and Maddaus. W. O. (1989). "Cost-Benefit Analysis of Conservation Programs." *Management and Operations*. March.

Maddaus. W. O. (1991). *Water Conservation*. Prepared for the American Water Works Association.

Martin. G. (1993). Survey of Purchaser Opinions About Ultra Low Flush Toilets. *Proceedings of Conserv93*. Las Vegas, Nevada. December 12-16.

Mingledorff. N. (1995). *Proposal Price Comparison for Sensible Sprinkling Program*. Tampa, Florida.

Montgomery Watson, Inc. (1993). *Report for Water Conservation Plan.* Prepared for the City of Austin, Texas. March.

Mulville-Friel. D. (1995). *An Evaluation of the Sunset Park Landscape Irrigation System Conservation Program.* Prepared for the City of Tampa. December.

Mulville-Friel. D., and Nero. W. L. (1996). Water Savings and Participant Satisfaction Realized: City of Tampa Toilet Rebate Program Evaluation. *Proceedings of Conser96.* January 4-6.

Nellis AFB Master Plan Criteria, *Design Base Wide Landscape Plan.* (1995). Prepared for 558 Civil Engineering Squadron. Project number RKMF 94-0094, contract number F26600-94-D00105005. Las Vegas, Nevada: J.W. Zunino & Associates and Welles-Pugsley Architects. October 2.

Nelson. J. O. M. (1987). "Water Conserving Landscapes Show Impressive Savings." *Journal of the American Water Works Association.*.

Nero. W. L., and Davis. B.. (1993). Landscape Water Audit and Improvement Program:. Motivating Outdoor Water Conservation. *Proceedings of Conserv93.* Prepared for the City of Tampa, Florida. December.

Nero. W. L., Mulville-Friel. D, and Anderson. D. (1993) The Impact of Water Conserving Plumbing Fixtures on Institutional and Multi-family Water Use Case Studies of Two Sites in Tampa, Florida. *Proceedings of Conserv93*. Prepared for the City of Tampa. December.

No-Flush Urinals- State of the Art in Water Conservation. (1993). Waterless Company.

Operation Desert Lawn Watering Guide: - Strategy for Maintaining a Beautiful Lawn in Southern Nevada. Las Vegas Valley Water District.

Parker. G. B. (1995). Personal communication. December.

Planning and Management Consultants, Ltd. (1992). *Evaluating Urban Water Conservation Programs: A Procedures Manual.* Prepared for California Urban Water Agencies. February.

Present Worth Factors for Life-Cycle Cost Studies in the Department of Defense. (1996). NISTIR 4942-3. Prepared by United States Department of Commerce Technology Administration, National Institute of Standards and Technology.

Pugh. C. and Samuel, W. (1996) Bureau of Reclamation Standards and Codes. Initiative to Promote Water Conservation. *Proceedings of Conserv96*. Orlando, Florida. January.

Residential Handbook. Las Vegas Valley Water District.

Scholze. R., and Nemeth. R. (1996). Comprehensive Water Efficiency Assessment on a Large Army Installation. *Proceedings of Conserv96*. Orlando, Florida. January.

Strus. C. A. (1996). High-Intensity Military Water Conservation Audit Techniques as a Component of Comprehensive Energy Audits. *Proceedings of Conserv96*. Orlando, Florida. January.

Summary of Report: Performance of Soil Moisture Sensors During Two Years of Field Operations, City of Boulder, Colorado, Utilities Division, Office of Water Conservation. (1995). Boulder, Colorado: Aquacraft, Water Engineering and Management. April 20.

The California Appliance Efficiency Program - Revised Staff Report. (1977). California Energy Conservation and Development Comm., Conservation Div. November.

Vergari. M. (1996). Personal communication. February.

Vergari. M. (1995). Correspondence to Sgt. Metcalf, Nellis AFB. March.

Wagner. C. L. (1992). *Residential Landscape Comparison Survey*. East Bay Municipal Utility District.

Walker. R. E., and Kah. G. (1995). *Landscape Irrigation Auditor Training Manual (The Irrigation Association Certification Program).* 2nd edition. Water Conservation Office, Department of Water Resources, State of California. November.

Wallace. B. Correspondence to Doug Simon. (1995). CH2M HILL. December.

Wallace. B. Correspondence to Doug Simon. (1996). CH2M HILL. January.

Water & Sewer Use and Distribution Study. (1995).Contract Number: F08635-93-C-0068, Task Order: 068-4-19, prepared for: Department of the Air Force Headquarters Air Combat Command, Langley Air Force Base, Virginia. Submitted by Delta Research Corporation (Niceville, FL) and Dorgan Associates, Inc. (Madison, WI).

Water Management Guidebook for Industrial and Commercial Site Managers (draft). (1992). California Department of Water Resources, Division of Local Assistance.

Panel Discussion III for Track 2

Moderator: • **Chizuru Aoki,** United Nations Environment Program, Japan

Panelists: • **Joo Hwa Tay,** Nanyang Technological University, Singapore

• **Wendy Nero,** CH2M HILL, Tampa, Florida, USA

• **Han Tong Ng,** Public Utilities Board, Singapore

Moderator: Good morning, everyone, this morning we have three very interesting presentations. First of all, Professor Tay did a very nice job in explaining the evolution of the green productivity concept and put it into the framework of what we can think about. Then Ms Wendy Nero explained to us some of the different measures and options of water conservation and water demand management and shared with us some of the key programs that have been implemented in the various places of the United States. She also shared with us some of the water use data. Then Mr Ng shared with us his experience from PUB and two prone approaches of developing new water resources, as well as curbing water demand. So those are the presentations we saw this morning and I believe there are many questions that the delegates and participants would want to ask. So I would now like to open the floor to the questions. If you have any questions for the panelists, don't be shy! Now questions or any comments?

Question: Are there any green areas and problems when you are in a water conservation project?

Han Tong Ng: I think one area that we will be looking at is encouraging the customers to play an active role in water conservation. I just share with you the water efficient program that we are currently working on. We are targeting at the end of the year or rather at the end of the program to reach out to 800,000 households. Since there are a lot of programs being seen, we have distributed or passed about a quarter of million water-saving kits. Based on the survey that we have carried out, in all the launches of the various constituencies, probably one in three households actually installed the water saving devices on their own costs. That is why we want to encourage customer participation and we are in fact one step further in helping to install the water saving devices. What happens is that after each launch, we have a team of officers who actually go around and conduct survey on how effective the program has been and how many households have actually installed the devices. So one in three households have installed it. When we asked around, there are probably 10 to 20 percent who actually requested assistance. I think the green area you probably refer to would be getting customers to play an active role in conserving water. I hope that is the answer to your question.

Joo Hwa Tay: Can I add on to that with my personal experience? All the above mentioned is very good when you implement it properly. The customer has to play an active role as what Mr Ng said. I believe that we have been traveling around the whole region. You can see that all these water saving devices are used in toilets and in public. For some of them you press it down, it will stop with a certain time lapse. The problem is when you press it down, after you wash your hand and go away, the next time you wash it again, the water is still flowing because they are not properly maintained. This is happening all the time. They thought that by installing it, you solve all the problems, but they are not properly maintained. Another one is that using the so-called light scanning to turn on and off the tap. It has been used in a lot of countries now. So that means when your hand is there, the water is flowing. When you hand is disappeared, the water is stopped. It is good. But the problem is, sometimes when you put your hand there, the water will not flow, because the sensor is out, it is not properly adjusted and the position is not right. So a certain thing to do is as what our Pakistan friend says: “What is the problem? What is the catch?” The catch is implementation. I think that is what I want to share with you my real experience. Good device, good law but not properly implemented, I think it is not just as good as that.

Wendy Nero: We are seeing similar problems with toilets in the United States where a lot of defects have been observed since 1992. A lot of new fixtures are installed in new constructions, but the problem is the flappers. They are actually the devices to close off the tank. They are deteriorating under the water quality condition that we have. So over a period of about one year after installation, the flappers are deteriorating and the rate of leakage is much higher in these new toilets than some of others because of the flapper product material. Now we are beginning to have flapper replacement programs in new toilet replacement programs. I think the whole idea of maintenance is a big one and your savings can erode very quickly over time if you do not have active on-going maintenance on special devices.

Moderator: There are three key things that came up: participation that follow up, implementation and maintenance. Any other questions, comments, or sharing of your experience?

Question: What is the cost of this leak noise localizer? Is it an expensive thing and where we can get this?

Han Tong Ng: The one that I have shown on the slides counts as a set of six localizers. It comes with a box set probably with laptop. Each set probably costs you about 11,000 to 14,000 Singapore dollars. We do have a local supplier in Singapore. If you are interested, I can make a list of suppliers and pass it to you. You may want to get in touch with them.

Question: I have some questions for Ms Nero. You have mentioned some water conservation plans in the United States like Austin, Denver. My question first is that by whom are those plans designed and implemented? The second one is by whom is the water supplied? I mean who produces the tap water. Because when these two parties are different, especially when there is a private company supplying the tap water, there will be a conflict between water conservation and profit making. Because the more water you conserve, the less water they sell and less profit they make. My third question is: is there any conflict between these two interests in the plans you have mentioned? If there is, what is the approach you use to solve the problem? Thank you.

Wendy Nero: That is a long and prepared question. I hope I can take that. Usually I would say that in 99 percent of the cases the utility that produces the water and sells it is also the utility that prepares and implements the water conservation plan. The preparation of the plan can be done by internal staff or by consultancy’s assistance. Implementation can be done in the same way, either by the staff or through contact. We have seen a lot of what we call the "turn-key" contractors, especially for the large programs like the kits that PUB is distributing. You are hiring a contractor to come in and basically handle the whole program. You do not have to add a whole bunch of staff for a short duration program. There are some cases when, for example, the National Environmental Policy Act declared what the plumbing fixture standards had to be. That was an outside legislative activity that affects the utility, plumbing industries, homeowners and building industries. Sometimes you would have state or other local or regional regulatory agencies that have responsibilities for water usage permitting and water management that may have specifications in a permit, for example, permit conditions that limit the per capital or per day water usage or permit conditions that limit the amount of unaccounted for water or permit conditions that stipulate you have to have a inclining rate structure. So a lot of times you do see that scenario. We have not seen a great deal of conflict because most of the time the utility delivering the water is designing and implementing the programs. When it is a regulatory kind of program, we take a more of a negotiated or consensus-based approach to develop the regulations. For example, for the cloth washer regulation, I started working on that ten years ago and just now it has been adopted by law and will go into effect from 2007. We go to greatest extremes to reach consensus because if there is an opposition, it will not work in the long term anyway. That is how the conflicts will be resolved. Your example about the private entity and private utility, they would have a disincentive to have conversation, is not necessarily always the case. In fact, they are often under stricter regulations in developing new sources of supply than some of the public utilities are. They tend to have higher efficiencies. They tend to have better rate structures. They are not necessarily disincentive if they are willing to do conservation. Just they need to be cautious about the structure of their rates. They are making the profits they promised to the shareholders and still doing what is right to the whole environment. We are seeing more and more of that. Would you like to share you experience in Singapore?

Han Tong Ng: On Singapore side, PUB supplies water, and at the same time encourages customers to conserve water. It was said that PUB has a very poor organization because we do not know how to maximize profit. But the whole idea is, if we are able to encourage customers to conserve water, we are actually deferring the capital investment costs in sourcing for new water supply sources. That is how we approach to the problem.

Question: I have a question for Ms Nero. It is a very simple question compared to the other questions they asked you. You showed in your slides about the usage of water and you compared a couple of household plans. One of them was dishwasher. I am just curious to know if some comparative studies have been done on the water usage between the amount of water that have been used by a dishwasher and conventional cleaning by hands. Whether there has been a study to show that dishwasher uses less water or washing by hands uses more water. Thank you.

Wendy Nero: I do remember seeing something about that. It has been quite a long time ago. I think it depends on the behaviors of the person who washes either by hand or with a dishwasher. If I recall the study correctly, a full dishwasher is more efficient comparing to an inefficient hand washing operation. Clearly, it can swing in either direction. If somebody is very efficient in hand washing and only has three cups in the dishwasher, the dishwasher turns to be an ineffective tool. Overall, the use of dishwasher is relatively small component of the total indoor waster use of the residence. I will try to look into that study and give you a card. I will see if I can send you the results from that. It has been quite a while. I think it has been updated by recent studies that were completed about two years ago. I just want to add that there are a lot of studies that have been carried out also in Japan to compare the water and energy usages from hand washing versus dishwashers. The other aspect is, especially in the United States, the replacement demand for dishwashers from old models to new models. There are also some studies that have been done to see how efficient the plan have become, because in the US, the availability of dishwashers and the percentages of households with dishwashers are much higher than Asian cities, including Japan.

Joo Hwa Tay: I would like to go back to the comment on the overall approach. It is not the matter of how much water we save or waste on using hand washing or dishwasher. It is actually a matter of fact that it is human behavior that makes the difference. For example, the dishwasher itself is designed to take the heavy load. However, if you look at a family, for convenience, they put two cups and use the full cycle of the washing machine. It is common. It is convenient and it is human behavior that wastes water instead of the machine that wastes water. The other one is that I happened to stay together with the students in the dormitory. The students sometimes dump even a single singlet into the washing machine after sports because they do not have to pay the water bill and electricity bill. So the whole cycle of the washing machine is to wash one of his underwear. It is very common. I tried to stop it but how can I stop 600 students doing the same behavior? No matter what study we are conducting, basically it turns out to how consumers behave themselves. You can have all the studies, but ultimately, if you wash two cups in dishwasher, of course the study will show that dishwasher was definitely not efficient. But, life goes on; quality of life has to be improved. Are we saying that because of this kind of waste of water, we have to go there and use our grandmother's hands and wash our clothes? Anyway, we can not go back. We appreciate the technology advancement, but the human behavior and mind-set have to change to be in line with the technology advancement.

Han Tong Ng: My comment would be similar as what Professor Tay has mentioned. From PUB side, we always encourage the public that whenever you wash, you wash with full load. We have actually done some preliminary surveys. We find that the feedback is that a household intends to wash probably 3 to 4 times a week. We asked some households, they said sometimes they wash with half load or even with quarter load. It is the households whose habits we actually want to change. At least they know what water conservation is in the household.

Question: I just want to ask and draw your attention to your figure on the unaccounted for water. In 1989, it was 10.6 percent, which has come to 5 percent in 2002. This is essentially the waste of your water which is taking place. Is this that thing?

Han Tong Ng: No. I think when you talk about unaccounted for water; it is not really a waste in sense but basically due to leakage and all these things. That is why we have all the programs of introducing good quality pipes, i.e., replacement program. You cut out the leakages and that contributes to the reduction of the unaccounted for water.

Question: So this is less than the loss of water from the source to the users in between whatever happens. What is your future plan? Do you want to squeeze further or probably this is the maximum one you can go for?

Han Tong Ng: Well, I guess there is always the limit. We endeavor to go as low as we could. But I think about 5 percent. I have mentioned earlier that the unaccounted for waters are due to the leakage and metering inaccuracy. When both components come in, on one hand, we endeavor to use meters accurately, we have tried our best to pin down the number of leakages that goes unnoticed to underground through our leakage detection program. We have been able to hover around 5 percent for the last few years.

Comment: My problem is that you are setting such as high standard for this problem. In Islamabad, we are losing about 30 percent. Just in root. So with this 5 percent, you are pushing us against wall. People are going to ask me what you are doing there.

Han Tong Ng: Probably it could be a start that you buy a few sets of the localizers and try them out in your place.

Wendy Nero: I think that Mr. Ng pointed out the 5 percent rate is, as far as I know, the lowest in the world at this point. But it is also good to know that you are striving to do more which is within the spirit of GP and cleaner production concepts. It is always good to know that the best is always trying to do better than others.

Comment: I would like to make a comment on that professor and student relationship. Listening to these three wise demand-controlling devices and systems, I kept thinking that before that, as what Professor Tay said, it is human behavior. How can we modify that behavior? I would like to introduce an episode from Korean Professor Lee' book of Seoul University. He is a professor of environmental engineering, written by a Buddhist monk called Mat Joo, we might call him Dalai Lama in Korea. He asked his students to write three pages about what they feel after reading that book. That is a very small book. That teaches not try to be happy by satisfying your desire, but demitting your desire. Within the lines, he confesses that he teaches all those engineering and science students how to protect environment, but he can not do more than reading that book and really feel what you can do. We have to think compassionately rather than analytically. In the base, as Professor Tay said it is the human behavior. We have to think differently rather than in one direction.

Joo Hwa Tay: I agree with him on that. If we want to change our human behavior, all governments are prepared to use carrot and stick, especially stick, to force people to change their human behavior. I would like to share with you that Singaporean are very good at protecting our environment because if you throw one piece of paper on the ground, they will fine you 500 dollars. No Singaporeans will throw away waste on the street. But we receive a lot of complaints from Malaysia, which needs to be verified. They say when Singaporeans go across the crossway; they throw everything on the street. That one yet needs to be verified. It is a human behavior and I believe it is true. The only reason I said that is because I am concerned about the younger generation. PUB has been doing a lot of educational and awareness campaign. Education can change a person's behavior. That is the only sure way to change a person. My daughter was walking on the street. Somebody threw a Coca Cola can, she patted his shoulder and say "Sir, you threw something on the floor, please". The man looked at her and said "none of your business." She just quietly picked it up and put it into the waste basket. That is what she learned from school. I think it is better to teach the young rather than teach the old because it is very difficult to teach a trick to an old dog. I agree on that. So we try to do a lot of awareness campaigns in the dormitories. We try to educate people rather than putting a stick. If you do this, I hit you three times. I can guarantee you that stick does work and carrot is never to be too sweet. Once you give him one dollar, he says why not ten dollars. Once you give him ten dollars, he says why not a hundred dollars. It is never satisfied for human greed. Education to teach our older generation is difficult, but to younger generation, yes, it works. I do not have time but I also want to tell you how successful we are in teaching the school children. Like the non-smoking campaign, we do not teach the smoker, we teach the daughter and son to tell the parents not to smoke at home. It works. If you tell the smoker not to smoke in the air-conditioned room, nobody cares. But if you ask the daughter to say "Daddy, put off the cigarette butt". It works. That is education. I am an educator; I solely believe that education can change human behavior. Thank you.

Wendy Nero: I would like add on that. I think you are right. One of our challenges is that it takes so much energy and money to change the least human behavior and mind-sets in Americans. That is more cost-effective to do a combinational approach with a little bit of education to tell them about the economic concerns we are going to offer them. Or by the way there is a regulation coming in two years so take the advantage of the money now. Here is the penalty if you don't. We have relied on the three parts: education, economic incentives and regulations because it is very hard to change behavior and sustain the behavior change, at least in our population.

Moderator: There was actually a question raised earlier about the leakage detection.

Han Tong Ng: About your enquiry about the cost that we invested to keep unaccounted for water low. In Singapore context, we are very different from other countries. You may have ample water supply, but in Singapore we have limited water resource. We find it worthwhile to invest in carrying out leak detection programs to keep unaccounted for water low and prevent water flow leakages. All of the investments that you put in will definitely be recovered back from the early detection of the leakages that go unnoticed underground through your leak protection program.

Comment: I am from PUB, Sinpoare. In the course of keeping unaccounted for water low, what we believe is to do things right from the start. For example, we used good quality piping material to make sure that that is ok. I understand that in some countries, they use galvanized iron pipes, so after a few years, it tends to have rusty yellowish water. The pipes may start to leak. If you are not careful, the contractor would put sand inside, not purposely. The sand will carry to meter position and cause the meter to stop. If you are using the good quality meter, the maintenance cost will also be lower. Basically there are two components of unaccounted for water. Besides leakage, there is another very important component that is metering error. I understand that in many countries, the customers receive the water supply from the roof tank. WRC in UK, they have discovered in 1977 that for those plumbing systems with water supply taken through roof tank, the meter can be under-registered between 4 to 16 percent. Just now the gentleman mentioned about 30 percent. If most houses taking water supply from roof tanks, then at least 4 percent of the error can be through metering errors. Thanks.

Moderator: Thank you for that clarification and contribution.

Question: I am from Thailand. I have two questions about the acoustical localizer. The first question is how to determine the leakage position by using the acoustical localizer. The second question is what the maximum leakage the localizer can detect.

Han Tong Ng: For the localizer, I think the first question you are asking is how to determine the leak location. I think the main purpose of leak localizer is to narrow down the possible leakage area. I am not talking about pinpointing. Now we have a network of 5000 kilometers of pipeline. It is very tedious if you cover every inch of the pipeline using the co-relaters. What this localizer can do is that it narrows down and gives the indication where is the leak zone. It has in-built software that analyzes the data that it collected. If you have a leak, it means a certain noise level. The purpose of this data logger is to log these noises. When the program analyzes, it will show that if there is a particular spike in their analysis, there is a possible location. The program will also tell you that this particular spike is probably about nine, ten, twenty meters from the localizer. So we are actually relying on the analysis of it. In terms of depth or width, in Singapore our main leak varies at least 1.5 meters below ground. Some of our mains have gone lower to 2 or 3 meters. What happens is that these localizers are placed in vault spider that is directly in contact with the pipe. In terms of that width, there should not be a noise problem because the noise will transmit through the metallic pipe to the data logger.

Comment: Can I clarify? We have divided Singapore into over 200 zones. We cover these 200 zones in 10 months. In the remaining two months, we visit those leak-prone areas. What we do is at day time, our people, contractor and officers, will visually check all the connections. They will use listening sticks to check the meter position and whether they hear any sounds. In the afternoon, they will place these noise localizers, which is the data logger on the vault spider. These noise localizers will collect the signal and the contractor will collect them back on the next day. We have a program to cover the 5000 km of mains over one year.

Moderator: Thank you for the practical example of how to conduct the leak detection program.

Question: On this localizer thing, do you install something along the pipeline? How do you find that you have to put localizer thing here. One way is to walk along the pipeline and see if this land is wet. You can find out that there is a leak that is taking place here. Otherwise, how do you decide if the pipeline is leaking here but you put the localizer there? How do you start the process of the leak detection program?

Han Tong Ng: We divided Singapore Island into over 200 zones. We make it a point that we have a program to visit all the 200 zones within a year, probably within 10 months.

Question: There must be some input to the program that shows leakage. How does the program take up the leak of certain points of the pipeline?

Han Tong Ng: No, that is why we make a point to visit the zones every year. What happens would be that even before visiting the site, we have our plans to show where the pipelines are and where our vault positions are. We actually do the planning in the office where to position the localizer. We do not just go down to a site and find a vault and just put down the localizer on it. No, we do our planning in the office and look at the pipeline network like where would be most effectively to put the localizer. Then after the planning, the officers actually go down to the site of the particular zone to place the localizer. It is done from zone to zone and we have a program to move around the 200 zones in Singapore, within 10 months. In the last 2 months, we will revisit the leak-prone zones.

Moderator: we are actually coming to a closure of our session. We will take one last question.

Comment: I don't have any questions but I have some comments to make. In fact we are discussing the water conservation throughout this morning. There have been some interesting discussions on water conservation. We are dwelling on to take a particular water part of the conservation. Perhaps one of the components that we are missing is we are mostly using water for washing as everybody saves it also. And washing means soaps and detergents. As you know, the soaps and detergents contain a lot of chemicals, the water could not be useful for implementation and other purposes. So I think if we could change the composition of soaps and detergents a little bit, the water after washing could be used for landscaping or something like that. Probably that will be the major future achievement to water conservation. We should do some research so that we can conserve water through the usage of soaps and detergents. And this is not only about the soap and detergent, but also about other chemicals. This is like the green productivity as you mentioned. That will give both water usage and water conservation strike force. Second comment is about wastewater. When we are conserving water, the quantity of wastewater also reduced quite a bit. Then the concentration of pollutants will be increased after the conservation of the water, as it is said that the solution to pollution is dilution. If there is no dilution, the concentration of the pollutant is certainly higher. In that level it is very difficult and tedious. It also seems that this is the right time for us to optimize the type of water conservation regarding the wastewater. There should be a ratio on water consumption and wastewater. We have to think about it because it is a very important thing. It needs a lot of discussions, a lot of researches and a lot of optimizations. It is the time we should at least do something. Thank you.

Moderator: Thank you for your comments. Any wise comments from speakers?

Wendy Nero: I would just like to comment on the laundry detergent. I don't know whether it has been a world wide activity but certainly in the United States, 15 or 20 years ago, the laundry detergent manufacturer's association engaged a negotiation with our EPA and devised the whole new composition of the soaps so that there is lower phosphor and lower other pollutants. They can be used on site for the water in landscaping. The second piece is on wastewater. I don't know again whether this is probably outside the United States. The waste water system is so leaky and there are so many inflow and infiltration problems that we don't get the concentrated issues in the wastewater flow as a result of water conservation, which is probably another set of discussions or a set of issues. But there has not been a serious problem at all that I have ever heard of.

Moderator: This comes to the closure of the panel discussion. Thanks very much for the speakers and all the audience for having a very interesting questions and comments.

TRACK 3 : WATER RECLAMATION

SEAWATER DESALINATION

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ABSTRACT

The paper aims at depicting the recent desalination aspects. Today, naturally available water (conventional water resources) no longer meets human demand, and therefore the "non- conventional water resources" are needed; they are "water conservation", "water reuse" and "desalination". Desalination is the most established and reliable method among them. The two major desalination processes are the reverse osmosis and distillation. The reverse osmosis process is becoming more and more popular except the Middle East countries due to less cost and more environment-friendly. The membrane technologies developed with the reverse osmosis are recently playing essential role in drinking water and wastewater reuse

INTRODUCTION

Definition of Desalination

Desalination is defined as removal of salts (mainly sodium chloride) from saline water to obtain fresh water for human consumption. Saline water is classified into seawater and brackish water.

The total dissolved solid (TDS) concentrations of seawater range from 35,100 mg/L of standard seawater to around 50,000 mg/L in the Arabian Gulf. Sometimes groundwater contains high concentrations of minerals. Water of around 1,000 to 10,000mg/L or more concentrations is called brackish water. According to Wangnick's Inventory Report No. 17 (Hirai and Goto 2002), the total desalination capacity is 32,382,000m^3/day, and seawater desalination is the mainstream.

Regions Requiring Desalination

Desalinated water is generally more expensive than natural water. However, desalination is indispensable in semi- or arid zones of the Middle East, Mediterranean coasts, Florida, California, U.S.A., North Africa, Australia, Caribbean Islands and others. Also, desalination reinforces water supply in densely-populated areas such as Singapore, Fukuoka, Japan where natural water per capita is scarce. Table 1 shows desalination applications in the world (Hirai and Goto 2002). The capacities are expressed as fresh water production per day.

Table 1 Seawater Desalination Capacities by Regions

Region	Capacity (m^3/day)	Percent (%)
Middle East	13,047,000	68.56
Europe	2,261,000	11.88
Asia	1,076,000	5.66
Africa	1,085,000	5.70
Central America, Caribbean	602,000	3.16
United States	442,000	2.32
South America	251,000	1.32
North America except U. S.	231,000	1.21
Pacific/Oceania	11,000	0.06
Total	19,006,000	100.00

Role of Seawater Desalination

Mankind has been usually obtaining fresh water from natural water resources of rivers, groundwater, lakes and dams in the past years. We call these water resources "conventional". Recently, the natural water per capita has been decreasing rapidly because of increase in population and higher living standard. On the other hand, availability of natural water is almost constant except some fluctuations. Consequently, we must expect serious water shortage in near future. This fact leads us to rely on "non-conventional" water resources. They are water conservation, desalination and wastewater reclamation.

In most cases, saline water is not suitable for domestic, industrial and agricultural uses. WHO (World Health Organization) recommends water of 500 mg/L or less TDS for drinking purpose (WHO 1996). Domestic use is the largest consumer of desalination, and industry is the second; desalinated water is too expensive for agriculture in general, but can be utilized in some regions such as Spain where no other water is available.

Desalination, especially seawater desalination is expected to play an important role in supplying fresh water in this century. A recent report on desalination market analysis states that there will be 14.65 million m^3/day of newly built desalination capacity in 2001 – 2006 based on the projected plants, and that the global desalination market has been growing at an average annual rate of around 12% in the past 1972 – 1999 (Henthorne 2002).

SEAWATER DESALINATION PROCESSES

The main processes are reverse osmosis and distillation (or thermal) processes. The other processes such as electro-dialysis, freezing, per-evaporation were studied in the past, but not used in practice; the electro-dialysis can be applied to only brackish desalination. The author will introduce here the two major processes of reverse and distillation processes.

Reverse Osmosis

Principle of the Process

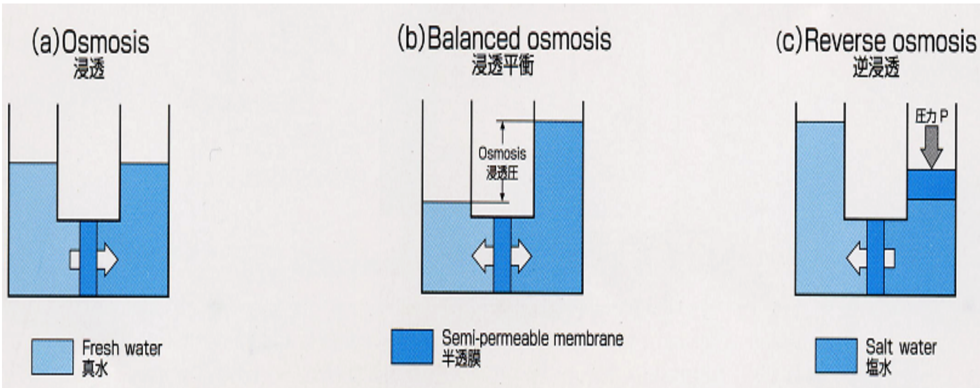

Fig. 1 Principle of Reverse Osmosis Desalination

The principle of the process is given in Fig. 1. Suppose that space is separated by a special membrane that is named "semi-permeable membrane". Then, one space (A, lighter) is filled with fresh water and the other space (B, darker) is filled with seawater. If high pressure of 2.5 MPa or more is applied to the space B with seawater, fresh water moves to the space A through the semi-permeable membrane. Therefore, if one feeds seawater continuously to the space B under the high pressure, fresh water is produced continuously and can be drawn from the space A under atmospheric pressure. In other words, the semi-permeable membrane rejects salt but permeates fresh water. This is the principle of seawater desalination by reverse osmosis process. The semi-permeable membranes are called reverse osmosis (RO) membranes.

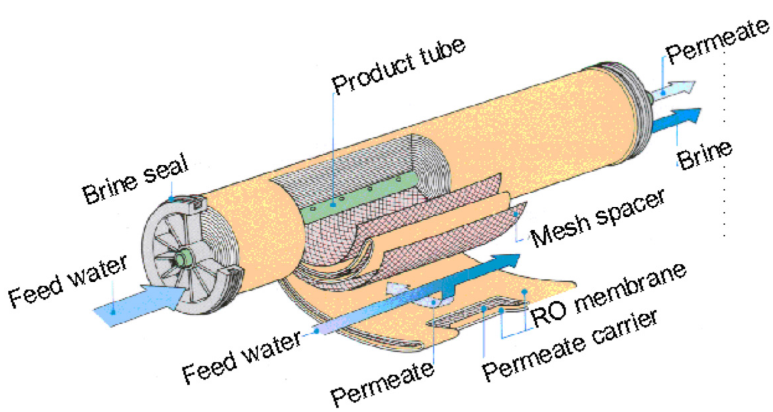

Fig. 2 Module of Spiral Wound Type

The fresh water stream or flux is so slow that one can increase fresh water production by increasing the RO membrane areas. This is done by rolling multi-layer membranes in a cylinder or by packing very fine hollow fiber membranes in a cylinder. These cylinders with large membrane areas are called RO membrane modules; the former of rolled membrane is named spiral wound type and the latter of fine hollow fiber is named hollow fiber type. Either type of membrane is packed in a pressure vessel and appears the same. In short, when seawater is put into the membrane module under high pressure, fresh water and brine (concentrated seawater) come out separately from the module. Figure 2 represents a module of spiral wound type.

Process Flow Diagram

The flow pattern of the process is shown in Figure 3. Raw seawater is fed to the pretreatment equipment where the feed seawater is filtered carefully through sand media or membranes to remove fine particles and colloidal (otherwise these materials will plug the flow or cause fouling on the surface of the reverse osmosis membrane). The capital and operating costs of pretreatment can occupy more than 50% of the overall desalination cost and control the performance of the plant. In addition, even clean seawater is fed to the RO modules, microbes breed on RO membranes unless appropriate disinfection is made. Fouling of membranes by microbe breeding is called bio-fouling. Prevention of bio-fouling is always the biggest problem for the RO process in practice.

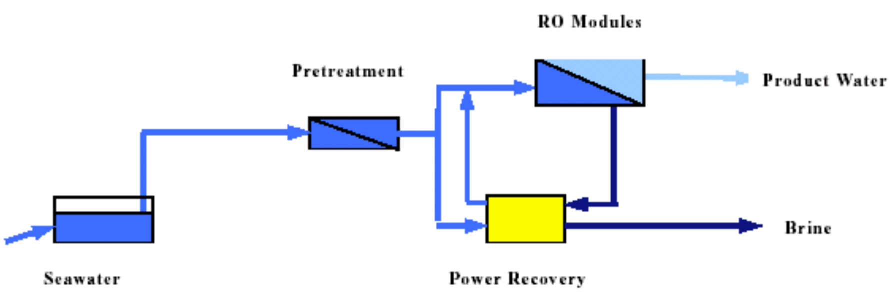

Fig. 3 Basic Flow Diagram of RO Plant

Distillation (Thermal) Processes

There are three major distillation processes; they are multi-stage flash (MSF), multiple effects (ME) or multiple effect distillation (MED) and vapor compression (VC). MED and VC are the conventional processes that are used in industry, but MSF is specialized in seawater desalination. MSF occupies the largest share in the distillation processes. Therefore, emphasis is put on explanation of the MSF process in this paper.

Multi Stage Flash (MSF)

The flow diagram of MSF is shown in Fig. 4.

The feed seawater is supplied by a seawater pump (upper right) to the condenser tubes that are located at the upper part of an MSF plant to cool vapor for condensation in the evaporation chambers. In turn, the fed seawater is preheated in the process. Continuously, the preheated seawater moves to the condenser tubes of the left (higher temperature) section to cool vapor for condensation again in the chambers. The temperature of the preheated seawater goes up gradually. At the final chamber or stage, the preheated seawater moves out to the brine heater where the seawater is heated to the highest temperature.

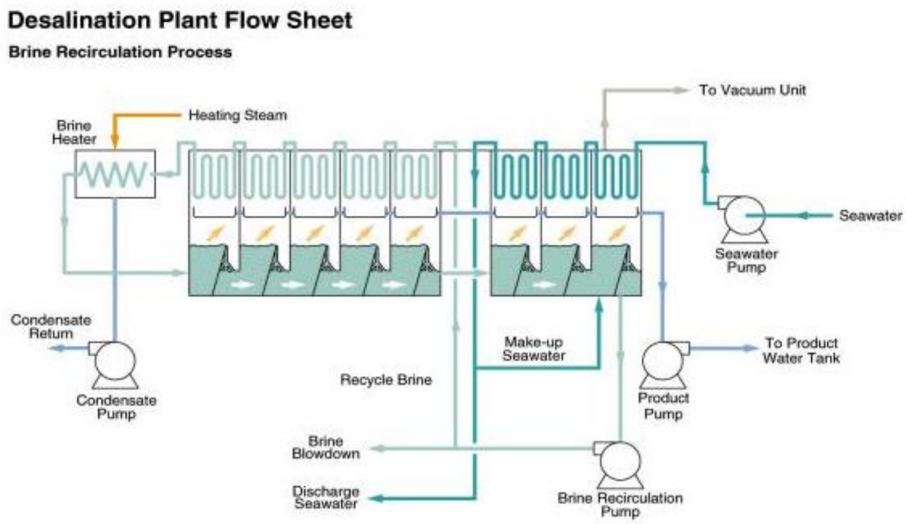

Fig. 4 Flow Diagram of Multi-Stage Flash (MSF) Plant

Then, the seawater is supplied to the bottom of the first evaporation chamber (the final chamber for preheating) through orifices. The hot seawater begins boiling immediately upon entering the first chamber. This rapid and violent boiling triggers a portion of the seawater to vaporize, using its own sensible heat. Consequently, the temperature goes down a little corresponding with evaporation. This vaporization is called flash evaporation. The flashed seawater moves to the second chamber through orifices to flash-evaporate again to produce vapor. This flash is repeated until the last stage.

The vapor in each stage is cooled with preheated seawater in the condenser tubes to condensate. The cooled condensate is collected with trays that are connected to the outside distillate tank. There are 15 – 25 stages that are grouped into heat recovery section and heat rejection section in practical plants. The seawater in the plant is recycled until it is concentrate around twice because once through cycle gives only a small portion of evaporation. This is why MSF requires rather much energy for re-circulation pumping.

The above is the outline of how the seawater is distilled in an MSF plant. The MSF plants in the Middle East countries have been supplying large part of fresh water since the development in 1950s and established reliability of the process. Fortunately, the GCC countries can provide with cheap oil although the MSF process demands both considerable thermal and electric energy. In addition, the dual purposes plant of thermal power generation and MSF desalination is a reasonable system when electric and fresh water are needed simultaneously.

Multi-Effect Distillation (MED)

The principal process of the multi-effect distillation is shown in Fig. 5.

As mentioned before, the process is conventional. However, the author likes to notice some points.

(a) While the highest temperature of heated seawater for MSF is around 105 – 110^0 C, that of MED is 65 –70^0 C. The fact gives advantages to MED over MSF;

some of them are relief of metal corrosion and scaling problem.

(b) MED does not need a big re-circulation pump, which reduce electric energy consumption considerably.

(c) The plant size is larger than that of MSF with a same production capacity, because it has to handle considerably larger volume of vapor in lower temperature compared to MSF. The largest unit of MSF is 15 – 17 MIGPD (Million Imperial Gallon per Day), but 5 – 7 MIGD is the largest capacity for MED at present.

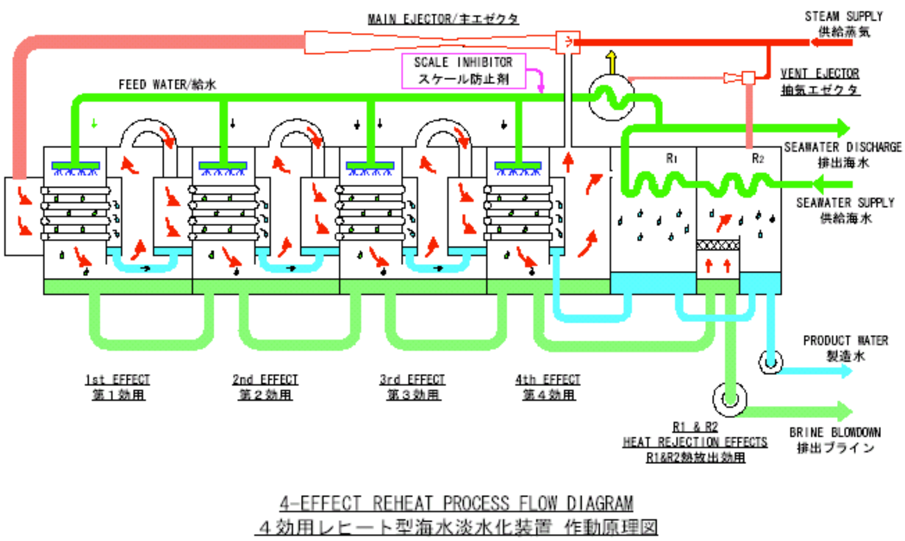

Fig. 5 Flow Diagram of Multiple Effect Distillation Plant

Vapor Compression (VC)

This process is also conventional. However, a combination process of MED – VC is being developed recently, and considered to be common. Most of the recent MED plants are combined with thermal vapor compression and are called MED – TVC.

COMPARISON BETWEEN REVERSE OSMOSIS AND DISTILLATION PROCESSES

General Characteristics of Reverse Osmosis

The RO process is becoming more popular and the market share in desalination is gradually growing world-wide. Most of newly built desalination plants adopt the RO recently except large plants in the Arabian Gulf region.

The RO process has both advantages and disadvantages compared to the distillation process.

(1) The reverse osmosis consumes less energy than the distillation process (Awerbuch 2002). As explained in the previous section, the RO process requires energy in form of electricity, while the thermal (distillation) processes consume both thermal and electric energy. Details are presented inTable 6.

(2) The total desalination cost of the RO process is less than that of the distillation process with some exceptions. That comes from less capital and operational costs (Water Reuse Promotion Center 2003). The practical total cost is presented in Tables 2 and 3.

(3) The product water quality is inferior to that of the distillation processes because the salt rejection of the membrane is not complete and some salt leakage to fresh water occurs. TDS of reverse osmosis product is around 200 – 500 mg/L, while that of the distillation will be less than 25 mg/L. Also, boron content cannot keep at less than 0.5 mg/L of the WHO standards for drinking water without any post treatment, but the product water of the distillation can meet the standards.

(4) The plant operation is delicate to handle. The membrane is made of organic polymer, and therefore is not always stable enough against microbes and chemicals in long-term operations. Microorganisms sometimes cause bio-fouling on membranes that will lead to degrading the membranes and damage its permeability.

Cost

It is common recognition that total cost of desalination of the RO process is less than that of the distillation with some exceptions. Tables 2 and 3 are compiled with data that appeared in a weekly journal, “Water Desalination Report”, a monthly journal, “Global Water Intelligence” and others by the author.

It is impossible to compare precisely the figures in the tables since conditions such as contract content, local requirements etc. are neglected. However, one can understand that most of the recent seawater desalination plants are built using the RO process except those in the Arabian Gulf.

Market

Table 4 gives the market shares of the RO plants worldwide (Hirai and Goto 2002). As shown in the table, the main stream in the U. S. and Europe is the RO process whilst only 10% share is occupied in the Middle East where energy cost is cheap and the fresh water supply has been depended largely on the distillation processes in the past years. In addition, the oil-producing countries need both water and electricity. Therefore, dual purpose plants of power generation and distillation is reasonable in the Middle East.

Asia, Africa and Central America & Caribbean Islands have older distillation plants, but almost all of recent desalination plants adopt the RO process.

Energy Consumption

There is a big difference of energy cost between the OPEC and non-OPEC countries (Hoffman et al, 2001). Table 5 gives the comparison. In the table, the fuel cost of non-OPEC is 2.25 times as much as OPEC, and the consequently the power generation cost becomes 1.67 times as much as OPEC.

Table 2 Total Cost of RO Seawater Desalination

Location	Capacity(m^3/d)	Contract	Investment (M$)	Cost ($/$m^3$)
Tampa Bay, USA	95,000	1999	100	0.642
Trinidad, Caribbean	109,770	1999	120	0.73
Ashkelon, Israel	136,000	2001	205	0.49
Singapore	136,000	2003	120 – 150	0.47

Table 3 Total Cost of MSF Seawater Desalination

Location	Capacity (m^3/d)	Contract	Investment (M$)	Cost ($/$m^3$)
Al Taweela 1, UAE	182,000	1998	258	0.70
Al Taweela 2, UAE	240,000	2000	255	0.70
Shuweihat, UAE	454,000	2001	518	0.73

Table 4 Market Share of RO Process in Seawater Desalination by Region

Region	Plant Capacity(m^3/day)	Percent (%)
Middle East	1,345,868	10.32
Europe	1,424,807	63.00
Asia	368,957	34.28
Africa	227,819	21.00
Central America & Caribbean	162,963	27.08
United States	349,282	78.97

Table 5 Comparison of Energy Cost between OPEC and NON-OPEC

Item	OPEC	Non-OPEC
Fuel Cost（US$/GJ）	1.2	2.7
Power Generation Cost（US＄/kWh）	0.03	0.05
GT/HRB, 3.0 Bar Steam Cost（US$/ton）	0.8 – 3.0	3.8 – 5.0
GT/HRB, 0.4 Bar Steam Cost（US$/ton）	0.7 – 2.3	3.0 – 4.2

Table 6 describes energy consumptions for the desalination processes. The RO process requires electric energy only (more precisely pressure energy) whereas the distillation processes need electricity and steam (Awerbuch 2002). Since almost all the RO plants have energy recovery equipment, electric energy consumption of RO plants is approximately equivalent to that of MSF plants. The author published a paper at International Desalination and Water Reuse Congress at Bahamas in October 2003 that the 200 m^3/day RO demonstration plant operated by Water Re-use Promotion Center in Oman is consuming 3 kWh/m^3 for desalination and 0.3 kWh/m^3 for others, totaling 3.3 kWh/m^3 energy consumptions for long term operations (Goto et al, 2003). The fact proved that the plant is one of the most energy conservative plants ever published in the world even if the feed seawater salinity is around 40,000mg/L.

Table 6 Consumption of Energy per Fresh Water Production by Process

Process		Steam(steam- ton/m^3)	Electricity (kWh/ m^3)
Multi-Stage Flash (MSF)		0.125	4
Multi-Effect Distillation (MED)		0.0833	2
Vapor Compression (VC)		N/a	8
Reverse Osmosis(RO)	Energy Recovered	N/a	3.5 – 5.5
	Energy Un-recovered	N/a	8.5

Reliability

Reliability of the RO process has been almost established around the world excluding the Arabian Gulf. As mentioned before, the RO process is the most popular among the rest of the world. However, the RO membranes incline to be fouled or degraded especially with polluted seawater if mistreated. Pretreatment is considered to be the key technology to overcome fouling. Even the spotlighted RO plant at Tampa Bay, Florida is having a trouble of pretreatment (Water Desalination Report 2003).

It is difficult to understand that the mainstream of desalination in the Middle East is the distillation processes that are higher in cost than the RO process. The reason is a problem of reliability. The RO process lost its reliability in the Arabian Gulf, because the two big projects failed to operate normally the plants. One was the Bahrain project of 45,000 m^3/day RO plant that was contracted by Du Pont for Saline Water Conversion Corporation (SWCC), Saudi Arabia in 1984. The other project was the Al-Jubail project that was contracted again by Du Pont for SWCC in 1993. The reason of the failures has not published yet, but common understanding is that seawater at the sites has too much silt and the salinity fluctuates frequently and that the adopted RO membrane was not suitable for such difficult seawater quality. Serious bio-fouling prevented from normal operation of the plants.

In the contrast to the Arabian Gulf, SWCC is successful to operate large scale RO plants at Jeddah in 1986 contract year and Yanbu in 1992 contract year on the Red Sea coast. Recently Abu Dhabi is planning to adopt the RO process in the Arabian Gulf. Water Re-use Promotion Center is operating successfully 200 m^3/day RO plant in Oman in cooperation of Sultan Qaboos University (Goto et al, 2003). It is believed that sooner or later the RO technology will be established in the Gulf area.

FABARABLE EFFECTS OF DESALINATION TECHNOLOGY TO WATER TREATEMENT

Development of Different Types of Membrane

The author has introduced the outline of the recent desalination in terms of position in water demand and usage in the introduction section. However, he would like to mention very important issues in water issues. The issue is, the recent desalination technology has given favorable impacts on other water technology; the two major impacts are made on drinking water and wastewater reclamation.

The present membrane technology was brought about by the development of reverse osmosis desalination in 1950s. The invention of reverse osmosis membrane was expanded to micro-filtration (MF), ultra-filtration (UF) and nano-filtration (NF) membranes. Today, these membranes are playing varieties of role in their own fields of water treatment. However, their common role is to separate fine particles, colloids or solutes. The followings are arranged by the order of separating particle size.

(1) RO (Reverse Osmosis): mono-valent ions

(2) NF (Nano-Filtration): poly-valent ions, trihalo-methanes, detergents, etc.

(3) UF (Ultra-Filtration): virus, polio, organic polymers, etc.

(4) MF (Micro-Filtration): bacteria, chryptosporidium, algae, vibrio cholerae

Consequently, these membranes can be applied to water treatment, depending to materials to be removed.

Applications of Membrane Technology to Drinking Water

MF and UF Membranes

Water resources for drinking have recently been polluted with chemicals and pathogens. The conventional coagulation/sand filtration process no longer guarantees the safety of drinking water. Chryptosporidium accidents in drinking water supply systems around the world are typical examples. Chryptosporidium is not infected with chlorine. Separation of pathogens with MF or UF membrane is the most powerful and economical tool for water supply systems.

NF Membrane

When there are water resources of high hardness, NF membrane is applied to remove poly-valent ions such as sulfate, calcium and magnesium ions, detergents and trihalo-methanes (THM). The process is popular in the U. S., but is also used to softening of industrial water. There are some applications to textile/dyeing and finishing industry in Thailand where underground water has high hardness.

Applications of Membrane Technology to Wastewater Reclamation (Reuse)

Reuse of Sewage

It is well known fact that serious water shortage is expected in this century around the world. Therefore, reclamation or reuse of wastewater is considered as one of the powerful measures to fight against the shortage. Sewage is the promising water resources because it is produced constantly where water shortage will occur like densely populated cities. Already secondary sewage effluents are treated with MF or UF membrane for reuse of irrigation, toilet flushing, greening cities and others.

The cost of sewage reclamation is estimated to be cheaper than desalination (Ejjeh 2003). The estimation says that sewage treatment costs US\$0.45-1.0 /m^3 for industry, US\$0.45-0.9/m^3 for indirect use while desalination cost ranges US\$0.5-1.2/m^3. In addition, reuse consumes generally less energy than seawater desalination. In other words, water reclamation is more environmentally friendly.

Reuse of Industrial Wastewater

Reuse of industrial water in a factory has been popular in industry, but recently the development of membrane technology enables to expand applications. In Japan, 34% of MF and UF membranes are used to industry. This share is the largest in the world (Watermark 2000). Also, there are some applications of wastewater reuse in food industry for example.

Water Re-use Promotion Center is implementing a project of industrial wastewater reuse of food, textile/dyeing industries in Thailand. The project is a government-government technical cooperation. We have already found that aerobic treatment of wastewater with MF membrane followed by low pressure RO are useful to boiler feed in a rice noodle factory. It is expected that industrial wastewater reuse with MF or UF membrane filtration will save water shortage from excess groundwater usage that causes serious land subsidence.

NEWater Program in Singapore

One more striking application has appeared in Singapore. It is called "NEWater Project" to reuse secondary sewage for drinking water. The Public Utilities Board (PUB), Singapore built a demonstration plant of 10,000m^3/day capacity that treats secondary sewage with MF filtration (pretreatment) and low pressure RO treatment followed by UV (ultra-violet) disinfection in 2000. Also, a two-year health effects testing program was started using both fish and mice in 2000. A full-scale plant has been operating since 2002, and the treated sewage is blended with natural water in the reservoir. This is surely a pioneering project that is attracting much attention in the world.

CONCLUSION

(1) Desalination is to remove salts from saline water (mainly seawater) to obtain fresh water.

(2) Water scarce regions need desalination. They are the arid and semi-arid zones of the Middle East, Mediterranean, Australia and California as well as population-dense areas such as Singapore, Fukuoka, Japan.

(3) The conventional water resources alone cannot meet the human demand, and therefore the non-conventional water resources become more and more important.

(4) The non-conventional water resources are:

  1) Water Conservation

  2) Wastewater Reclamation (Reuse)

  3) Desalination

(5) Desalination is the most expensive, but the most established and reliable method among the non-conventional resources.

(6) The desalination processes are classified into two majors, reverse osmosis and distillation (multi-stage flash and multiple effect processes).

(7) The reverse osmosis dominates recently around the world. The exception is Arabian Gulf, the largest market where the MSF is the mainstream.

(8) The strong needs of desalination promoted rapid developments of desalination technology. This development is generating favorable effect on other water technology. The biggest impact is advancement of membrane technology that is an essential role in drinking water and wastewater treatment.

(9) The recent water business is growing rapidly to achieve the goal of water shortage mitigation in this century.

REFERENCES

Awerbuch. L. (2002). "Introduction to the Needs of Desalination and Financing of Projects", Situation of Desalination and Investment Opportunities, Madrid (October 23).

Ejjeh. G. (2003). “Industry and Water Session”, Third World Water Forum, March 18.

Goto. T. et al. (2003). “A Full SWRO Plant”, IDA Congress, Session 6, October.

Henthorne. L. (2002). “Desalination Market Analysis 2002” 1-4.

Hirai. M. and Goto. T. (2002). Compiled “IDA Worldwide Desalting Plants Inventory Report No. 17”, Edited by K. Wangnick.

Hoffman. D. et al. (2001). “Hybrid Desalination Systems Effective Integration of Membrane/Thermal Desalination and Power Technology” MEDRC Series of R&D Reports, Project: 97-AS-008a, Executive Summary p. xx, December.

“Water Desalination Report”. (2003). Vol. 39, No. 28, July 10.

Watermark. (2000). Issue 10, September.

Water Reuse Promotion Center. (2003). “Internal Report for Study on Hybrid Desalination System of MSF and RO”, June.

World Health Organization (WHO). (1996). “Guidelines for Drinking-Water Quality (2nd edition)”, Vol.2, p. 942.

SINGAPORE'S EXPERIENCE IN WATER RECLAMATION: THE NEWater INITIATIVE

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ABSTRACT

Since the 1970s, Singapore has been testing new water technologies to produce water of drinking standards from secondary treated wastewater effluent. With advancement in membrane technology coupled with better understanding and lower membrane cost, it is now feasible to produce water of drinking standards, called NEWater in Singapore, from treated effluent reliably and at reasonable cost.

The primary use of NEWater is for non-potable use. It is currently supplied mainly to wafer fabrication plants for the production of ultra-pure water for the wafer manufacturing processes. This achievement is the first in the world. NEWater is also supplied direct to the industries and commercial buildings for process use and air-con cooling. Since February 2003, Singapore has been introducing a small amount of NEWater to existing local raw water reservoirs for potable use. This indirect use of NEWater for potable purposes is not new and has been in practice in the United States for more than 20 years.

INTRODUCTION

The intensification of the human population density in towns and cities has escalated the water demand in these built-up areas, thereby stressing the water supply. With industrialization and modernization, the increasing scarcity of good quality water is a growing concern almost in every parts of the world. Being a small island city-state with only 680 square km in land area and a population of 4 million, Singapore has to always look for innovative ways to find new water resources to meet its growing need for clean water.

The Public Utilities Board (PUB) is the national water authority of Singapore. It manages, in an integrated manner, the nation's water resources. These include the collection and management of raw water, production and supply of water, and collection, treatment and reclamation of used water. PUB's mission is to secure an adequate supply of water at an affordable cost for Singapore.

PUB has leveraged on advanced technology and innovative solutions to optimise its limited water resources by reclaiming high-grade water, called NEWater, from treated secondary effluent. NEWater has become a good example of how advanced technologies can be leveraged to provide alternative water resources reliably and at reasonable cost.

WATER RECLAMATION STUDIES

The effort over the last 3 decades to put in place a comprehensive sewerage infrastructure in Singapore has resulted in everyone in Singapore being provided with modern sanitation. All used water is collected through a comprehensive network of sewer reticulation system and treated at centralized water reclamation plants to international standards before discharging it into the sea. The treated secondary effluent presents a viable potential as a water resource if it is harnessed through exploitation of advanced water reclamation technology.

In the 1970s, a study was done to determine the feasibility of producing drinking water from secondary treated wastewater effluent. Though the study concluded that producing drinking water was technically achievable, it was not implemented at that time because of the high cost of membrane technology and the technology was also not as reliable and robust.

In the 1990s, there was tremendous improvement in membrane technology in terms of performance and reliability. More important, the cost of membrane has come down substantially. There are also growing trend on the use of membrane technology in water treatment and water reclamation, especially in the United States.

In 1998, a water reclamation study team was set up to test the latest proven membrane technology to produce drinking water from secondary treated wastewater effluent. Reliability in quality and quantity of the water produced were to be looked into. In 2000, a 10,000 m^3/d full-scale demonstration plant called NEWater Factory was commissioned. The NEWater Factory was used to undertake extensive full-scale plant studies to test the quality of reclaimed water and the technical capability and operational reliability of the membrane technology to recover good quality water from treated effluent of a municipal activated sludge wastewater treatment plant.

A multiple barrier 3-stage purification process comprising microfiltration(MF), reverse osmosis(RO) and ultra-violet (UV) disinfections was adopted for the production process. The MF/RO treatment scheme was selected based on the stringent product water quality goals and the successful application of this treatment combination at various water reclamation facilities in the U.S. The process schematic for the NEWater Factory is shown in Figure 1.

Some of the technical details of the membrane processes are given in Table 1.

Process parameters and plant operation are monitored continuously using the SCADA system. The operation of the plant is fully automated and is manned with only one operator.

A comprehensive water sampling and analysis program was implemented and the quality of the NEWater benchmarked against World Health Organisation (WHO) Drinking Water Guidelines and the United States Environmental Protection Agency (USEPA) Drinking Water Standards. Leading advanced water testing laboratories of local and foreign institutions were engaged to carry out extensive and comprehensive physical, chemical and microbiological tests for the water at various stages of the production process over a 2 year period. Chemical parameters of emerging concerns were also included. In all, some 190 parameters and over 25,000 analyses were carried out to-date.

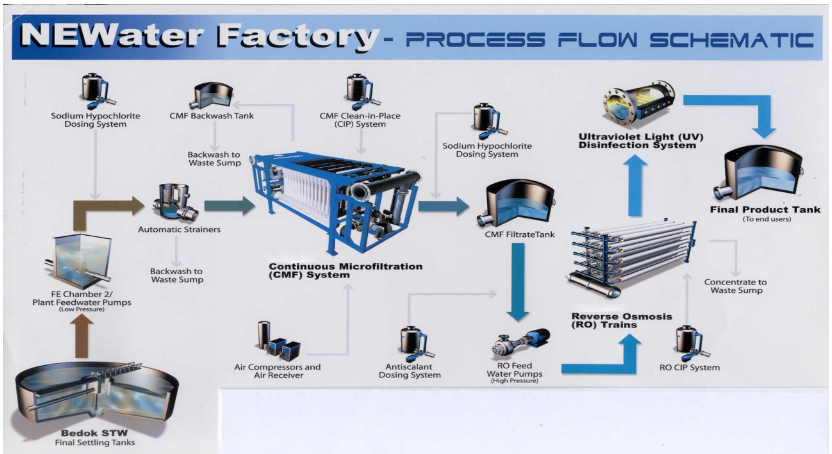

Fig. 1 Process Schematic of NEWater Factory

Table 1 Details of Treatment Processes at NEWater Factory

Treatment Processes		
Microfiltration	Supplier	Memcor, Australia
	Type	CMF – P
	Pore Size	0.2 μm
	Water Recovery	> 90 %
	No of Trains	5
	Capacity of each train	115 m^3/h
	Backwash interval	30 minutes
	Cleaning Frequency	21 days, minimum
Reverse Osmosis	Supplier	Hydranautics, US
	Type	LFC 1
	Water Recovery	85 %
	No. of Trains	2
	Capacity of each train	5,000 m^3/d 1 month, minimum
	Cleaning Frequency	
Ultra-violet Disinfection	Supplier	Hanovia
	Type	Medium Pressure
	No of units	2 duty, 1 standby
	Dosage (minimum)	80 mJ/cm^2

The product water produced is called NEWater. The typical qualities are listed in Table 2.

An international panel of experts comprising renown local and foreign experts in engineering, biomedical science, chemistry and water technology was formed to provide independent advice on the water reclamation study and to evaluate the suitability of NEWater as a source of water for potable use. The test results and the plant operation were regularly audited and reviewed by the Panel. The Expert Panel concluded that NEWater is consistently of high quality, well within the requirements of the USEPA and WHO standards for drinking water. It is safe as a source of water. The Panel also recommended indirect potable use by introducing NEWater into raw water reservoirs to supplement Singapore's water supply. This practice of planned indirect potable use is not new and has been done in parts of the United States for more than 2 decades – Orange County Water District in Southern California and Upper Occoquan Sewage Authority in North Virginia.

Table 2 NEWater Quality

Water Quality Parameters	NEWater	USEPA / WHO Standards
Physical		
Turbidity (NTU)	< 5	5 / 5
Colour (Hazen units)	< 5	15 / 15
Conductivity (µS/cm)	< 200	Not specified (- / -)
pH Value	7.0 – 8.5	6.5 – 8.5 / -
Total Dissolved Solids (mg/L)	< 100	500 / 1000
Total Organic Carbon (mg/L)	< 0.5	- / -
Total Alkalinity (CaCO3) (mg/L)	< 20	- / -
Total Hardness (CaCO3) (mg/L)	< 20	Not available
Chemical (mg/L)		
Ammonia nitrogen (as N)	< 0.5	- / 1.5
Chloride (Cl)	< 20	250 / 250
Fluoride (F)	< 0.5	4 / 1.5
Nitrate (NO3)	< 15	- / -
Silica (SiO2)	< 3	- / -
Sulphate (SO4)	< 5	250 / 250
Residual Chlorine (Cl, Total)	< 2	- / 5
Total Trihalomethanes (as mg/L)	< 0.08	0.08 / -
Metal (mg/L)		
Aluminium	< 0.1	0.05 – 0.2 / 0.2
Barium (Ba)	< 0.1	2 / 0.7
Boron (B)	< 0.5	- / 0.9
Calcium (Ca)	< 20	- / -
Copper (Cu)	< 0.05	1.3 / 2
Iron (Fe)	< 0.04	0.3 / 0.3
Manganese (Mn)	< 0.05	0.05 / 0.5
Sodium (Na)	< 20	- / 200
Strontium (Sr)	< 0.1	- / -
Zinc (Zn)	< 0.1	5 / 3
Bacteriological		
Total Coliform Bacteria (Counts/100ml)	Not detectable	Not detectable
Enterovirus	Not detectable	Not detectable

LARGE SALE PRODUCTION NEWater

The success of the NEWater studies has confirmed that extremely high quality reclaimed water can be reliably and consistently produced by the NEWater Factory. PUB hence embarked on a program for the large scale production and supply of NEWater directly to industries and commercial sector for direct non-potable use. Two large-scale NEWater plants with a total capacity of 72,000 m^3/d were constructed and have been in operation since December 2002.

The operation of the NEWater Factory has provided valuable operation data and experience which are incorporated into the improved design and reliability of the two new NEWater Factories. They are:

i) Ability to do 2nd stage RO water recycling

Provision of 2nd stage RO water recycling provides flexibility to the plant to ensure consistent NEWater quality for all operating conditions. For example, the conductivity of the effluent feed water could vary from 800 μS/cm to 2500 μS/cm, caused by sea water intrusion. This recycling provision enables the plant to produce NEWater with only small variation in conductivity. This recycling provision also enables consistent low TOC levels in the NEWater in the event of wastewater treatment process upset upstream.

ii) 20% more membrane in the pre-treatment unit

Allowance of 20% more membrane area in the pre-treatment stage to ensure stable operating condition. Higher filtration rate in the microfiltration process during chemical cleaning of individual units would have a long term adverse impact on the chemical cleaning intervals. For the first 3 months, chemical cleaning intervals of 21 days were achieved. But the interval started to reduce to 14 days after 6 months and then to 7 days after 8 to 9 months, affecting NEWater production. By allowing 20% more membrane area, normal filtration rate and 21-day cleaning intervals are maintained at all times.

iii) Chloramination to prevent membrane bio-fouling

Ammonia is naturally present in the effluent which could combine with the hypochlorite to form chloramines. By maintaining 1 to 2 ppm chloramines concentration in the feed effluent, cleaning at more than 6 months for the 1st (50% recovery) and 2nd (50% recovery) stages of the RO trains is achieved. The 3rd stage RO trains require cleaning every 3 months due to organic fouling. No deterioration in the performance of the RO membranes was observed after more than 3-year exposure of chloramines. The two new NEWater Factories are designed to recover 75% of the feed water, achieving more than 6 months cleaning interval. There is provision to further recover the remaining 25% (reject) to increase water recovery.

iv) RO trains on elevated platform to prevent net positive pressure from the permeate side

Net positive pressure from the permeate side could damage the RO membranes due to failure of the glued line. On elevated platform, all inlets and outlets of the

RO trains during cleaning will be at atmospheric pressure and the possibility of net positive pressure from the permeate side is negated.

v) Accuracy of on-line readings

Regular checks on the accuracy of the on-line readings by comparing with laboratory test results are instituted. Water samples are collected and tested for each 8-hour shift (or 3 times a day) to ensure the accuracy of the on-line readings. The on-line readings are also regularly calibrated for accuracy also.

vi) On-line TOC analyser for on-line RO integrity monitoring and Pressure Decay Test for on-line Microfiltration / Ultrafiltration integrity

The TOC analyzer is found to be more sensitive than on-line conductivity meter for monitoring RO integrity as it can measure very low TOC concentrations in parts per billion. For microfiltration / ultrafiltration membrane, pressure decay test is the preferred method, complemented by on-line turbidity and particle counter. The pressure decay test is the most sensitive method to detect broken fibres in the microfiltration / ultrafiltration process units.

vii) No enhanced performance polymer or dispersant in anti-scalant

Anti-scalant reagent without any added enhanced performance polymer or dispersant is found to be most suitable for the RO treatment units. It was observed that the polymers or dispersants present in anti-scalant reagent tend to "react" with the organics present in the feed water, accelerating the rate of organic fouling.

PRIMARY USE OF NEWater

The primary use of NEWater is for direct non-potable use as its ultra-clean characteristics makes it well-suited for use in wafer fabrication plants, various industrial processes and in commercial buildings for air-cooling purposes. Currently, the bulk of the NEWater is supplied to the wafer fabrication plants. Singapore is the first in the world to use high grade reclaimed water (NEWater) as a feed source for the production of ultrapure water for wafer manufacturing processes. Wafer fabrication plants using NEWater have reported savings in the production of ultra pure water. Similarly, commercial complexes using NEWater for their cooling towers have reported using less volume of NEWater as compared to using PUB water. This is because the higher quality NEWater allows it to be recycled more. Coupled with less maintenance and the lower price of NEWater, companies save both on quantity and on cost. The target is to supply 250,000 m^3/d of NEWater for direct non-potable use by year 2011.

In addition, a small amount of NEWater, about 9,000 cu metres per day or less than 1 % of Singapore's water demand is being pumped into raw water reservoirs for planned indirect potable use. It is blended with raw water in the reservoirs to undergo a naturalisation process before further treatment at the waterworks for potable use. This volume is expected to gradually increase to 45,000 m^3/d by 2011, or about 2.5% of the daily consumption then.

CONCLUSION

Singapore has successfully leveraged on advanced water treatment technology to reclaim water of a quality that surpass drinking water standards. It is at the forefront of technology in water reclamation at municipal scale, supplying NEWater (high grade reclaimed water) to wafer fabrication plants and other industries and commercial buildings which require high quality water.

USE OF NEWATER AS FEEDWATER FOR THE PRODUCTION OF ULTRA HIGH PURITY DEIONISED WATER

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ABSTRACT

The use of Newater as feedwater in the production of DI water for SSMC was evaluated. It includes studying the presence of urea, ionic contaminations, and all online analytical parameters. Sophisticated studies on the impact of Newater on the manufacturing processes were reviewed.

INTRODUCTION

There are altogether 12 Wafer Fabs in Singapore which utlilises substantial amount of Deionised water (DIW). It accounts for 7% of the total water consumption in Singapore. Recently, the Republic has started to boost its water supply to the Industry by providing an alternate source of water to Semiconductor sector- Newater. Newater is produced from used water and transforming it into High Grade Water using advanced membrane technology. The process step employed in the production of Newater includes Micro-filtration, Reverse Osmosis and Ultra Violet Photo-radiation. Two major water reclamation plants, with a total capacity of 15 MGD (million gallon per day) have been constructed to support the Wafer Fab industry.

SSMC is one of Wafer Fab identified to be provided with Newater as feed to the production of her in house DIW plant. There was a recent paper (Rydzewski and Godec 2002) that raises concern of the possibility of urea affecting the Photolithography process in Semiconductor Manufacturing. As the source of Newater is from wastewater, a similar phenomenon is perceived to be likely to occur. Studies were conducted to validate any detrimental effect on the use of Newater for the production of DIW on SSMC manufacturing processes including the Lithography process.

APPROACH

There are altogether 3 Phases to study the possibilities of Newater causing T Top effect to the Photolithographic processes and any other possible quality issues associated with the use of Newater.

Phase 1:

Center for Advanced Water Technology, a division of SUI (Singapore Utilities International) took the responsibilities to study, via indirect method, the amount of carbon-nitrogen compounds found in Newater and ultra pure water produced from NEWater as discussed in 1(a) and 1(b). The Centre constructed a high purity water pilot plant that was built on the plug and play concept to determine the quality of UPW produced from Newater (Viswanath et al, 2003).

1(a) UV Oxidisable Nitrogen

Samples of DIW were pumped through a high intensity UV-radiation, the amount of nitrate was measured. This is an indirect method to measure the amount of oxidisable nitrogen in the water. Table 1.1 shows the results of 4 samples with 2 has Newater as feed.

Table 1.1 Nitrate Detected after High Intensity UV Radiation

Samples	NO_3^- (After High Intensity UV)	UV Oxidisable N, as C*
Fab 1, DIW	1.4	0.14
Fab 2, DIW	2.2	0.21
Newater DIW 1	9.9	0.96
Newater DIW 2	12.4	1.19

Urea undergoes complete oxidation under High intensity UV to give Nitrate.

The chemical reaction for the oxidation of urea is as follows:

(NH2)2CO + 4O2 ⇒ 2HNO3+ CO2+H2O

Each mole of urea will give 2 moles of nitrate and 1 mole of Carbon. Therefore even if we assume all nitrates (12.4ppb) detected after UV is a result of urea, the maximum amount of contribution of TOC by urea is 1.2ppb {[12.4* 60/(2*62)] *12/60}.

1(b) Urea enzymatic determination via Ammonium with Urease

Enzymatic determination of the conversion of urea to ammonia and subsequent colormetric determination by the indophenol method was used (Merck Laboratory method). This established laboratory method has a detection limit of 500ppb. When sample of Newater was subjected to this test, it was found to be below detection limit.

Phase 2: Control Experiment on effect of DIW (produced from Newater) on Photolithography process

Active patterning was done on a lot. Existing developer recipe was to manually pour the DIW instead of the usual DIW dispense rinse by robotic arm. 2 wafers were used - one with city water as feed to produce DIW (FDIW) and one with NEWater as feed to produce DIW water (NDIW). In both cases the DIW was poured manually. CD (Critical Dimension) measurement was done for both the wafers and data compared. Tilt SEM was done to study the possibility of T-topping Effect. Defectivity Scan was done on both wafer for defect comparison

Table 2.1 CD Measurement Result

	CD Data							
Water	**Site1**	**Site2**	**Site3**	**Site4**	**Site5**	**Site6**	**Mean**	**Range**
NDIW	212.8	217.8	219	220.1	220.5	217.2	217.9	7.7
FDIW	212.9	219.3	217	221.9	217.9	216.8	217.6	9
Delta	-0.1	-1.5	2	-1.8	2.6	0.4	0.3	1.3

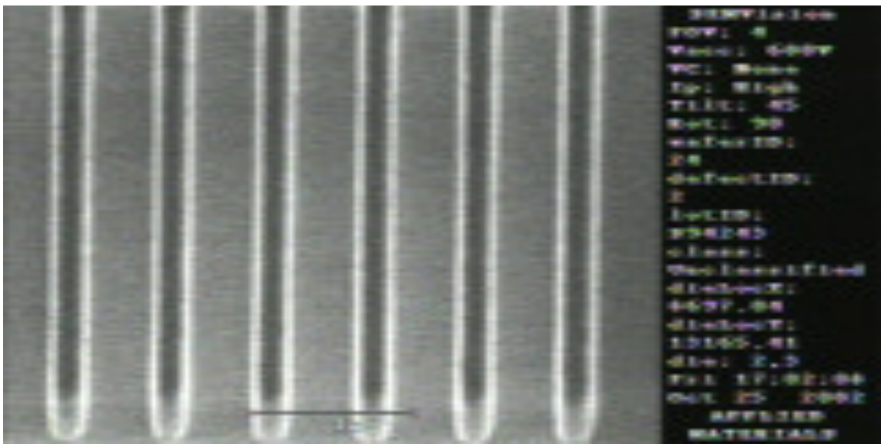


Fig. 2.1 Tilt SEM Pictures (2.1.1 Tilt-SEM Profile for NDIW)

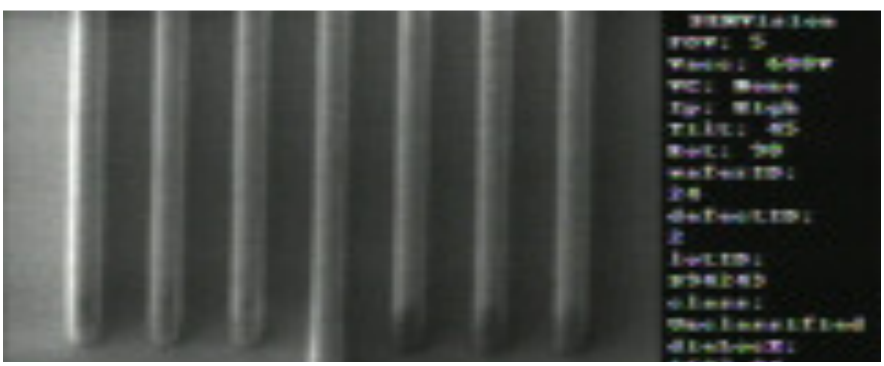
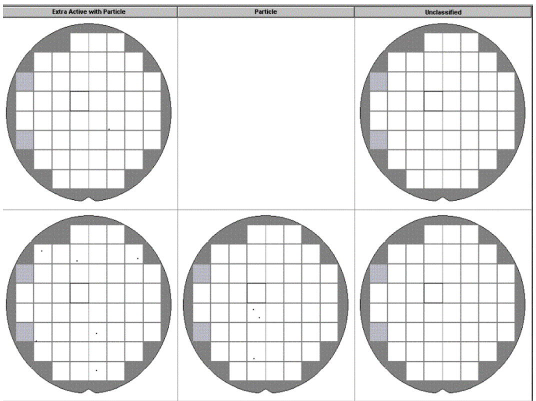


Fig. 2.1 Tilt SEM Pictures (2.1.2 Tilt-SEM Profile for FDIW)

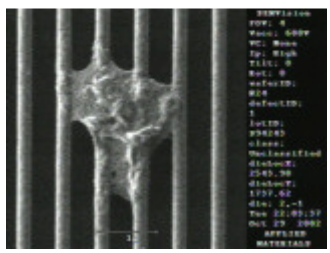


NDIW

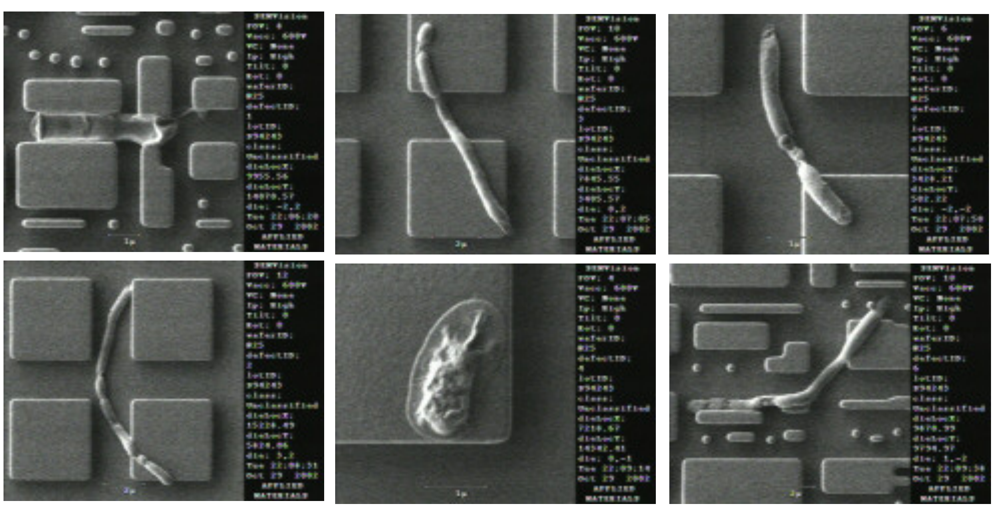
	NDIW	FDIW
Extra Active pattren	1	6
Particle	0	3
Unclassified	0	0
Total	1	9

Fig. 2.2 Defectivity Scan Results

NDIW Defectivity Picture



FDIW Defectivity Pictures



CD data are equal in both cases. TiltSEM data does not show any T-topping effect. Defectivity Scan result shows that the NEWater and existing Fab DIW results are comparable

Phase 3: On Line Newater for Manufacturing Processes

With Phase 1 and Phase 2 completed and all other concerns being addressed for the use of Newater, SSMC has proceeded to use Newater as feed to produce UPW for Manufacturing process. % of Newater used was gradually increased from 10% on 7 Jan 03 and gradually increasing to 100% on 14 Apr 03. The mix of Newater and City Water are illustrated in Fig 3.1

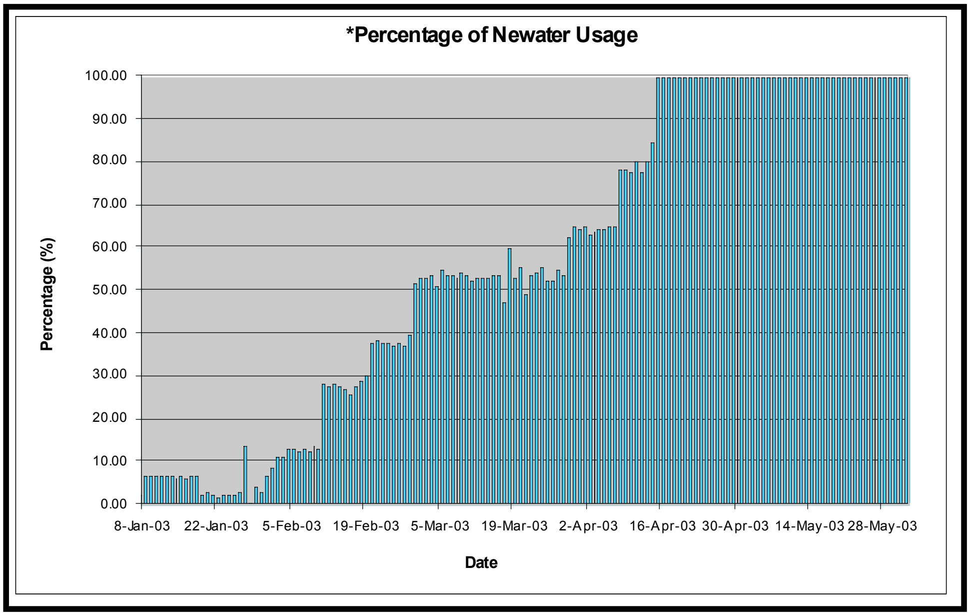


Fig. 3.1 Shows the % of Newater Blended with City Water since 7 Jan 03

DIW Quality and Profiling:

The qualities of incoming and outgoing of the DIW were monitored closely to detect any significance deviations. From the feedwater, the key parameters that were measured include Silt Density Index (SDI), Iron, Total Organic Carbon (TOC). The SDI for feed, after multimedia filter (MMF) and before entry to reverse osmosis (RO) was monitored and as illustrated in the figures 3.2, 3.3, 3.4, respectively. The iron content before and after the MMF were monitored and illustrated in Fig 3.5 and 3.6 respectively. The total organic carbon at the incoming was monitored and illustrated in Fig 3.7.

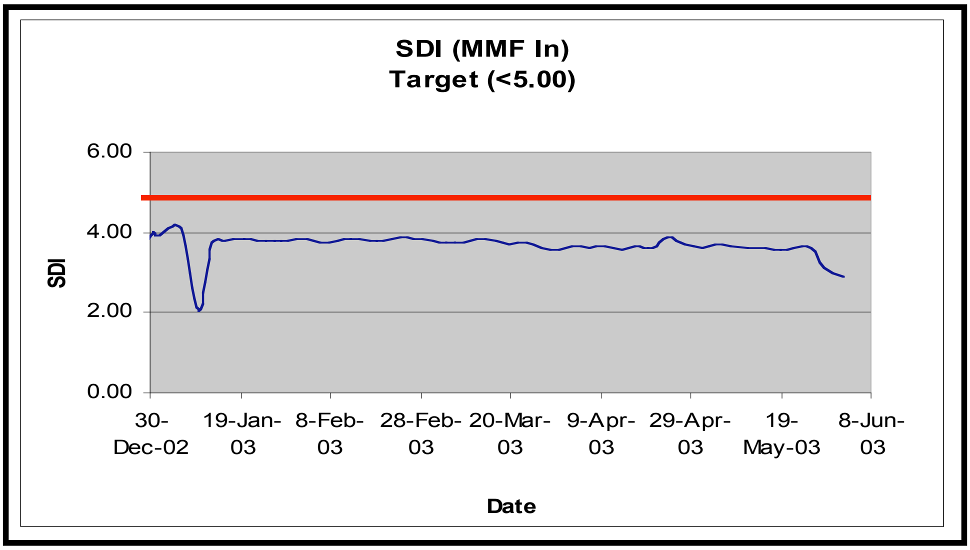


Fig. 3.2 SDI at Feedwater Supply

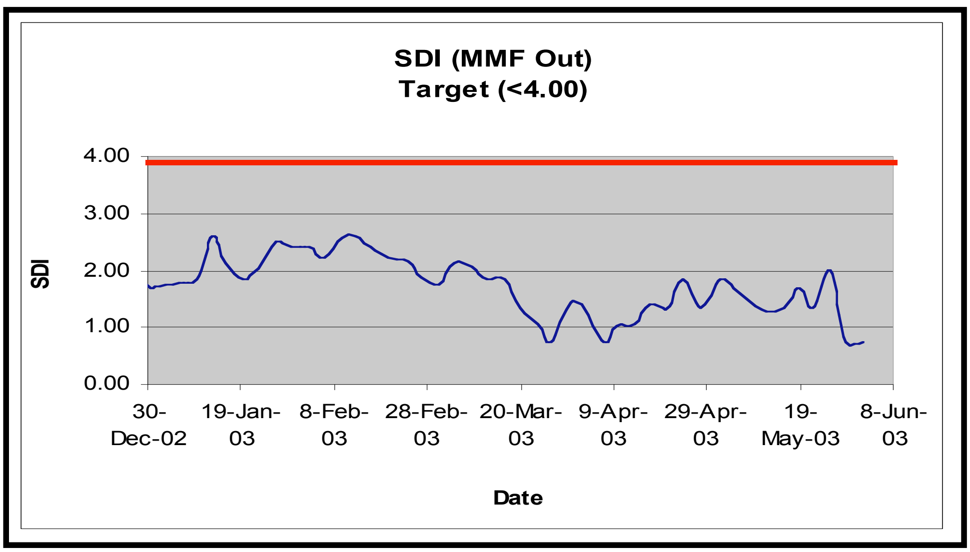


Fig. 3.3 SDI after Multimedia

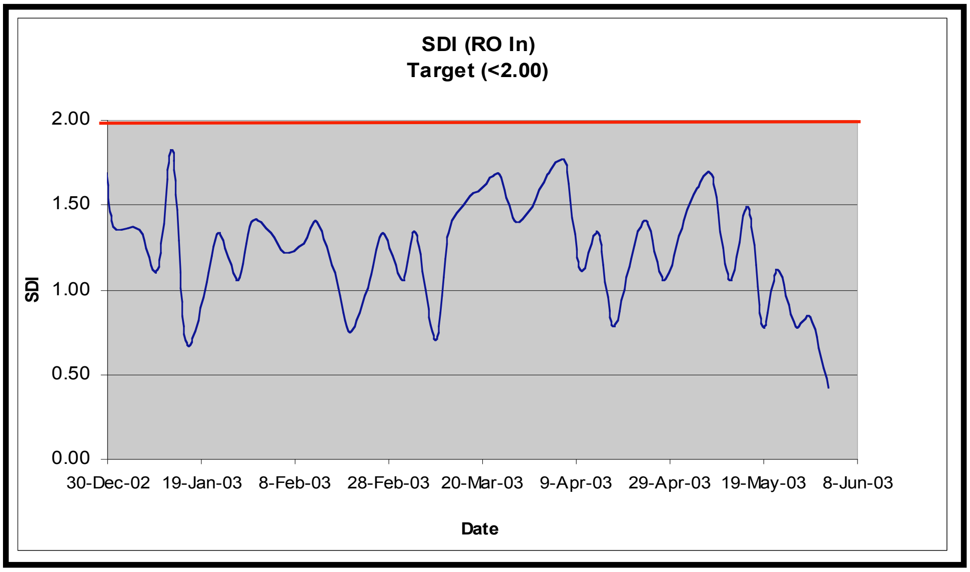


Fig. 3.4 SDI at Inlet to RO

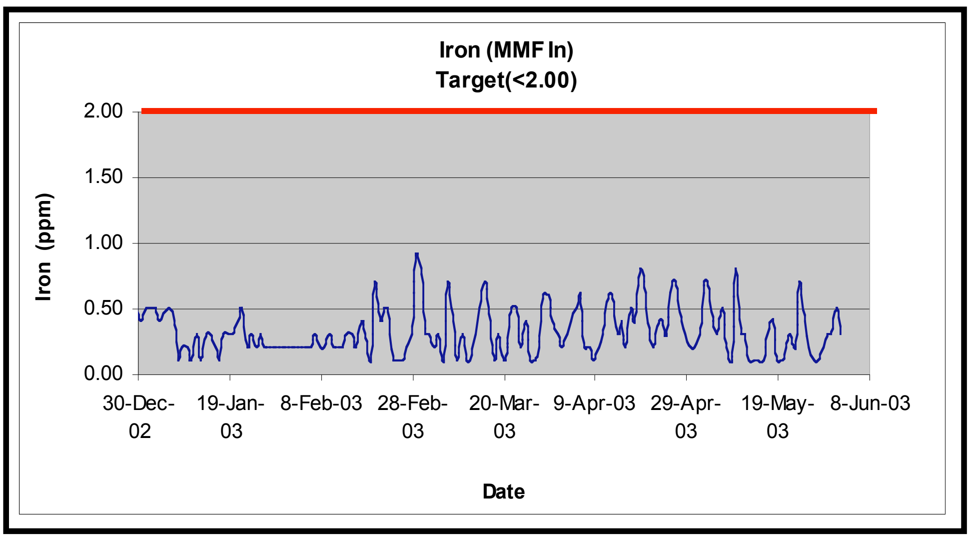


Fig. 3.5 Iron Measured before the MMF

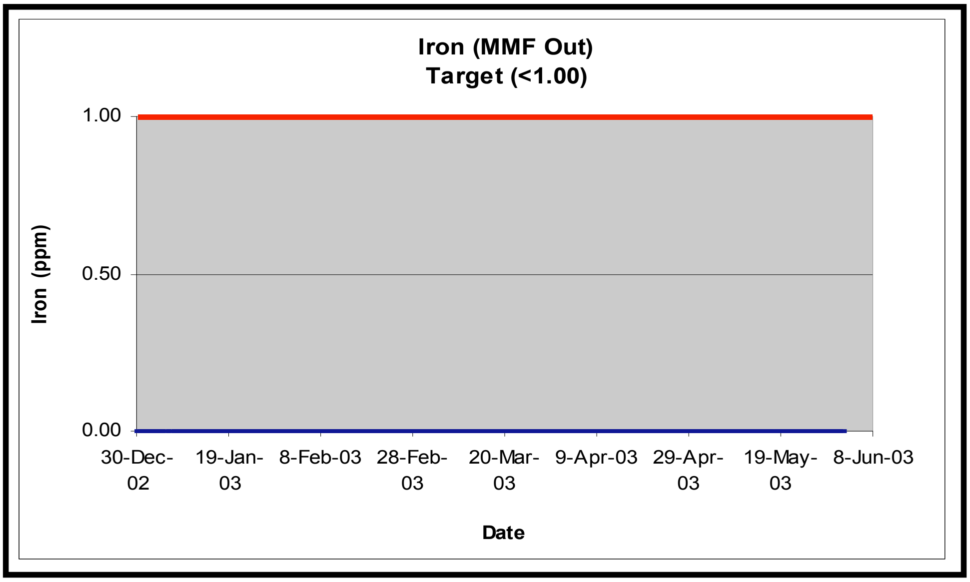


Fig. 3.6 Iron Measured after the MMF

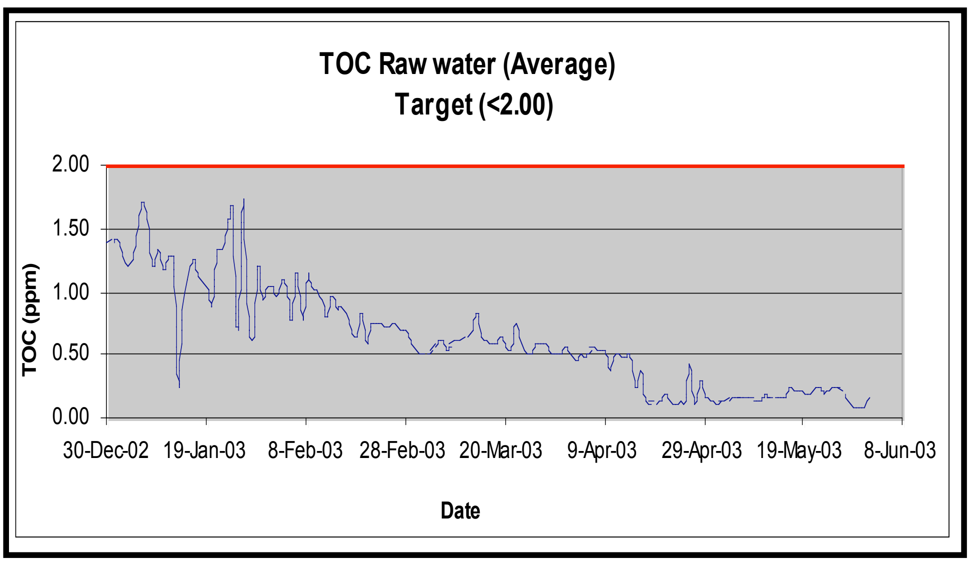


Fig. 3.7 Incoming TOC as Measured by Anatel A2000

No measurable iron was detected after the MMF. Full spectrum analysis of the Feed water was taken for the blended water. It includes fluoride, chloride, nitrate, sulphate, aluminium, boron, barium, calcium, copper, iron, potassium, manganese, nickel, silica, strontium and zinc. Ionic analysis shows no impact for the production of Ultra high purity water. Few metals such as barium, manganese and strontium are appreciably lower in

Newater. A few sample graphs (key parameters and manganese) are shown from 3.8 to 3.12.

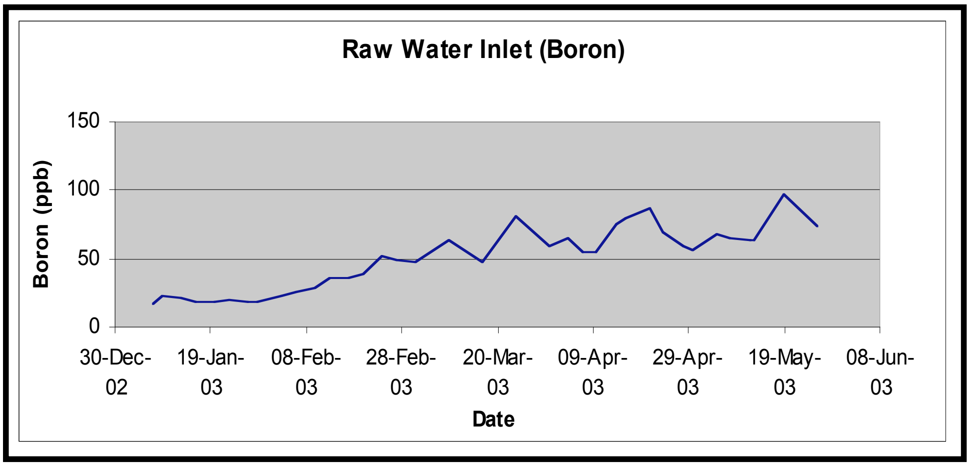


Fig. 3.8 Raw Water Boron

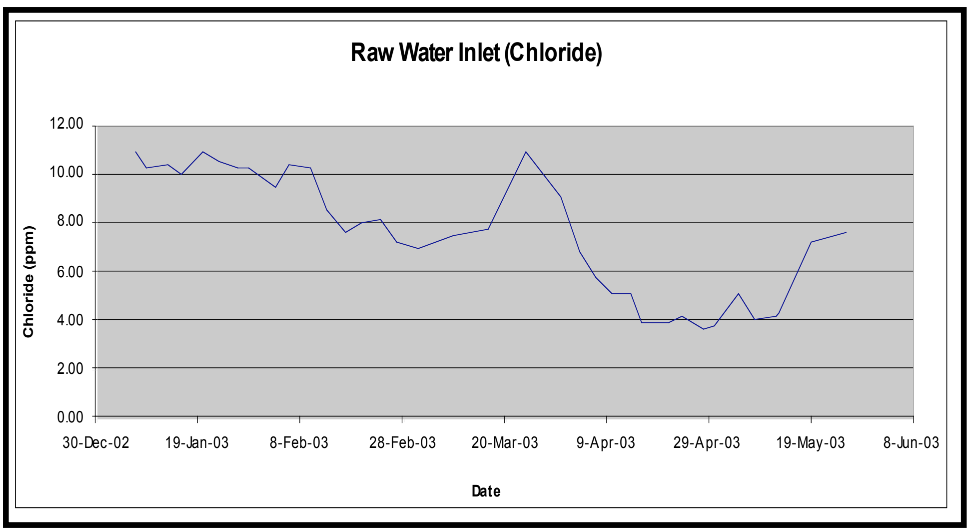


Fig. 3.9 Raw Water Chloride

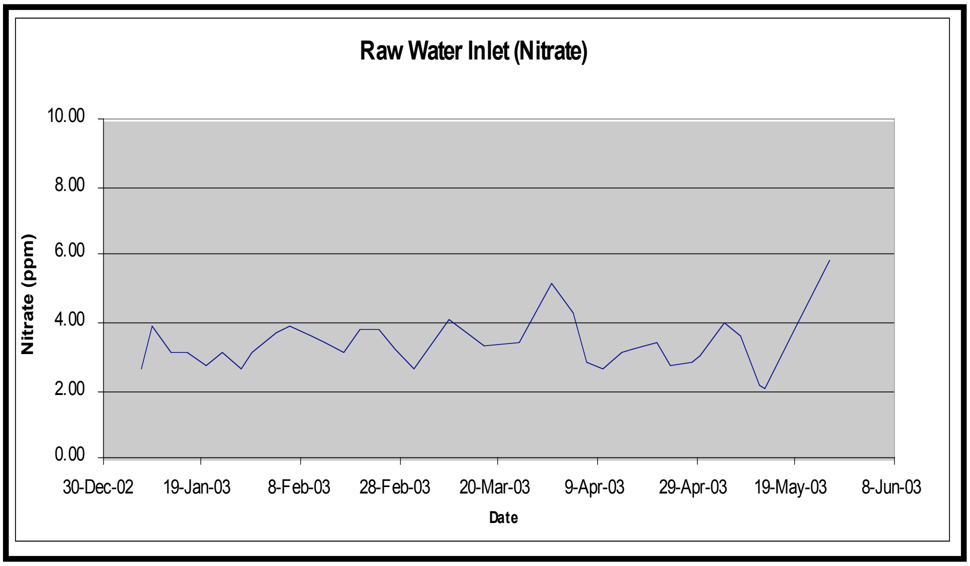


Fig. 3.10 Raw Water Nitrate

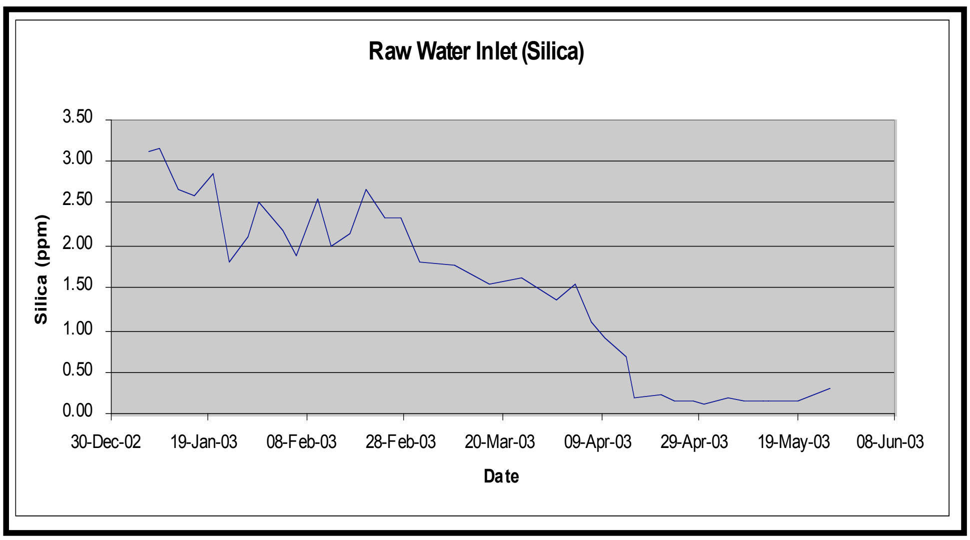


Fig. 3.11 Raw Water Silica

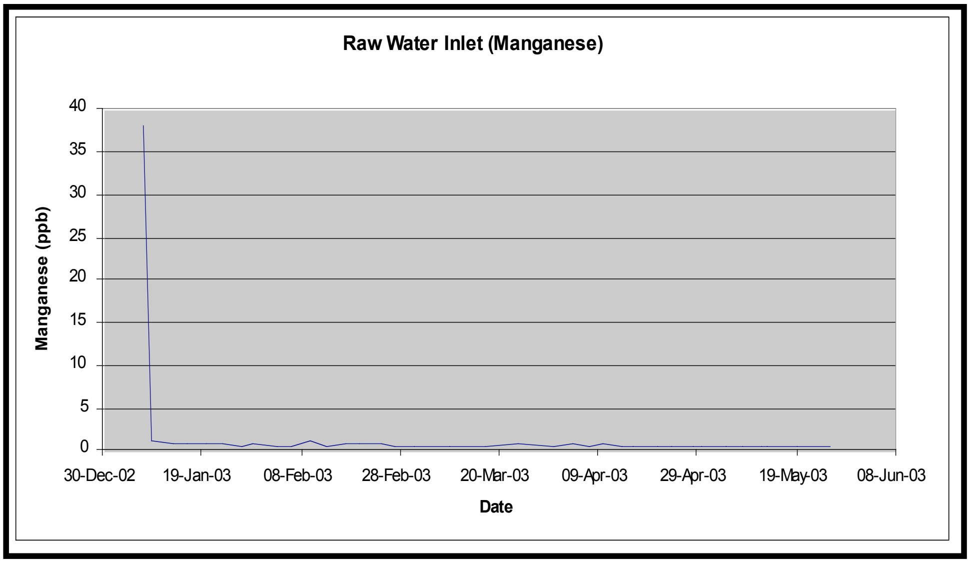


Fig. 3.12 Raw Water Manganese

The concentration of Nitrate after UV was monitored. Fig 3.13 indicates the nitrate concentration after the first UV in the Primary Plant (MGR) and Fig 3.14 indicates the nitrate concentration after the second UV in the Polish Plant.

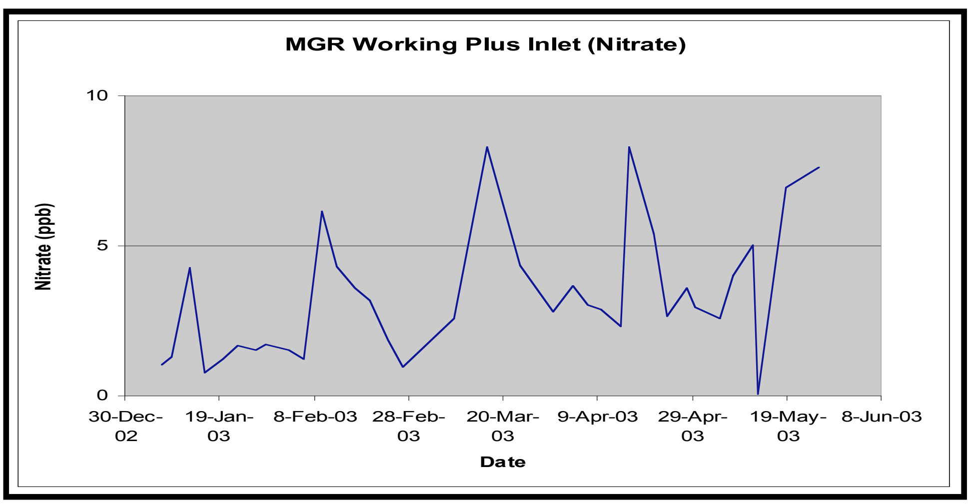


Fig. 3.13 Nitrate Concentration after 1st UV

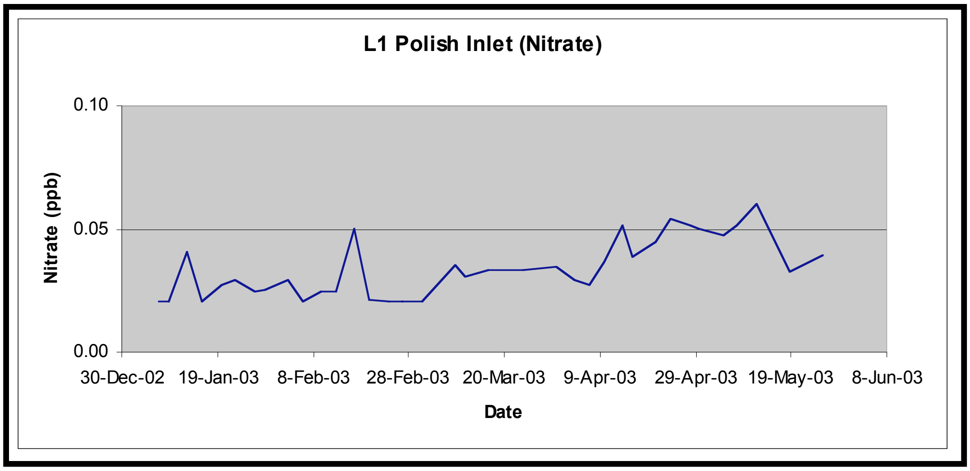


Fig. 3.14 Nitrate Concentration after 2nd UV

The quality of DIW with city water as feed and with blended water (50% of Newater) as feed are illustrated in the Table 3.1. The quality of DIW with Newater as feed is illustrated in Table 3.2. Elemental analysis were done on a twice-weekly basis, no significant increase in Ionic Impurities were detected including Ammonium (<50ppt), Sodium (<30ppt), Chloride (<20ppt) and Nitrate (<50ppt).

Table 3.1 DIW Performance with City Water and with 50% Blended Newater

S/n	Quality Parameter	City Water Average Quality	Blended Water (50%) Average Quality	UPW Performance with City Water	UPW Performance with Blended water
1	TOC	<2,000ppb	<1,000ppb	0.3-0.5ppb	0.3-0.5ppb
2	Conductivity	<200 uS/cm	<100 uS/cm	>18.2mOhm-cm	>18.2mOhm-cm
3	Dissolved oxygen	8,000ppb	8,000ppb	4.5-5.0ppb	4.5-5.0ppb
4	Silica content	<3,000ppb	<2,000ppb	0.3-0.4ppb	0.3-0.4ppb
5	Particle count	Numerous	Numerous	<200/Litre for 0.05um	<200/Litre for 0.05um
7	Bacteria (cultured)	200 col/ml	200 col/ml	Zero col/ml	Zero col/ml
8	Sodium	<10,000ppb	<5,000ppb	<0.03ppb	<0.03ppb
9	Chloride	<10,000ppb	<7,000ppb	<0.02ppb	<0.02ppb

Table 3.2 DIW Performance with City Water and with Newater

S/n	Quality Parameter	City Water Average Quality	Newater Average Quality	UPW Performance with City Water	UPW Performance with Newater
1	TOC	<2,000ppb	<500ppb	0.3-0.5ppb	0.4-0.6ppb
2	Conductivit y	<200 uS/cm	<60 uS/cm	>18.2mOhm-cm	>18.2mOhm-cm
3	Dissolved oxygen	8,000ppb	8,000ppb	4.5-5.0ppb	4.5-5.0ppb
4	Silica content	<3,000ppb	<1,000ppb	0.3-0.4ppb	0.3-0.4ppb
5	Particle count	Numerous	Numerous	<200/Litre for 0.05um	<200/Litre for 0.05um
7	Bacteria (cultured)	200 col/ml	200 col/ml	Zero col/ml	Zero col/ml
8	Sodium	<10,000ppb	<5,000ppb	<0.03ppb	<0.03ppb
9	Chloride	<10,000ppb	<7,000ppb	<0.02ppb	<0.02ppb

As an illustration, the continuous monitoring of the point of use TOC are plotted.

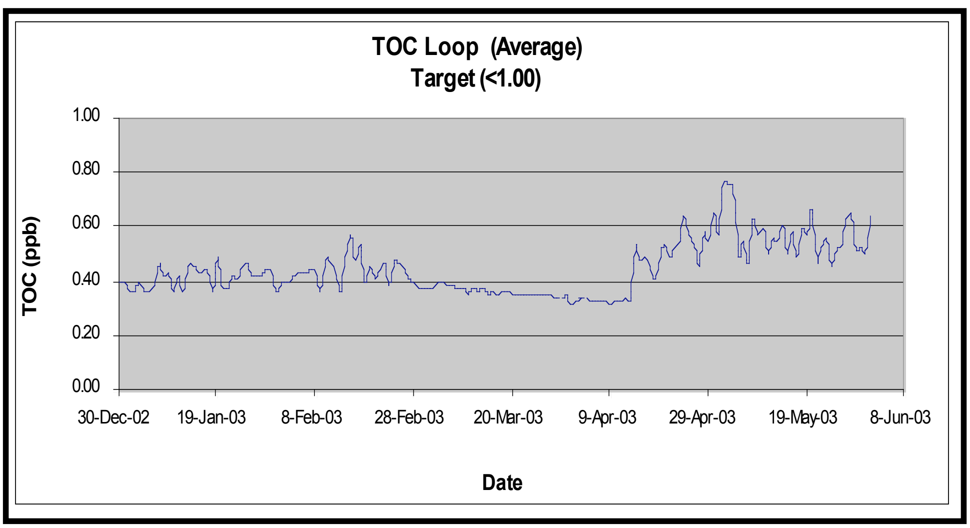


Fig. 3.15 TOC in the Point of Delivery

Fab Monitoring

In the Photo process, Etch Bias is determined for each flow through the litho process. Etch Bias is the difference between ADI (After Developed Inspection) and AEI (After

Etch Inspection). Stringent Statistical Process Control (SPC) is managed for the Etch Bias. If there is T Top effect at the litho process, there will be significant change in the Etch Bias due to unpredictable etching from the T-Top. And it will subsequently fail the SPC for Etch Bias.

In the wet process, it measures the Surface Photo Voltage- (SPV) on a weekly basis. Fig 3.16 and 3.17 shows the trends from Nov 02 (without Newater) to 30 May 03 (with 100% Newater) for iron contamination and diffusion length.

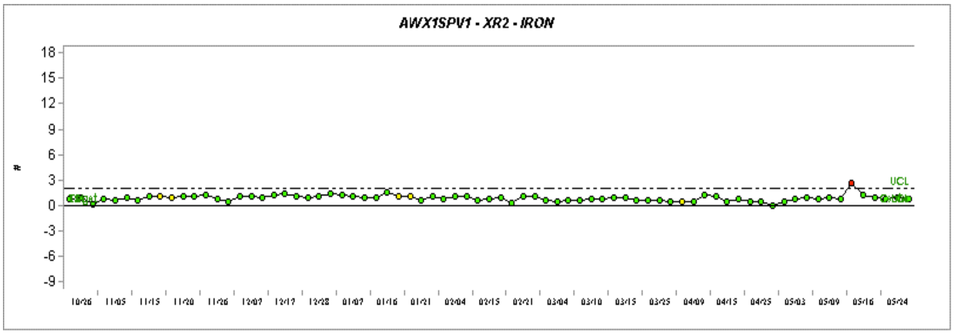


Fig. 3.16 Fe Contamination Studies

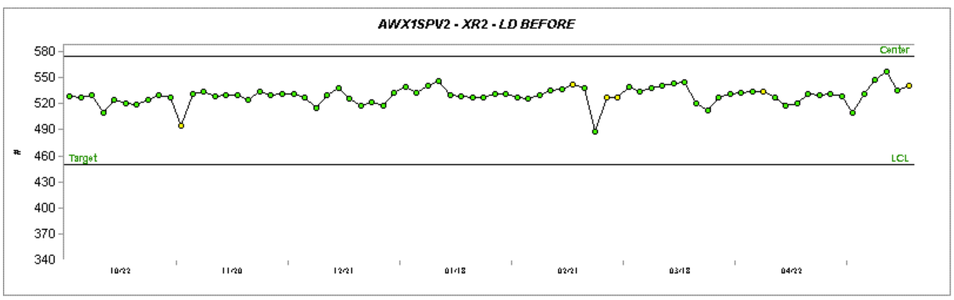


Fig: 3.17 Diffusion Length Studies

DISCUSSION OF RESULTS

Analytical laboratory results were used in the determination of urea level in Newater. It is not deterministic as to the level of urea found in Newater. It is sure that the level is <500ppb based on Merck's method. With the inference that all oxidisable nitrogen is from urea after an aggressive high dosage of UV light, there is a maximum increase of 10 ppb of Nitrate which implies a maximum of 1ppb as organic carbon. According to Bala Viswanath et al (Viswanath et al, 2003), the High Purity Water pilot plant establishes that TOC concentrations of less than 1 ppb could be achieved consistently with Newater as the feed source. In addition to TOC, other key parameters such as ionic concentrations, particle counts, and resistivity of the high purity water produced from Newater were comparable with high purity water generated from potable water.

With the In Situ introduction of Newater produced DIW manually, these are the few conclusions that were arrived from SSMC internal engineering report. Defectivity Scan results show the Newater produced DIW and existing Fab DIW are comparable. CD Data are equal in both cases. TiltSEM data shows there is no T topping effect. Above three tests show the data are comparable as far as Photo process is concerned. There are limitations to the "bench" test conducted. The proper way of checking will be to use a separate line for DIW as pouring is not controlled as far as flow and quantity is concerned. It is also very difficult to follow the recipe exactly without modification. It is prone to contamination while pouring, during transportation and storage.

With the phase in of Newater up to 100%, there is no change or instability in Etch bias reported. We can therefore conclude that there is no T-Top effect in the Photolithography process. On line supply of Newater to produce DIW (progressively from 10% to 100%) shows no appreciable difference with respect to Fab in line contamination measurements. Both the Fe contamination and diffusion length studies have not shown any significant change. The level is still within the target and upper control limit (UCL) of the statistical process control.

Key parameters from the Pretreatment to the DIW water were analyzed. There was no significance difference with the use of Newater that could point to potential quality escalation. Nitrate profiling was done with no appreciable difference for the blended Newater.

CONCLUSION

Newater is a good alternative to the production of DIW. There is no evidence to indicate any significant detrimental effects on the Manufacturing process within the current analytical technique available in the FAB.

REFERENCES

Viswanath. B., Kekre. K., and Tao. G. H. PhD. (2003). Reclaimed Water: AN alternate source for High purity water production in the Semicondcutor Industry. Ultrapure Water Journal, Vol 20, #5, 41-46.

Rydzewski. John., and Godec. Richard. (2002). "Undetectable TOC in UPW can influence Photolithography Processes" in Proceedings of Semiconductor Pure Water and Chemicals Conference (SPWCC) on March 12.

Merck Laboratory method: 14843 Microquant Urea Test for swimming pools.

WATER RECYCLING – AN INDUSTRIAL CASE STUDY

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ABSTRACT

Water recycling is an effective measure to protect precious water resources. Facing water scarcity issue, Singapore government encourages industries to reclaim and reuse wastewater. Nowadays water consumers have more choices than before to tap on various water sources. This paper presents an industrial case study on water recycling, where a variety of grades of recycling water are being produced from municipal wastewater, i.e., Industrial Water and High Grade Industrial Water (HGIW). Industrial Water is biologically stable, of low organic contents (COD 30 ~ 60 mg/L) and low suspended solids (TSS 3.0 ~ 6.5 mg/L). In comparison, HGIW is being further polished using advanced reverse osmosis technology. Comparable with potable water, HGIW is superior in quality, characterized by low dissolved solids (TDS 60 mg/L) and hardness (Hardness 3 mg/L as $CaCO_3$). It can be used as process water, cooling water makeup, boiler feed water and so on. If it is used as the feed to a demineralized water plant, cost saving is significant. For water consumers, understanding the water quality characteristics is essential for choosing the most cost-effective water source.

Key Words: Water Recycling; Water Reuse; High-grade Industrial Water; Industrial Water; Demineralized Water.

INTRODUCTION

Water shortage is a prevailing issue that the modern world is facing. In the context of scarcity of water resources in Singapore, water recycling and reuse are strongly encouraged. Wastewater is one of the available water resources ready for reclamation. Singapore has seen great development of wastewater collection and treatment infrastructure. It was reported that total volume of wastewater treated in year 2002 is around 477 million cubic meters (http://www.pub.gov.sg).

Municipal wastewater treated by conventional biological process is adequate to discharge into the environment; however, further treatment is required before extensive reuse is possible. As a typical water conservation project, Jurong Industrial Water Works (JIWW) was constructed in 1966 to reclaim the final effluent from Ulu Pandan Water Reclamation Plant (UPWRP).

Jurong Island is situated at southern Singapore harboring a world class petrochemical and chemical industrial park. Everyday huge amount of water is consumed by refineries, crackers and downstream chemical industries. As pioneers in integrated utility, SUT Sakra Pte Ltd and SUT Seraya Pte Ltd (SUT) take the initiative to manage the precious water resources on Jurong Island. An effluent recycling plant was built and commissioned in 2000. Taking JIWW effluent as feed water, the plant produces 30,000 m^3/day High-grade Industrial Water (HGIW) and supplies to the petrochemical and chemical industries. Figure 1 briefly illustrates the wastewater treatment and water recycling regime.

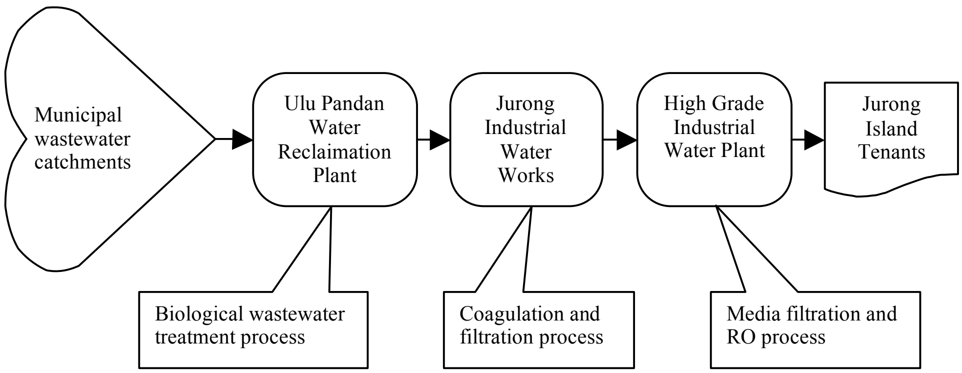

Fig. 1 Water Recycling Scheme

This paper presents the case studies of water recycling in Singapore. Being reclaimed from municipal wastewater, Industrial Water and HGIW are supplied to industrial consumers as an alternative water sources. In additional to remarkable significance in water conservation, recycling water is welcomed by industries due to its extra economic benefits.

INDUSTRIAL WATER

Jurong Industrial Water Works was set up to reclaim municipal effluent from the Ulu Pandan Reclamation Plant into Industrial Water as an alternative source of water for the industries in Jurong/Tuas Industrial Estate, Tuas View and Jurong Island, Singapore. The plant capacity has increased over the years to meet the increasing demand for Industrial Water. In 2002, the average consumption of Industrial Water is about 94,300 m^3/day (http://www.pub.com.sg).

Treatment Process Description

The origin of raw water is sewage which is collected from catchments area including Bukit Timah, Clementi, Orchard, Jurong East, Bukit Merah, Queenstown, Telok Blangah, Pasir Panjang and Marina South.

As the first step of treatment, the sewage is processed in Ulu Pandan Water Reclamation Plant using biological wastewater treatment technology. Suspended solid is removed through sedimentation, producing relatively clear water with TSS less than 20 ~

60 mg/L. The majority of organic substance is biodegraded by aerobic activated sludge. Effluent from this plant normally contains 6 ~ 20 mg/L BOD5 and 50 ~ 120 mg/L COD, respectively (see Table 1).

Table 1 Water Quality Comparison

S/N	Parameters	Unit	UPSTW Effluent	JIWW Effluent
1	Color	Hazen Unit	15 ~ 30	5 ~ 15
2	Turbidity	NTU	5 ~ 25	0.5 ~ 2.0
3	pH	-	6.8 ~ 7.3	6.8 ~ 7.3
4	BOD_5	mg/L	6 ~ 20	1.0 ~ 3.0
5	COD	mg/L	50 ~ 120	30 ~ 60
6	DO	mg/L	1.5 ~ 3.5	5.0 ~ 7.0
7	Total Suspended Solids (TSS)	mg/L	20 ~ 60	3.0 ~ 6.5
8	Total Dissolved Solids (TDS)	mg/L	500 ~ 1,400	350 ~ 1,300
9	Conductivity	µS/cm	700 ~ 1,600	700 ~ 1,600
10	Alkalinity as $CaCO_3$	mg/L	50 ~ 150	30 ~ 80
11	Total hardness as $CaCO_3$	mg/L	100 ~ 250	100 ~ 250
12	NH_3-N	mg/L	5.0 ~ 20.0	5.0 ~ 15.0
13	NO_2-N	mg/L	0.1 ~ 0.3	0.1 ~ 0.3
14	NO_3-N	mg/L	5.0 ~ 10.0	5.0 ~ 10.0
15	TKN	mg/L	8.0 ~ 20.0	8.0 ~ 20.0
16	Total PO_4-P	mg/L	3.0 ~ 5.0	1.0 ~ 4.0
17	Chloride as Cl	mg/L	100 ~ 500	100 ~ 500
18	Sulfate as SO_4	mg/L	80 ~ 145	80 ~ 145
19	Detergent as LAS	mg/L	0.1 ~ 0.4	0.1 ~ 0.2

*Courtesy of PUB.

Effluent from UPWRP is ready to discharge to the environment. But it is not suitable for reuse in most occasions since the impurities are still high. For the purpose of industrial water reuse, UPSTW effluent is further treated by JIWW.

Figure 2 describes the basic process in JIWW. Coagulation, sedimentation and filtration are the core processes which aim to remove majority of suspended solids and colloidal. Raw water, after screening by a band screen, undergoes chemical conditioning such as pH adjustment and pre-chlorination. Alum and polymer are injected into the water to make small particles aggregate and form floc that is subsequently being separated from water in lamella clarifiers. Fine particles are filtered in gravity sand filters. Treated water is free of suspended solids and colloidal. After post treatment with aeration and chlorination, the water is ready to be supplied as Industrial Water.

Water Quality

The water quality of JIWW water is shown in Table 1. In comparison with UPWRP effluent, JIWW water is characterized by low suspended solids, moderate organic content and dissolved solids. Typically TSS is around 3.0 ~ 6.5 mg/L, COD 30 ~ 60 mg/L and TDS 350 ~ 1,300 mg/L.

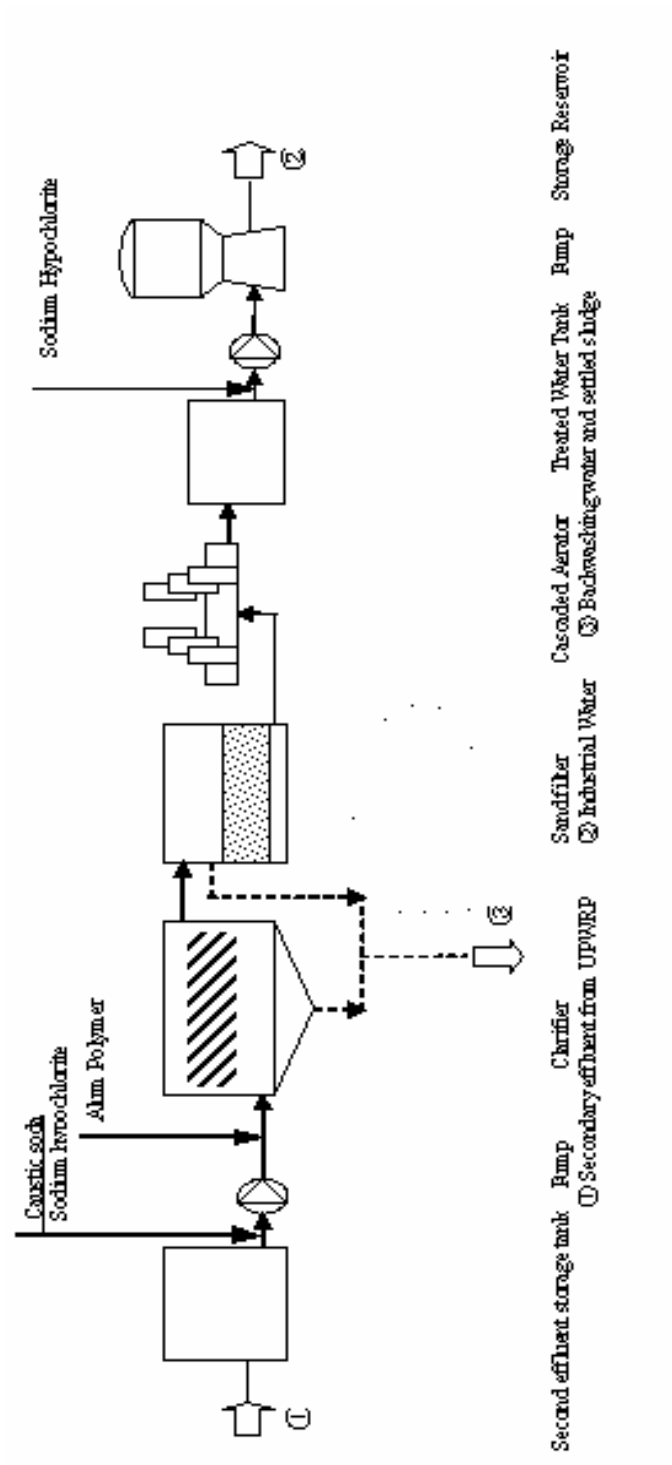

Fig. 2 Process of JIIWW Plant

Usage of Industrial Water

Today there are over 130 km of underground distribution mains, supplying Industrial Water to industries as a good alternative water source to replace potable water. Water cooling is a major usage, contributing to 56% of total Industrial Water consumption (see Figure 3). Other applications such as textile manufacturing and washing consume over 10%. There are 32% of Industrial Water, about 36,000 m^3/day, is being transmitted to Jurong Island for High Grade Industrial Water production (http://www.pub.com.sg).

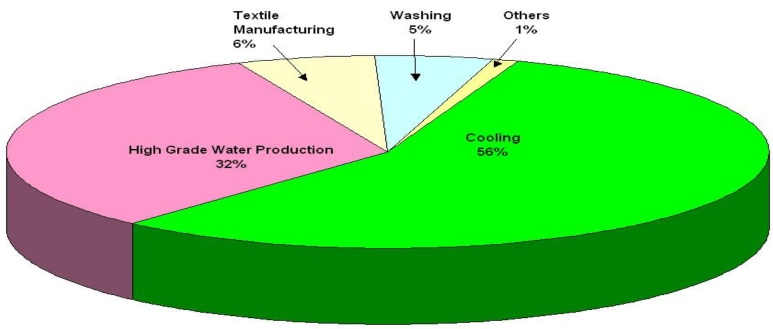

Fig. 3 Water Usage of Industrial Water

HIGH GRADE INDUSTRIAL WATER

High Grade Industrial Water plant, owned and operated by SUT Seraya Pte Ltd, supplies HGIW to tenants on Jurong Island. HGIW plant is taking effluent from JIWW as feed and treated to high quality water for industrial uses.

Process Description of HGIW Plant

Figure 4 illustrates the process of HGIW plant. The process basically consists of two main treatment processes: in-line media filtration pretreatment and reverse osmosis (RO). The former removes suspended solids and colloidal particles, producing low membrane fouling potential water to suit RO process. The latter retains almost all the free particles and majority of dissolved solids. As such, good quality water is obtained. When it enters HGIW plant, JIWW water is injected with sodium hypochlorite and coagulant. The purpose of chlorination is to eliminate biological propagation in the subsequent media filters. It also helps reduce the possibility of biofouling to RO membranes. Coagulation is essential to filter efficiency since it enables small particles to agglomerates into large particles by mechanisms of charge neutralization and floc sweep. Water rich in large flocs is then pumped to a pressure of 5~6 bars and directly fed to filters. The primary filters are loaded with anthracite and sand to establish dual media filtration maximizing filtration efficiency. Secondary filters contain only fine sand further polishing the water. As safety filters, a number of cartridge filters of nominal size 5 μm are installed to maintain a consistently good water quality in case of filter effluent quality excursion. By such an arrangement, pre-treatment effluent quality is able to meet RO process requirements, normally turbidity less than 0.25 NTU and SDI less than 5.

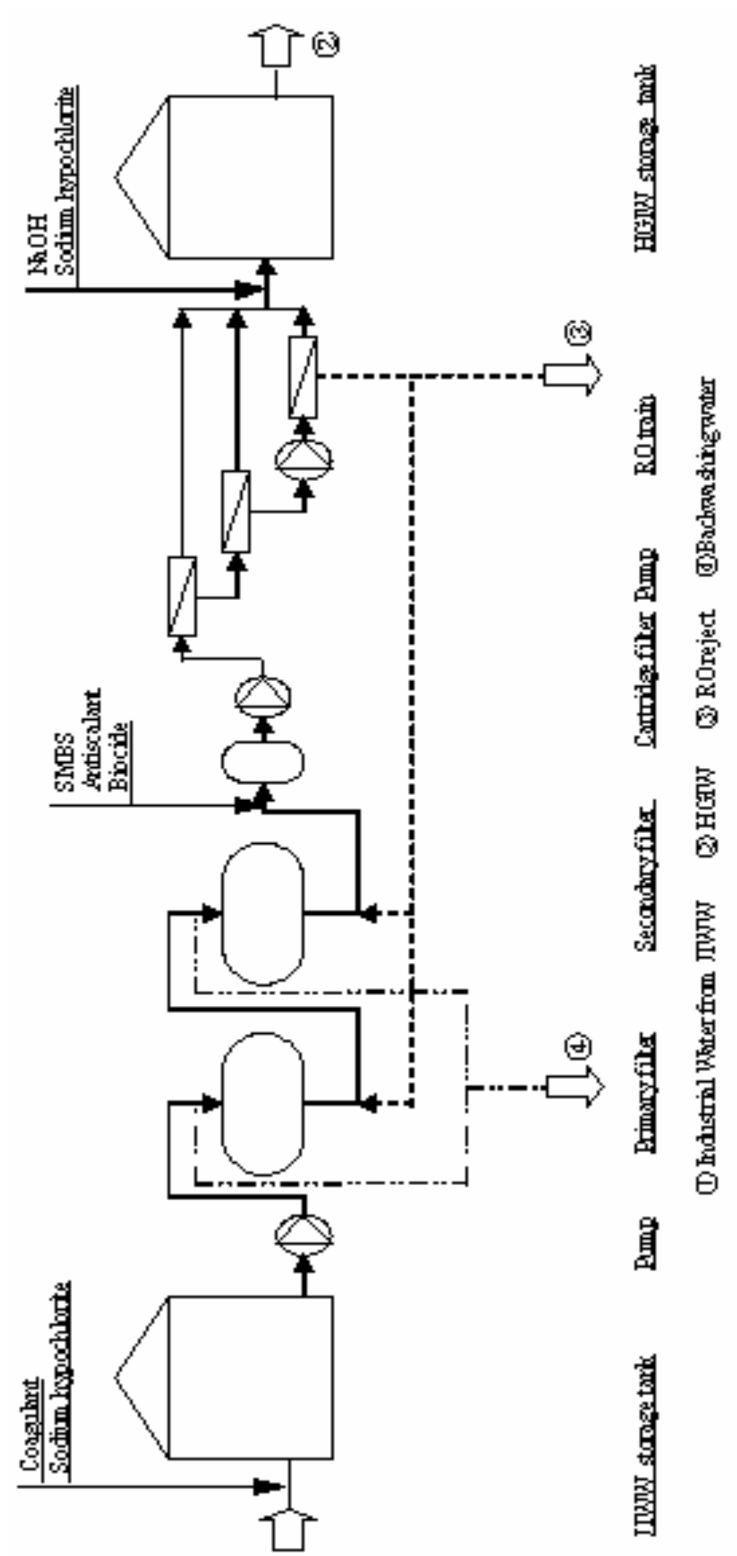

Fig. 4 Process of HGIW Plant

The RO unit consists of six RO trains, with installed capacity of 5,000 m^3/day each. The RO train is designed in the configuration of single pass and three arrays. A total of 52 pressure vessels houses 364 elements (membrane model FILMTEC BW30-365FR2). Multiple arrays elevate recovery up to 86%, an industrial benchmark in similar applications. The membrane works under a pressure of 10~14 bars to counter for osmosis pressure and membrane resistance. Post-pretreatment or chemical conditioning is being performed by dosing sodium hypochlorite and sodium hydroxide.

Table 2 Typical Water Quality of HGIW

S/N	Parameters	Unit	Operational average
1	pH	-	7.1
2	Conductivity	μS/cm	101
3	Total Dissolved Solids (TDS)	mg/L	60
4	Turbidity	NTU	0.2
5	Total Suspended Solids (TSS)	mg/L	0.1
6	Total Hardness as $CaCO_3$	mg/L	2.8
7	Alkalinity as $CaCO_3$	mg/L	24
8	Color	Hazen Unit	<5
9	Odor	-	Unobjectionable
10	Fluoride	mg/L	0.1
11	Chloride as Cl	mg/L	11
12	Sulfate as SO_4	mg/L	2
13	NH_3-N	mg/L	0.5
14	NO_3-N	mg/L	0.02
15	Total PO_4-P	mg/L	0.02
16	Silica as SiO_2	mg/L	0.4
17	Cyanide	mg/L	N.D.
18	Sodium	mg/L	18
19	Iron	mg/L	0.02
20	Aluminum	mg/L	0.01
21	Copper	mg/L	0.01
22	Manganese	mg/L	0.01
23	Zinc	mg/L	0.01
24	Arsenic	mg/L	N.D.
25	Cadmium	mg/L	N.D.
26	Chromium	mg/L	N.D.
27	Lead	mg/L	N.D.
28	Selenium	mg/L	N.D.
29	Mercury	mg/L	N.D.
30	TOC	mg/L	1.2

Note: N.D. --- Non detectable.

Characteristics of HGIW

Pressure-driven RO membranes retain solutes in aqueous solution by solution-diffusion and exclusion mechanisms. Small particles are rejected by the water layer adsorbed on the surface of membranes, which is known as dense membranes. Ionic species are transported across the membrane by diffusion through the pores of the macromolecules comprising the membrane. Typically, RO can reject particles as small as 0.0001 µm (Tchobanoglous et al, 2003). Effective removal of dissolved solids or ionic species is the merit of RO, distinguishing from most conventional water recycling technologies.

Table 2 shows the typical water quality of HGIW. The water is characterized by low TDS and hardness, less silica and organic contents. Comparing with raw water (JIWW water), TDS has been reduced from 800 mg/L to below 100 mg/L; hardness (as CaCO3) from 100 mg/L to 0.2 mg/L, silica (as SiO2) from 9 mg/L to 0.4 mg/L and TOC from 10 mg/L to 1.2 mg/L, respectively. These characteristics have greatly broadened the spectrum of uses of recycling water. HGIW is being widely used for process water, boiler feed water, ultra-pure water production, cooling water makeup and so forth in chemical industry.

Stability of water quality and reliable supply is a concern for industry users. RO process together with pre-treatment system is capable of supplying constant quality water, regardless of great fluctuation of incoming water. This is demonstrated in Figure 5, where the conductivity trends of JIWW water and HGIW are illustrated. Statistical analysis of water parameters are shown in Figure 6.

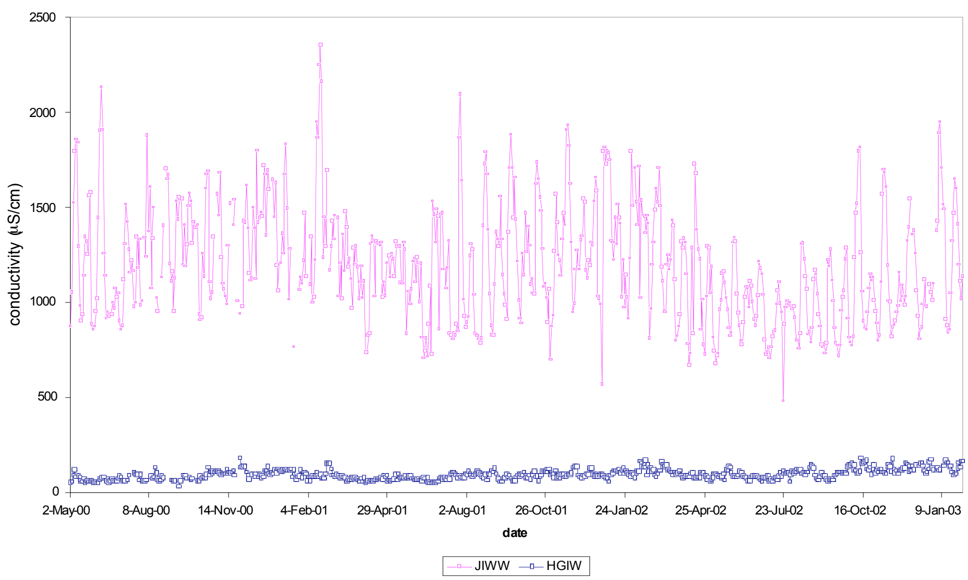

Fig. 5 Variation of HGIW Water Quality Corresponding to JIWW Water

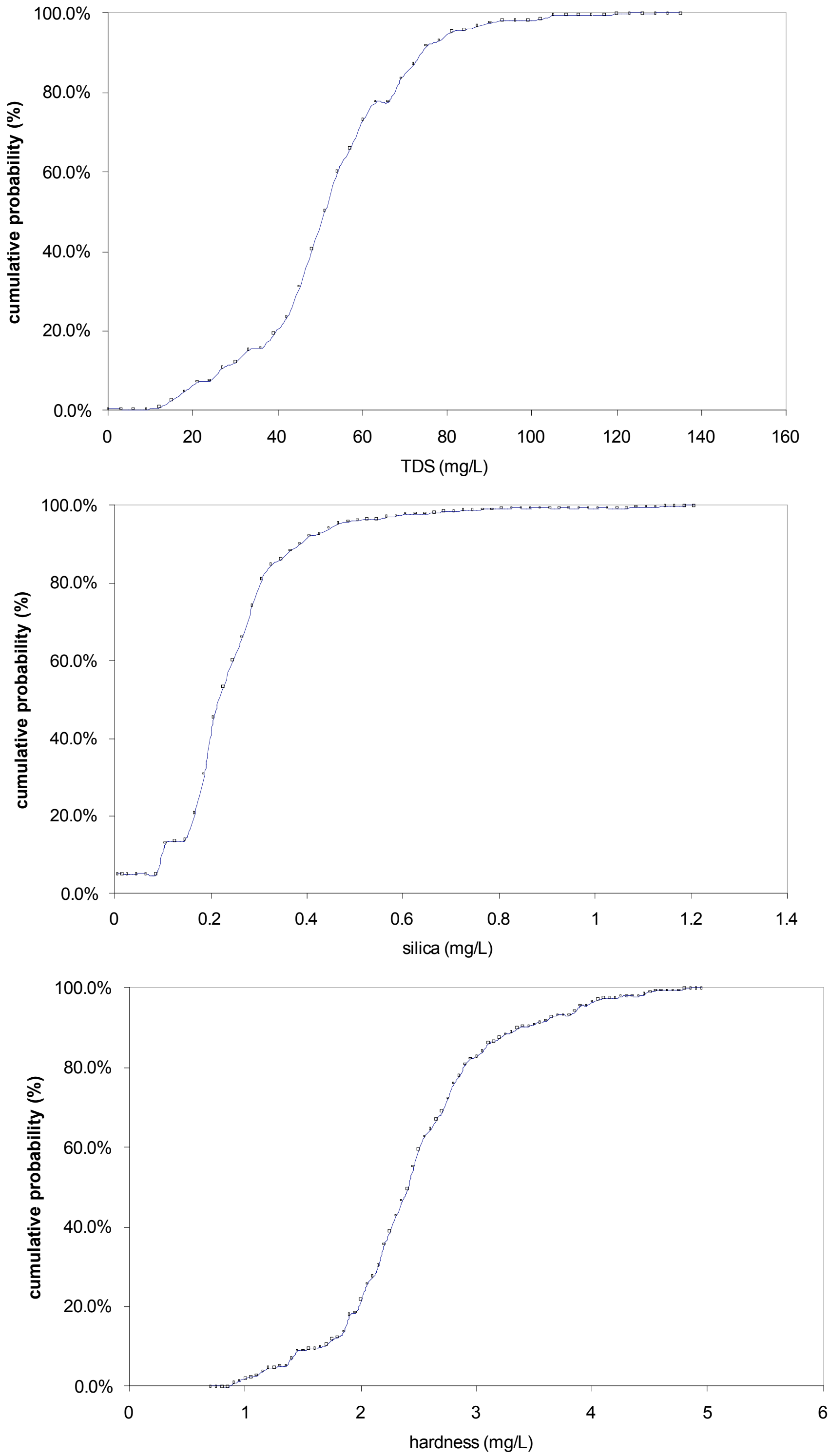

Fig. 6 Statistical Analysis of HGIW Quality

A CASE STUDY – USAGE OF HGIW

Demineralized (Demin) water production is a typical usage of HGIW. SUT Sakra Pte Ltd operates a Demin water plant, supplying demineralized water to boilers, cogent plant and chemical plants. As an alternative feed to Demin plant replacing potable water, HGIW brings additional merits to the operation and value added to end users.

Demineralized Water Plant

High pressure boilers and cogent plant require high quality water as boiler feed water. Basic requirements are conductivity less than 0.1 µS/cm and silicate less than 10 µg/L as SiO2 in chemical industries. These targets can be achieved by application of ion exchange process. Figure 7 shows the process flow diagram of SUT Demin plant. There are three trains running in parallel, with capacity of 380 m^3/hr each. The Demin train comprises activated carbon filters (SAC), cationic ion exchanger (SAC), anionic ion exchanger (SBA) and mixed bed ion exchanger (MB). SAC reduces chlorine, suspended solids and trace organic substance to safeguard ion exchanger resins while ion exchangers remove minerals in the water.

Operation Experience of Demin Water Plant

The Demin plant treats raw water and condensate while raw water can be either potable water or HGIW. Potable water originates from natural surface water whereas HGIW is a recycling water processed by RO. Potable water normally contains 100 mg/L TDS and 5.4 mg/L silica whereas HGIW is of better quality of TDS 60 mg/L TDS and 0.4 mg/L silica. Operation experience demonstrates that ion exchangers are capable of running longer service cycle of 12,000~13,000 m^3 throughput using HGIW as feed, comparing with potable water, only 7,000~8,000 m^3 throughput is achievable. In that sense, savings on chemical cost and downtime are significant if HGIW is used.

Another benefit using HGIW is prolonged resin life. HGIW is free of suspended solid and less organic substance, resulting in less resin fouling. It is expected that resin life will extend 30%~40% if HGIW is used to replace potable water.

CONCLUSION

Recycling water is a vital water resource. Under the circumstances of water scarcity and technology advancement, water reclamation becomes a profitable business driving private utility companies to enthusiastically involve in this mission. The recycling water is a rising market in Singapore, which sets an example for the world to resolve water resources issue.

Conventional water treatment technologies such as chemical coagulation, sedimentation, filtration, together with advanced technologies such as membrane filtration, form the basis of treatment processes in a water recycling plant. In additional to the traditional water source, consumers are at their discretion to choose from different grades of water sources. For example, there are Industrial Water, HGIW and potable water available on Jurong Island. Chemical companies can choose either of them to suit their needs with competitive economic benefit.

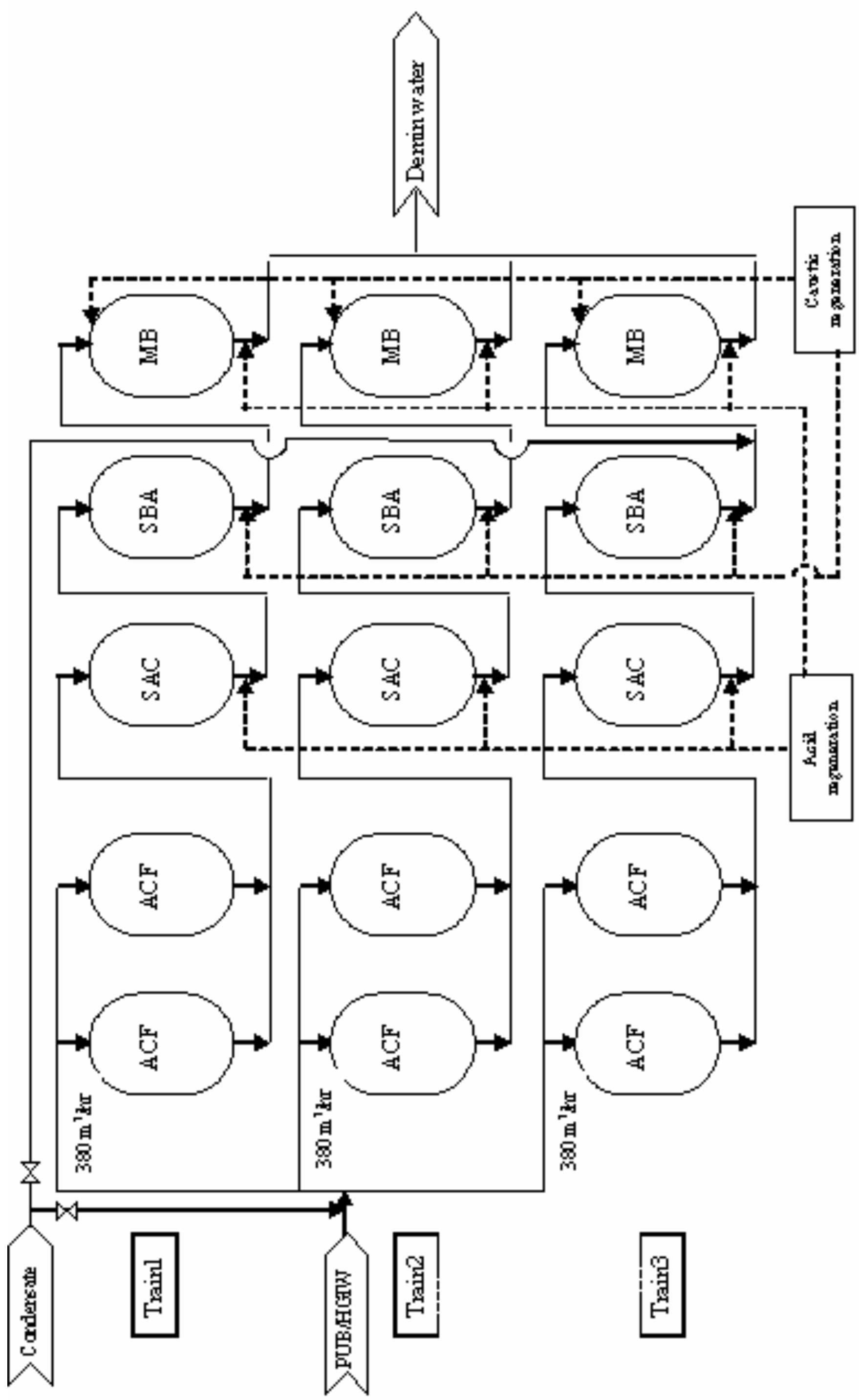

Fig. 7 Process of Demin Water Plant

Membrane filtration is a growing technology. With wide spectrum of membranes from microfiltration, ultrafiltration, nanofiltration to reverse osmosis, a variety of grades of recycling water can be produced solely using membrane filtration as core process. Currently the major hindrances to membrane technology are membrane cost and operational problems such as membrane fouling. If these issues can be resolved, recycling water will be the most cost-effective alternative water resource benefiting human society.

REFERENCES

Tchobanoglous, G., Burton, F.L. and Stensel, H. D. (2003). Wastewater Engineering Treatment and Reuse. McGraw Hill Companies, Inc., 1107.

Website: http://www.pub.gov.sg.

RECYCLING OF NON-INDUSTRIAL WATER IN JAPAN

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ABSTRACT

The recycling of non-industrial water in Japan will be examined first from the standpoint of water recycling in the broad sense, i.e. in terms of the current status of the repeated use of water from the Tonegawa River and Arakawa River systems. These rivers provide water to the Tokyo metropolitan area and the longitudinal variations in the quality of source water for the public water system. Secondly, from the same perspective, the environmental conservation functions of rice paddies (recharging of ground water, water purification and so on) will be examined. Finally, from the standpoint of water recycling in the narrow sense of the term, the use of water for miscellaneous purposes that is introduced in urban areas will be discussed. Water is a resource that is continuously circulated, and achieving healthy water circulation is crucial for ensuring sustainable development. **Keywords:** River Water, Rice Paddies, Rain Water, Water Reuse

INTRODUCTION

Japan is located in the Asia monsoon region, one of several places on earth that receive heavy precipitation. Average annual precipitation is 1,718 mm. This figure is nearly double the 970 mm average annual precipitation for the world as a whole. However, a calculation of average annual precipitation per capita (by multiplying the figure for Japan's average annual precipitation by the area of its land, and dividing by the number of people in the country) reveals that Japan's annual per capita water resources is roughly 5,100 m^3 which is only about 1/4 of the 22,000 m^3 annual per capita water resources available to people on average throughout the world.

In addition, per capita water resource reserves in Japan are 3,337 m3 per person per year, only about half the world average of 7,044 m3 per person per year. In the Kanto area in particular (where Tokyo is located), per capita water resource reserves are 905 m3 per person per year, only about one eighth the world's average.

As shown in Figure 1, water resource reserves are 420 billion m3/year, a figure derived from the rainfall of 650 billion m3/year minus the evaporation quantity of 230 billion m3/year. Of this amount, 87 billion m3/year is used as agricultural water (57.2 billion m3/year), industrial water (13.4 billion m3/year) and household water (16.4 billion m3/year). In terms of the source of the water, 76 billion m3/year is river water and 11 billion m3/year is ground water.

In 2001, 54 billion m3/year of recycled water was used by industry. In recent years, this quantity has remained constant. The recovery rate is 78.6%, and there are signs that this may have peaked in certain industries. An examination of quantities of fresh water used by industry shows that the chemical industry, iron and steel industry, and pulp, paper, and paper goods manufacturing account for approximately 70% of the overall total. The chemical and steel industries have maintained high (80%-90%) levels of water recovery efficiency. The water recovery rate for pulp, paper, and paper processing industry, on the other hand, is only 45%, but this figure is gradually improving. The recovery rate is being increased not only from the standpoint of effective water use but also in terms of restraining ground water pumping to prevent ground settling and placing restrictions on drainage for environmental reasons.

It is difficult to analyze quantitatively the current recycling status of agricultural water and household water, both of which are types of non-industrial water. Water is a resource that is continuously circulated, and since the water that is taken at the upstream areas of rivers is returned to the river in the downstream areas, a large quantity can be recycled.

The remainder of this report will examine (1) the repeated use of river water and (2) the environmental conservation functions of rice paddies (such as recharging of ground water, water purification and so on) from the standpoint of water recycling in the broad sense of the term, as well as, from the standpoint of water recycling in the narrow sense of the term, the use of the water for miscellaneous purposes that is introduced in urban areas.

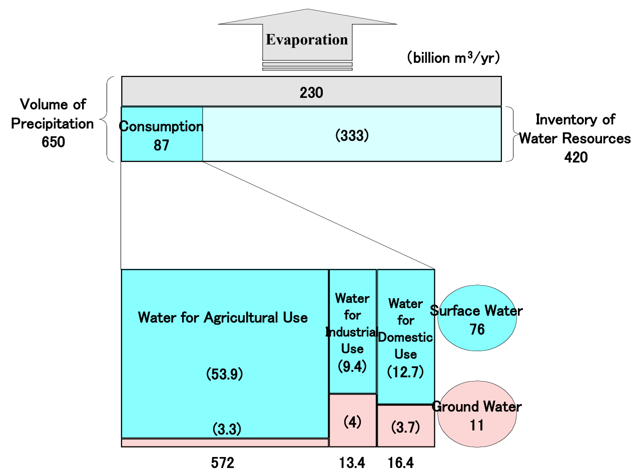


Fig. 1 Water Resource Reserves and Water Use by Application

REPEATED USE OF TONEGAWA RIVER AND ARAKAWA RIVER WATER AS A SOURCE OF WATER FOR THE PUBLIC DRINKING WATER

Figure 2-1 shows that the Tonegawa River and Arakawa River water is used repeatedly as a source of public drinking water. The proportion of wastewater discharge that is mixed in with the river water increases as one goes further downstream. In this section, the repeated use of water will be viewed as recycling in the broad sense of the term, and the current status of water quality and case studies of measures to improve water quality will be examined, with the focus on longitudinal variations in the quality of river water.

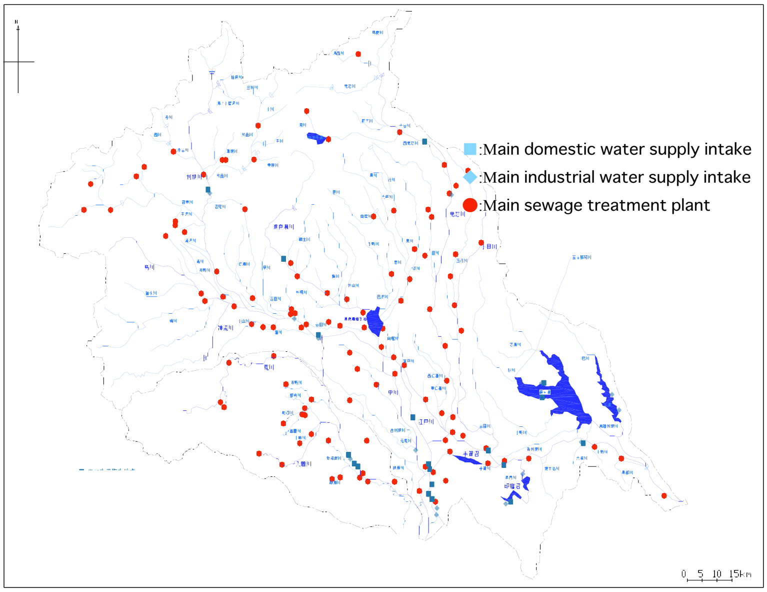


Fig. 2-1 Sewage/drainage Locations and Water Supply Intake Locations in the Tonegawa and Arakawa River Systems

Wetland Frame

The Tonegawa River system is located on the Kanto Plain on the main Japanese island of Honshu. The region that depends on the Tonegawa River system as a source of water covers an area of approximately 25,000 km^2, and this region has a population of 31 million people. Industrial products valued at approximately 58.6 trillion yen are shipped from this area of agricultural land is 565,000 hectares.

Waste water treatment plants are located in various parts of the region. The following figures show the proportion (by prefecture) of the Tonegawa River and Arakawa River systems served by sewer systems: Gumma Prefecture 37.5%, Tochigi Prefecture 50.7%, Saitama Prefecture 66.7%, Tokyo Prefecture 97.3%, Chiba Prefecture 56.3%, Ibaraki Prefecture 40.5%. The water intake points for the water used by urban areas are concentrated in downstream regions.

Current Status of Pollution Load in Tonegawa River and Arakawa River

In the Tonegawa River system, water quality is declining due to pollution of the river sources of these are household wastewater, pollution of both river and ground water by chemical substances, eutrophication of lake water and so on, leading to the concerns for the safe use of the water. In recent years, new water quality problems have also arisen, such as the problem of endocrine disruptors. Partly due to delays in the construction of wastewater treatment systems, much of the problem with water quality is due to the load from household wastewater. The pollutant loads (BOD and COD) become worse as one goes further downstream. In recent years, the levels have remained constant. (Figures 2-2, 2-3 and 2-4)

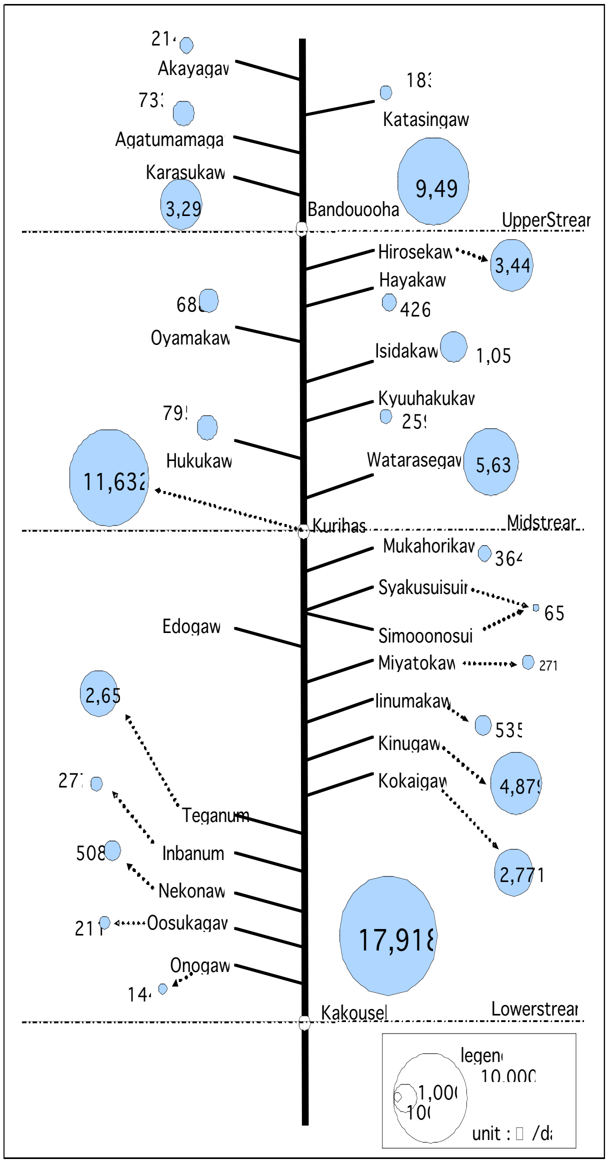


Fig. 2-2 Pollutant Load in the Tonegawa River (BOD) River Systems

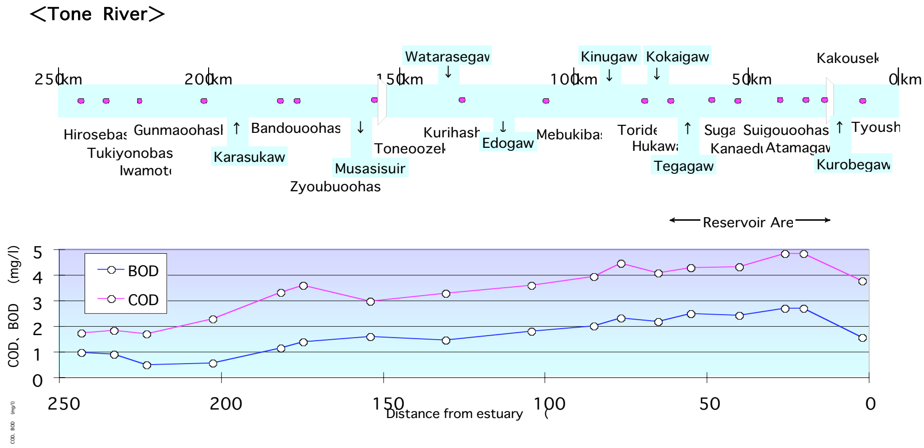


Fig. 2-3 Longitudinal Variations in Water Quality due to Organic Pollutant Load (BOD and COD)

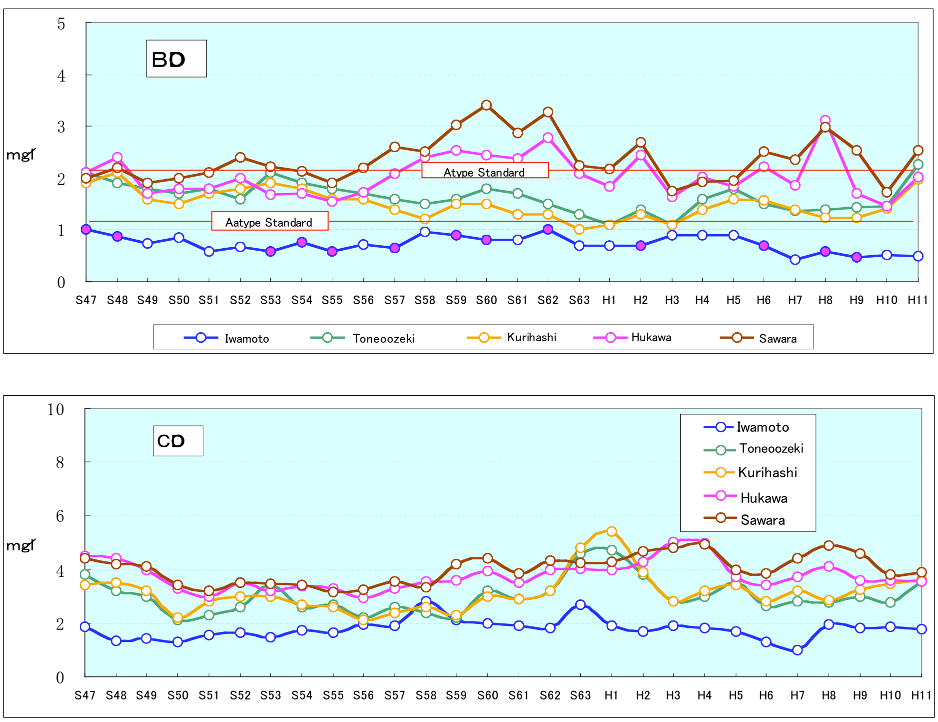
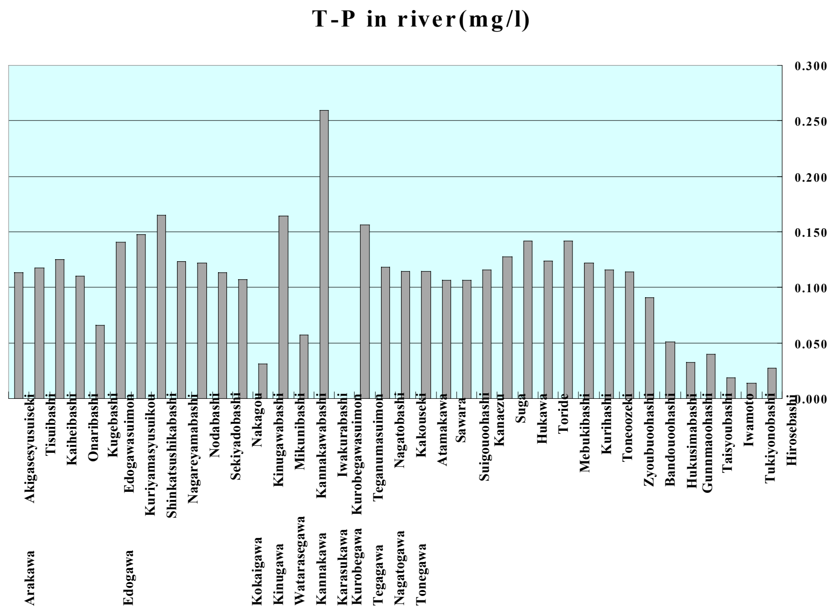


Fig. 2-4 Changes in Organic Pollutant Load Over Time (BOD and COD)



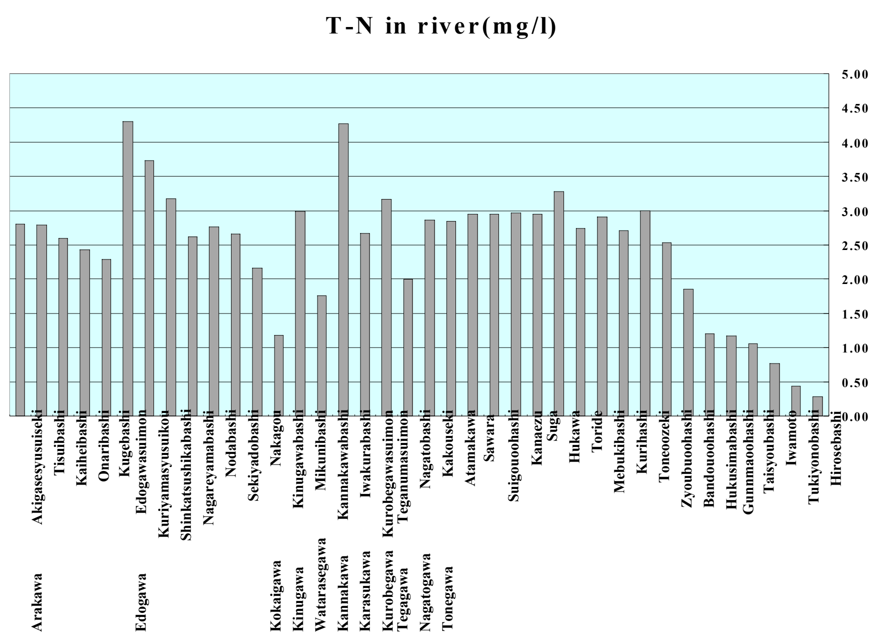


Fig. 2-5 Status of Nutrient Salts (T-N and T-P)

In both lakes and rivers, the concentrations of the pollutants tend to become higher as one goes further downstream. These include nutrient salts (T-N and T-P) causing eutrophication, 2-MIB causing musty-smelling water, ammonium-nitrogen (ammonia is produced during the hydrolysis of proteins present in the domestic wastewater, which is then oxidized to nitrate) as well as the potential formation of trihalomethane (Figures 2-5 and 2-6), and dioxins.

Status of Repeated Use of Water in the Tonegawa River and Arakawa River

The river water in the Tonegawa River system is taken as drinking water. Subsequently this water is returned to the river as treated waste water and once again taken as drinking water. It is estimated that the water is used up to three times. (Figure 2-7)

For this reason, policies are formed to improve water quality by preserving water quality in public water regions and efforts to promote the introduction of advanced treatment at waste water treatment facilities.

Case study: Improvement of Water Quality

As a case study of efforts to improve water quality in order to build a healthy water circulation system, this section will discuss the movement of the outfall for the Nakagawa Edogawa channel to the downstream side.

The Nakagawa River is easily affected by the tides in Tokyo Bay. In the past, at high tide, the treated wastewater effluent discharged downstream flowed back and passed through the channel into the Edogawa River, affecting the source water for the public water system. For this reason, in order to restructure the water intake and discharge system that was a cause of declining quality, the outfall for the channel was moved to the downstream side of the intake port for the public water system. (Figure 2-8)

The move is expected to improve the quality of the source water for the public water system and reduce the cost of chemicals at purification plants.

RECYCLING FROM THE STANDPOINT OF ENVIRONMENTAL CONSERVATION FUCTIONS SUCH AS GROUND WATER RECHARGING AND WATER PURIFICATION

As shown in Figure 3-1, some of the water that seeps into the ground from rice paddies becomes ground water. It is estimated that 20% of the ground water in Japan resulting from the presence of rice paddies represents an increase in ground water.

Economic development in Japan increased the pumping of ground water. In the 1970s the problems of salt water intrusion, ground settling and other ground water problems resulting from excessive water pumping in coastal plains came to the fore. Now, however, ground water problems have been almost entirely brought under control due to pumping restrictions and the switch over to the use of surface water.

Even with these restrictions presently, ground water use is 13 billion m^3/year. Because of the many difficulties involved in switching to the use of surface water (due to the purity, constant temperature and other properties of ground water), this ground water represents a precious source of water.

This section will examine the environmental conservation functions of Japan's agriculture in the Asian monsoon region (such as ground water recharging and water purification). Looking from the perspective of water recycling in the broad sense of the term, including their relationship to the natural conditions in Japan and the long history of rice cultivation based upon these natural conditions.

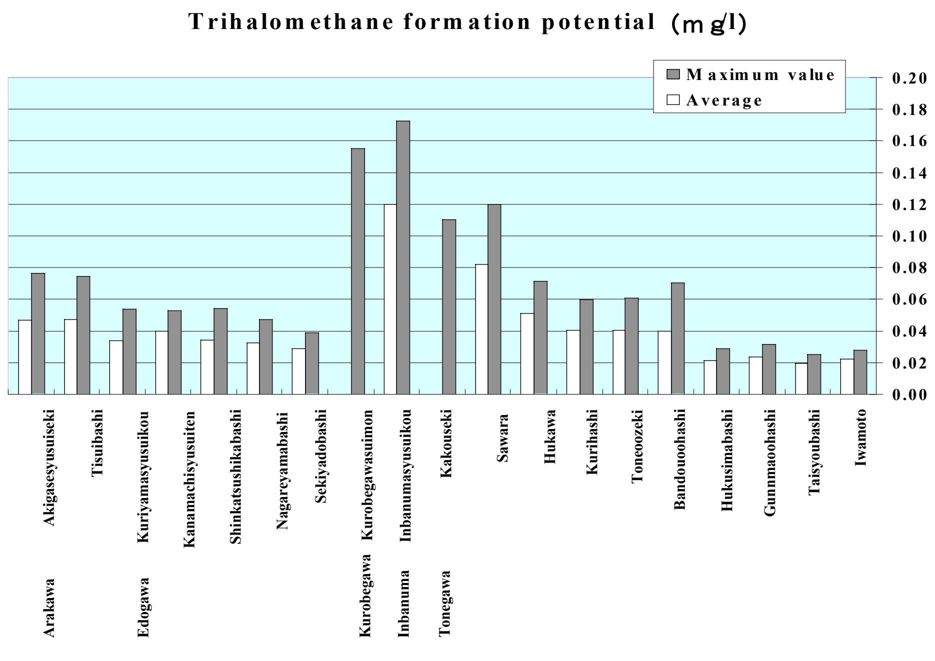


Fig. 2-6 Status of Trihalomethane Formation Potential

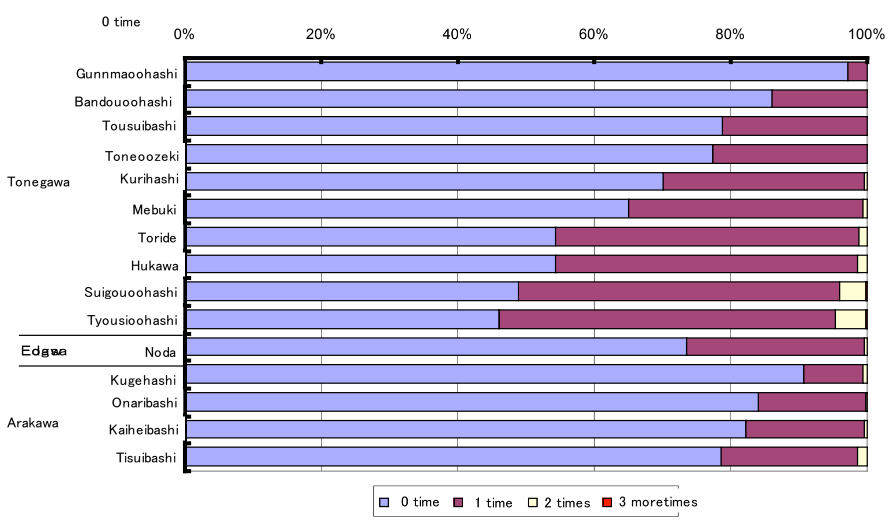


Fig. 2-7 Status of Repeated Use

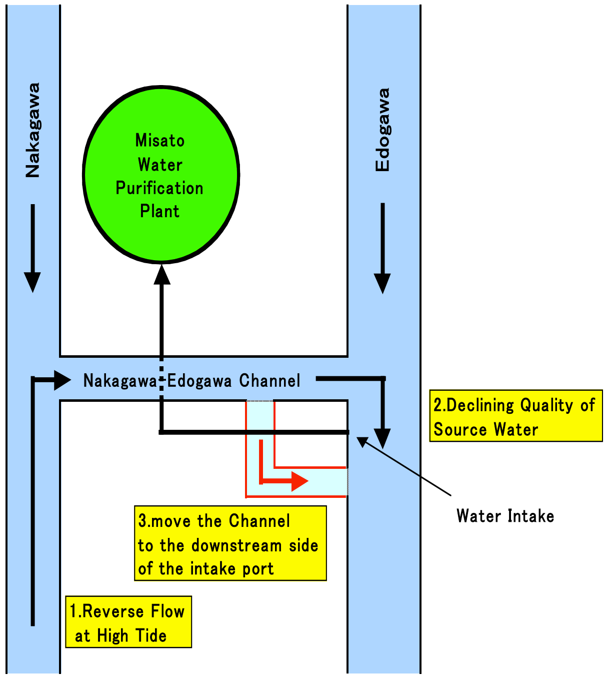


Fig. 2-8 Case Study: Nakagawa-Edogawa Channel

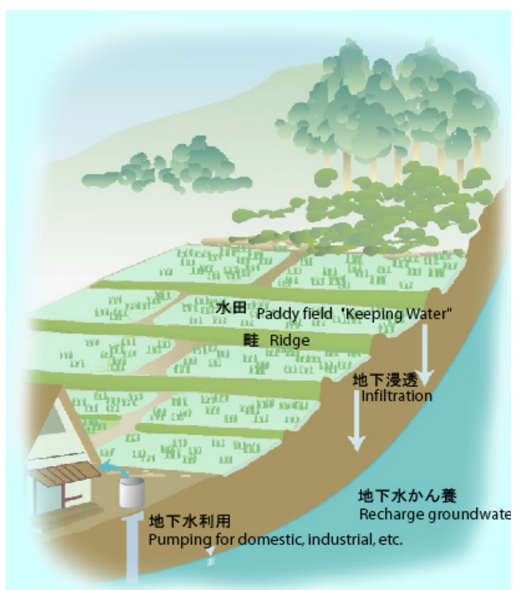


Fig. 3-1 Ground Water Recharging by Rice Paddies

Ground Water and Rice Paddies

Rice paddies hold water within the ridges that surround the paddies, and a portion of this water seeps into the ground. During the irrigation period from April to August, the quantity that seeps into the ground is about 18 mm per day for a maintained rice paddy and about 14 mm per day for an old paddy.

As little nitrogen fertilizer is used in rice paddies and the paddies store water, the reduced condition of the soil promotes denitrification, so the paddies served as a purification zone for the nitrate nitrogen from the fields in upland areas and the like. This is known as the land use / topographical chain, involving a flow from upland to lowland and from field to paddy. This system, not seen in Western countries, plays an important role in environmental conservation in Japan.

The following pages illustrate the role of rice paddy agriculture in ground water recharging, using typical examples of Japanese topography: alluvial plains, alluvial fan, the foothills of a volcano, and upland buffer zones.

Alluvial Coastal Plain

Rice paddies replenish even deep aquifers. The Nobi Plain is an alluvial plain located in the Chubu region of the island of Honshu, on the Pacific Ocean side. In Japan, it is second in size only to the Kanto Plain, covering an area of approximately 1,800 km^2. From the 1960s through the 1970s, ground settling due to excessive pumping of ground water was a serious problem, although this has now subsided. The ground water level observations shown in Figure 3-2 illustrate the role of rice paddy irrigation in ground water levels in addition to pumping. The water level in shallow aquifers increases during the period of irrigation, illustrating how rice paddies recharge ground water. When the water level in deep aquifers was low in the 1970s, the increase in the water level in shallow aquifers accompanying the start of the irrigation period was delayed. This is thought to be because the water in the shallow aquifers that was recharged by the rice paddies replenished the deep aquifer whose level had decreased.

Alluvial fan

Ground water added from rice paddies (underground dam function)

The Tedorigawa alluvial fan is located in the Chubu region of the island of Honshu, on the Japan Sea side. It is a semicircular alluvial fan with a radius of a little over 12 km. Rice paddy agriculture is conducted throughout the entire alluvial fan.

As shown in Figure 3-3, the ground water level in the Tedorigawa alluvial fan shows dramatic seasonal fluctuations due to the existence of rice paddies. When rice is not being cultivated, the ground water level increases along the river. However, when rice is being cultivated, the recharging of ground water from the rice paddies causes the ground water level to become high throughout the entire alluvial fan. In some places, the ground water level rises 10 meters or more.

In the Tedorigawa alluvial fan, 120 million m^3/year of ground water is used. It is estimated that 50% to 70% of this ground water is recharged through rice paddies. In recent years, however, ground water levels have decreased due to the reduction of rice paddies due to the increase in urbanization, which has become a matter of growing concern.

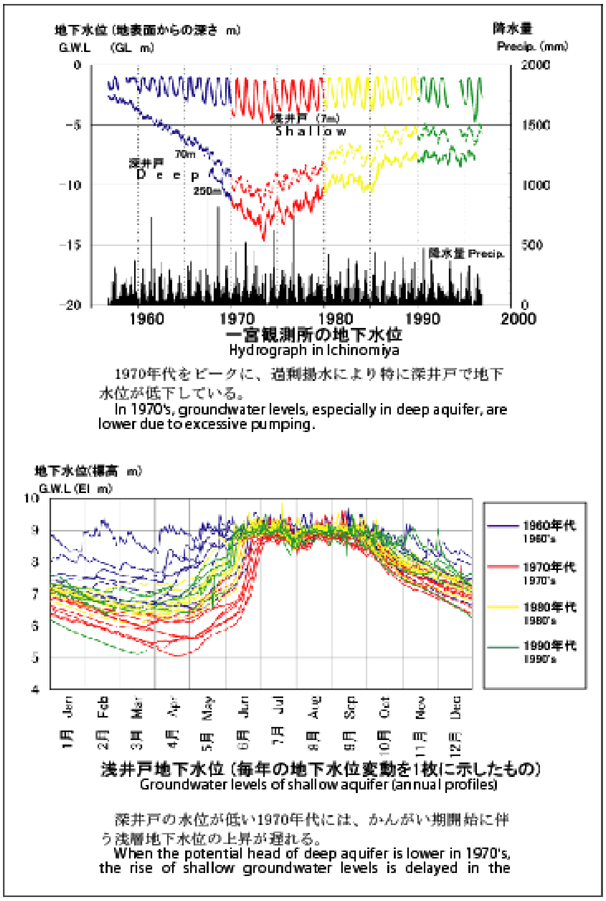


Fig. 3-2 Case Study: Replenishment of Deep Aquifer on Alluvial Plain from Rice Paddies

Volcano foothills

Rice paddies support urban water resources. The city of Kumamoto on the island of Kyushu has a population of around 900,000. The city relies entirely on ground water; approximately 200 million m3/year of ground water is pumped for household and other use. In the region of the volcanic terrace and the alluvial plain, there are many springs such as Suizenji, Ezuko and Hakenomiya.

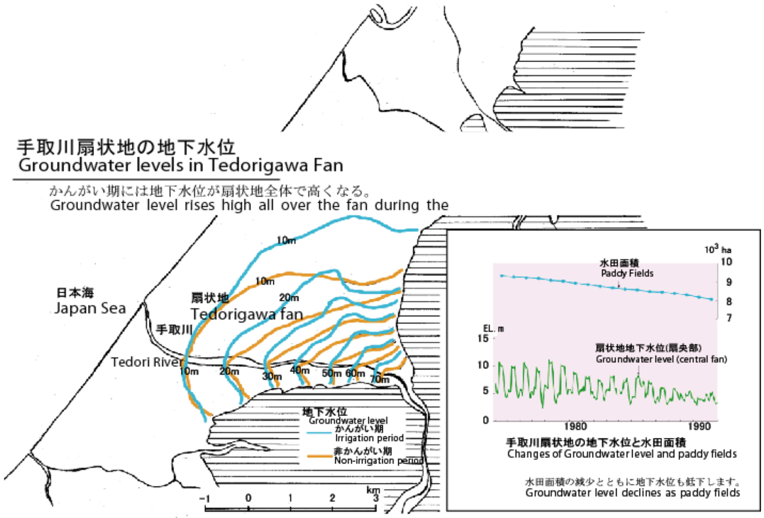


Fig. 3-3 The Ground Water Level in the Tedorigawa Alluvial Fan

The rice paddies in the middle reaches of the Shirakawa River are one of the most important sources of ground water in this region. (Figure 3-4) It is seperated that paddy cultivation in this region began in the 16th through the 17th centuries. An average of 86 mm of water per day seeps into the ground from these rice paddies. According to recent water balance calculations for the region, it is estimated that about half of the ground water recharge of 9.6 billion m^3/year comes from rice paddies. If all of the rice paddies should disappear, it is estimated that the ground water would be reduced by approximately 190 million m^3/year.

Diluvial Upland Buffer Zones

Water purification through topographical chain

The interaction between the Joso Plateau, Shimosa Plateau and other highlands and hills and the lowlands (valleys and alluvial plains) bordering these regions constitutes one of Japan's typical topographies. In general, there are fields in the highlands, while the dendritic lowlands and alluvial plains are used for rice paddies known as "yachida" (paddy fields at valley bottoms).

The rice paddies (including "yachida") and other wetlands are generally recognized to perform a water purifying function through absorption, denitrification and so on. However, since observations have frequently shown that the concentration of nitrate nitrogen in the spring water from the buffer zone between upland and lowland areas is much lower than the nitrate nitrogen concentration in highland ground water, in recent years attention has focused on the purification function in the ground water in the border regions between highlands and lowlands (Figure 3-5).

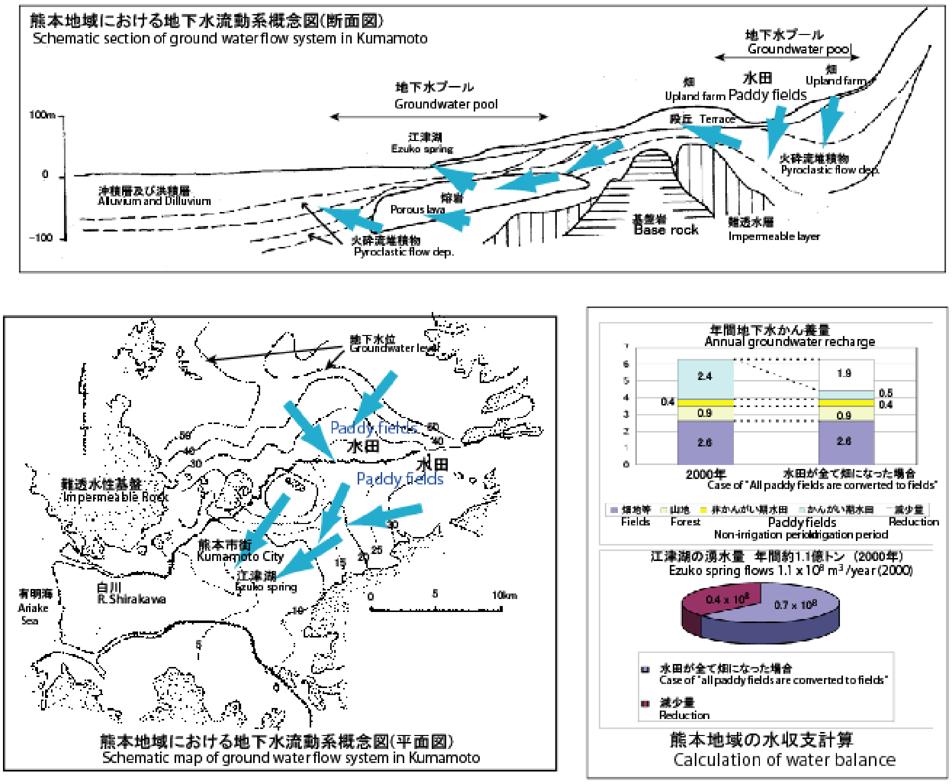


Fig. 3-4 Schematic Section of Ground Water Flow System in Kumamoto

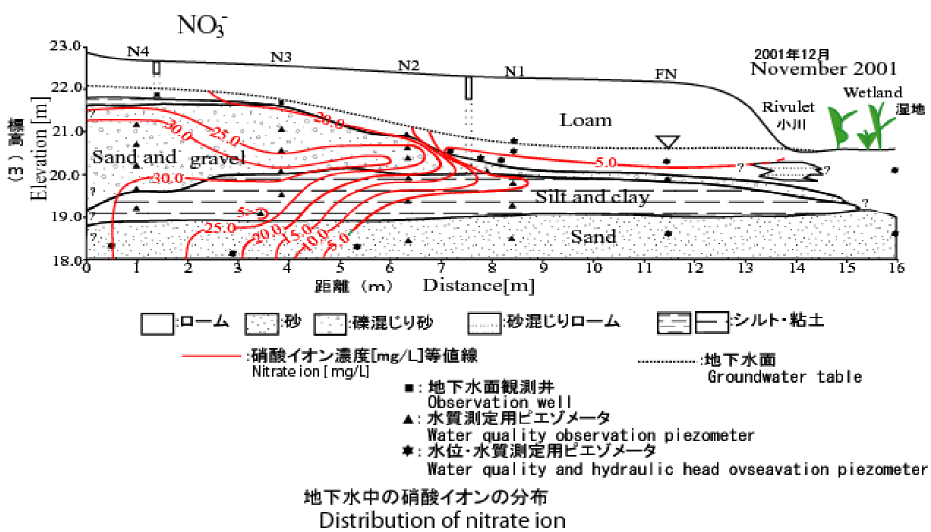


Fig. 3-5 Distribution of Nitrate Ion

The location of the purification zone, the process of purification and other details must be left to future research. However, water purification is thought to be a function not of the rice paddies alone but of a series of topographical chains from the fields in highland areas to the "yachida" in lowland areas.

USE OF WATER FOR MISCELLANEOUS PURPOSE

In urban areas, water recycling including water reuse and use of rain water and so on and the effective use of water are issues of great importance. This section will examine water recycling and rainwater use in urban areas as seen from the perspective of water recycling in the narrow sense of the term, focusing on current status, examples of use and so on.

Use and Systems of Water for Miscellaneous Purposes

"Water for miscellaneous purposes" refers to treated sewage and recycled industrial wastewater, as well as rainwater and other types of water that is lower in quality than water provided by municipal water supplies. This water is used for purposes such as flushing toilets, refrigeration and cooling, and sprinkling. (Figure 4-1)

There are a variety of scale-dependent systems for the use of water for miscellaneous purposes. Examples include individual circulating systems that cover only a particular office building, circulating systems that cover multiple buildings in a large-scale housing complex or urban redevelopment area, wide-area circulating systems that are supplied by sewage treatment plants or other types of wastewater treatment facilities (or from industrial waterworks), and non-circulating systems that mainly use rainwater. (Table 4-1)

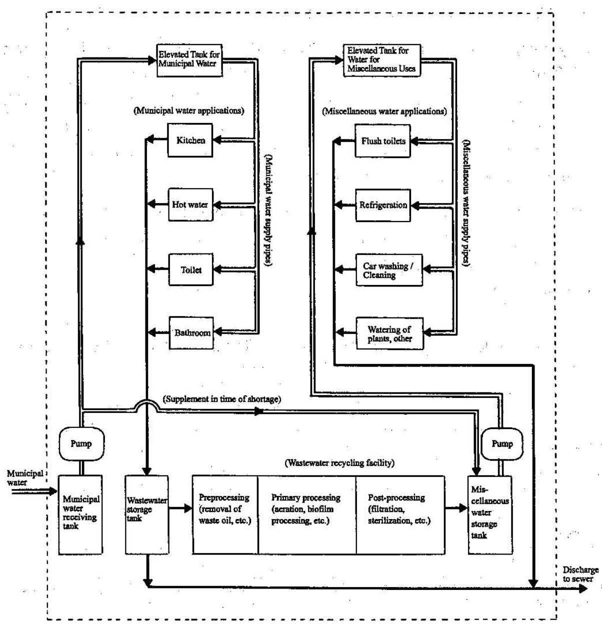


Fig. 4-1 Example of a System for Utilizing Water for Miscellaneous Uses

Effects

The use of water for miscellaneous purposes can be expected to have the following effects:

- It will reduce tap water use and ease the demand gap in regions with pressing water demand.
- It will help reduce demand for sewers and other drainage and treatment facilities through the reduction of drainage quantities and pollution load.
- In the case of rainwater use, it will combine with the use of equipment for preventing runoff in cities to help control flooding.
- It can be expected to ease restrictions to some extent when water intake restrictions are in effect, and also to improve the corporate image of building construction companies through the publicizing of efforts to conserve water and prevent water pollution.

Table 4-1 Average Daily Application of Water for Miscellaneous Uses by Type of System

System Type	# of Facilities	Daily Application of Water for Miscellaneous Uses	
		Volume of Water Use (m3/day)	Average Daily Use Per Facility
Individual Circulating Systems	928	127,561	137
Area Circulating Systems	129	22,141	172
Wide-Area Circulating Systems	775	275,648	356
Non-Circulating Systems	654	20,823	32
Total	2,486	446,173	–

(Note)Research by the Water Resources Department of the Ministry of Land, Infrastructure and Transport (as of the end of fiscal 1999).

Current Status of Water for Miscellaneous Purposes

2,500 facilities for using water for miscellaneous purposes have been introduced nationwide. It is estimated that approximately 450,000 m^3 of water from these facilities is used each day. This represents to about 1% of the daily domestic water consumption in Japan. (Figure 4-2 & 4-3)

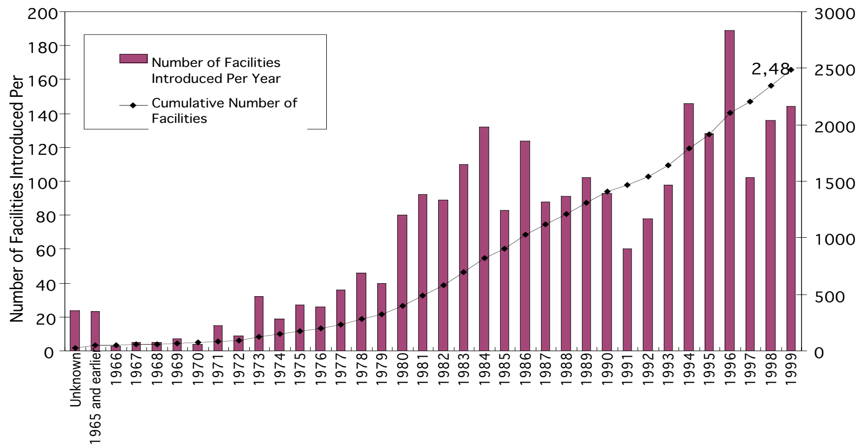


Fig. 4-2 Number of Facilities for Applying Water for Miscellaneous Uses

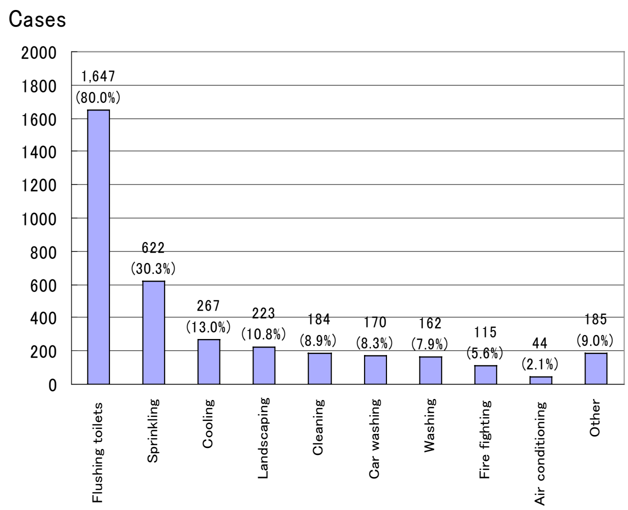


Fig. 4-3 Applications of Water for Miscellaneous Uses

Use of water for miscellaneous purposes began in the 1960s, when frequent droughts underscored the need for measures to promote effective water use. Efforts at full-fledged introduction of water for miscellaneous purposes began in the early 1980s with the deployment of appropriate measures by national and local governments. In recent years, nationwide droughts have led to a widespread recognition of the need for water for miscellaneous purposes, and its use is increasing. There is also an active effort to promote the use of water for miscellaneous purposes through the creation of taxation, loan, grant and subsidy policies.

Increasingly, recycled wastewater is being used in flush toilets, cooling and air conditioning systems, sprinklers and so on, as well as in the form of environmental water for restoring normal flows in rivers, as water for agriculture and so on. 160 million m^3 of treated sewage from 169 sewage treatment plants was reused outside of the targeted sewage treatment plants. With regard to rainwater use, the treatment facilities can be of a smaller scale than those for wastewater recycling and its maintenance is also easy. However, to make such facilities effective during droughts when there is little rainfall, storage tanks with sufficient capacity with respect to demands are needed. In many cases, rainwater collection facilities that were constructed to prevent outflow in cities are also being used to collect rainwater for use as water for miscellaneous purposes. Rainwater often plays an important role for the global environment in recharging ground water and maintaining the flow of urban rivers and so on. A thorough consideration of these factors is also needed.

In this way, although many issues remain to be resolved, active efforts to use urban rainfall as a water resource are underway in various locations. 934 (38%) of the nation’s facilities for utilizing water for miscellaneous purposes are using rainwater to flush toilets and for other miscellaneous purposes. It is estimated that seven million m^3 of water are being used each year for such purposes.

Utilization Rate and Cost

At 80% and 20%, respectively, the utilization rates for recycled water and rainwater differ widely. Possible explanations for this difference are the great variations in utilization rates that exist at the level of individual applications, as well as the great differences in the size of the facilities themselves. (Tables 4-3 & 4-4)

The cost of using water for miscellaneous purposes tends to decline as the volume of water usage increases. However, differences in building structures, processing systems and maintenance / management systems can provide significant cost differences among facilities. (Figure 4-4)

Table 4-2 Current Status of the Reuse of Treated Sewage by Application (Fiscal 1998)

Reuse Application	Number of Plants	Reuse Volume (10,000 m3/yr)	Representative Examples		
			Treatment Plant Name	Reuse Volume (10,000 m3/day)	Users
Water to Flush Toilets	31	515	Fukuoka City Central Water Treatment Center	3,216	Tenjin, Momochi, Hakata area, etc.
Supply to Industrial Waterworks	4	787	Nagoya City Chitose Sewage Treatment Plant	15,752	Nagoya City Waterworks
Direct Supply to Commercial Locations	31	1,753	Kure City Hiro Purification Center	2,173	Sanitary sewage treatment plant
Water for Agricultural Use	18	1,814	Kumamoto City Central Water Purification Center	37,056	Land Improvement Association
Water for Environmental Use	65	7,428	Tokyo Ochiai Treatment Plant	74,480	Meguro River, Nomi River, etc.
Watering of Greenbelts	51	126	Kobe City Higashinada Treatment Plant	204	Area greenbelts, street-side greenery, etc.
Water for Melting Snow	22	2,336	Asahikawa City Western Final-Stage Sewage Treatment Plant	70,000	Snow Countermeasures Section, Public Works Department,
Other	40	1,035	Yokohama City North Treatment Plant No. 1	110	Waste material resources public corporation
total	169	Approximately 160 million m^3			

Source: Research by the Ministry of Land, Infrastructure and Transportation.

Case Studies

This section will introduce case studies of the use of water for miscellaneous purposes. (Table 4-5)

At the Fukuoka Dome, a rainwater use system has been adopted, with a storage tank capacity of 2,900 m^3. 260 m^3 of rain water is used each day to flush toilets, water plants and so on. (Figure 4-5)

At the Saitama New Urban Center, a wide-area circulation system has been put in place for an area measuring approximately 47 hectares, and the water is subjected to two types of advanced treatment: biological filtration treatment and ozone treatment.

The treatment capacity is 4,000 m^3 per day, and the treated water can be used as water for flushing toilets, fire hydrants, sprinklers and so on.

Table 4-3 Utilization Status for Water for Miscellaneous Uses (Utilization of Rainwater)

System Type	Type of Facility	Utilization Rate for Recycled Water	Utilization Rate for Rainwater	Utilization Rate for Water for Miscellaneous Uses	Sources of Water for Miscellaneous Uses (%)		
					Recycled Water	Rainwater	Municipal Water Supplement
Individual	Medical / welfare institution	90	10	100	90	10	0
Individual	Government building	40	18	58	40	18	42
Individual	Office building	36	7	43	84	16	0
Individual	Office building	31	21	53	53	37	10
Individual	Government building	24	16	41	49	33	19
Individual	Office building	23	10	33	44	19	37
Individual	Gymnasium	20	14	34	53	39	8
Individual	Assembly hall	19	9	28	61	28	11
Individual	Assembly hall	18	16	34	41	38	21
Individual	Office building	10	15	25	41	59	0
Individual	School	6	24	30	19	81	0
Area	Office building	19	11	30	39	22	39
Area	Hotel	73	9	82	89	11	0
Non-circulating	Government building	—	37	37	0	97	3
Non-circulating	Office building	—	2	2	0	0	91

Table 4-4 Utilization Status for Water for Miscellaneous Uses (Utilization of Recycled Water)

System Type	Type of Facility	Utilization Rate for Recycled Water	Sources of Water for Miscellaneous Uses (%)	
			Recycled Water	Municipal Water Supplement
Individual	Hotel	63	81	19
Individual	Office building	57	100	0
Individual	Office building	48	90	10
Individual	Hotel	48	48	52
Individual	Government building	41	81	19
Individual	Office building	40	93	7
Individual	Office building	36	70	30
Individual	Office building	36	70	30
Individual	Government building	30	78	22
Individual	Office building	29	81	19
Individual	Assembly hall	28	68	32
Individual	Department store / supermarket	27	75	25
Individual	School	25	39	61
Individual	Office building	21	64	36
Area	Government building	14	76	24

Table 4-5 Examples of Rainwater Utilization

Name	Application	Volume of Rainwater Used	Rainwater Storage Tank Effective Capacity	Start of Utilization
Ryogoku Kokugikan	Cooling, toilet flushing	20.9 m^3/day	750	January 1985
Tokyo Dome	Toilet flushing	186 m^3/day (used together with treated sewage)	1,000	March 1988
Fukuoka Denki Building	Toilet flushing, car washing, sprinkling	7.4 m3/day (used together with treated sewage)	1,000	April 1983
Fukuoka Dome	Toilet flushing, watering of vegetation	260 m^3/day (used together with water processed by aquatic environment creation enterprise hydrologic cycle recycling system, under the new generation sewage system support enterprise system.)	2,900	April 1993
Nagoya Dome	Toilet flushing, watering of vegetation	36,000 m^3/day (planned)	1,500	February 1997
Osaka Dome	Toilet flushing, watering of vegetation	28,000 m^3/day (planned)	1,700	March 1997

At the Shinjuku secondary city center, a wide-area circulation system has been put in place for an area measuring approximately 80 hectares, and the water is treated by advanced treatment and membrane filtration. The planned treatment capacity is 8,000 m^3 per day, and most of the treated water is discharged into rivers for use as source water to restore the clarity of river water. In recent years, water quality has improved, and ayu (sweetfish) and other fish can be seen swimming upstream to spawn. In addition, water subjected to advanced treatment is treated further by means of membrane filtration, in order to create hygienically safe water for use in places where children swim and play in the water.

At the Saitama Stadium 2002, there is an independent circulation system that uses sand filtration for water treatment. The treatment capacity is 100 m^3 per day, and the treated water is used primarily to flush toilets, water lawns, replenish cooling towers and so on. In the event of a disaster, the water can also be used as an emergency drinking water supply.

At the Nagoya City Minami Ward Office, there is a rainwater harvesting system that uses sand filtration for water treatment. The treated water is used to flush toilets, water lawns, replenish cooling towers, supply water for fire prevention systems and so on. Separate supply systems are used for drinking water and water for flushing toilets. The collection of rainwater also has the great advantage of helping to prevent urban flooding. In addition, small scale rainwater harvesting systems are also in use in Sumida Ward and other areas, in the form of "rojison" or underground roadside tanks that collect rainwater from the roofs of houses. These provide water for children to play in, for adults to sprinkle on roads to keep dust down and so on, helping to make life in the community more pleasant.

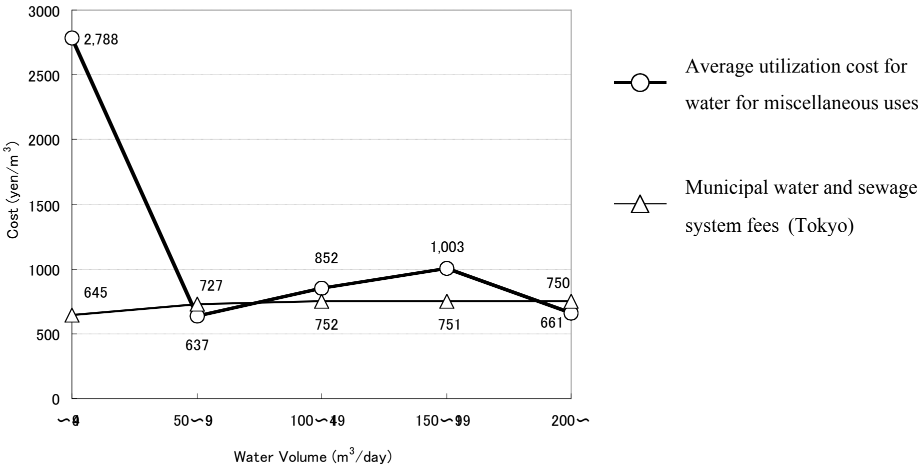


Fig. 4-4 Utilization Costs for Water for Miscellaneous Uses and Municipal Water and Wastewater Fees

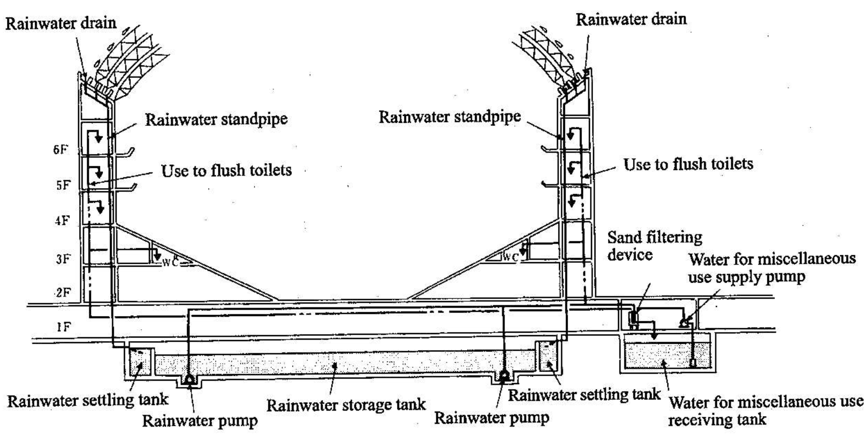


Fig.4-5 Rainwater Utilization Example (Fukuoka Dome)

Issues

Even as the number of facilities for using water for miscellaneous purposes increases, there are cases of facilities suspending operations because of maintenance and management problems.

Major maintenance and management problems include the following:

- High burden of maintenance and management costs
- Considerable costs needed when facilities are upgraded
- Unstable quality and quantity of source water for water recycling

Efforts to develop technologies to reduce costs must be promoted in order to resolve these problems. Moreover, at the planning stage, the quantities of recycled water and water usage must be accurately determined, and a thorough study conducted to secure water resources if the quantity of recycled water is insufficient.

In the case of rainwater use, however, thorough consideration is needed, as rainwater plays an important role in the regional environment in terms of ground water recharging, maintaining the flow of rivers in urban areas and so on.

CONCLUSION (TOWARD THE CONSTRUCTION OF A HEALTHY WATER CIRCULATION SYSTEM)

Balance between Human Society and the Water Circulation System

Drinking water, industrial water and agricultural water systems are all enterprises that use water, a circulated resource. Water circulation systems fulfill their purpose only to the extent that they function in a sound manner. For sustainable development in the 21st century, it is crucial to construct a healthy water circulation system. For this purpose, it is essential to create a balance between the activities of human beings and the water circulation system, in order to ensure safe and pleasant lifestyles and healthy industrial activities while preserving the environmental conservation and other functions of water.

Efforts to Integrate Rivers and Watersheds with Social Systems

Local residents must recognize the importance of water circulation, and there must be a society-wide effort to ensure proper water circulation. Governments must value the partnership with local residents and companies, and these entities must cooperate and work with one another. In addition, water policies must be designed in terms of watershed units in order to utilize the special features of each watershed based on the natural and social conditions of that watershed.

REFERENCES

Japan Water Research Center, "Survey of Comprehensive Policy Studies Aimed at Ensuring Healthy Water Circulation"

Ministry of Agriculture, Forestry and Fisheries, Rural Development Bureau / National Institute for Rural Engineering / University of Tsukuba, Institute of Geoscience, "Agriculture and Groundwater"

Ministry of Land, Infrastructure and Transport. (2003). "Water Resources in Japan", August.

Ministry of Land, Infrastructure and Transport. (2002). "Case Studies of the Use of Water for Miscellaneous Purposes", March.

River Council. (1999). "A New Approach to a Comprehensive Administration for Water Circulation and Land Management", Report/March.

"Toward the Construction of a Healthy Water Circulation System" (1999). (Interim Report), October 6.

APPLICATION OF KRISTAL 300™ UF MEMBRANE IN WATER RECLAMATION

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ABSTRACT

The application of membrane filtration has in recent times been expanded significantly in diversified fields such as water treatment, food processing, pharmaceutical and biotechnology. Shortage of fresh water resources and stringent discharge standards has resulted in the need for efficient treatment methods to reclaim the wastewater and provide a pollution free environment. Dual membrane technology using ultrafiltration and reverse osmosis following municipal secondary treatment plants has been effectively used in reclamation of sewage water as an alternate to potable water. The performance of reverse osmosis is directly linked with the effectiveness of the pretreatment system. In the advanced dual membrane system, the pretreatment can be either microfiltration or ultrafiltration system. This pilot study has been conducted to evaluate performance of ultrafiltration membrane as pretreatment unit.

The secondary treated municipal effluent from Seletar Wastewater Reclamation Plant (WRP) was tested with a Hyflux Kristal 300 ultrafiltration membrane pilot plant. The performance evaluation of Kristal 300 in terms of its efficiency in turbidity reduction, fouling factors, removal of microorganism and cleaning frequency have been studied. This article discusses in detail the results of an extensive pilot study carried out over 6 months.

Key Words: Kristal 300, Ultrafiltration, Sewage water, Pretreatment, Seletar WRP

INTRODUCTION

Membrane technology is widely accepted as a means of improving the quality of water from surface water, well water, brackish water and seawater. Membrane technology is also used in industrial processes, in industrial wastewater treatment and, of late, applied to the area of treating secondary and tertiary municipal wastewater. One type of membrane may thus enhance the function of another to meet goals ranging from disposal of wastewater to production of drinking water. As such, membrane technology offers the possibility of managing all potential water resources in a region, which is of special interest in geographical areas where natural water resources are scarce.

The application of ultrafiltration (UF) process to treat secondary and/or tertiary treated wastewater for reuse purposes is gaining popularity all over the world today (Tchobanoglous et al. 1998; Graff et al. 1999; Reith and Birkenhead 1999; Randles 1996). This is a result of the continuing depletion of fresh drinking water supplies and the development of regulations and guidelines associated with reclaimed water production (Ammerman 1998; Crook and Surampalli 1996). Membrane processes provide an effective means of meeting these demands because of their ability to remove solids as well as microbial contaminants including viruses by size exclusion (Madaeni 1999; Wiesner and Laine 1996). In addition, these technologies require small footprints and minimal chemical addition compared to conventional wastewater reclamation processes.

Reuse of domestic effluents for potable purposes is rapidly becoming a necessity for many municipalities throughout the world. Potable reuse is often indirect by infiltration, discharging into river or direct injection of treated effluent into the subsurface. Indirect potable reuse projects currently established in Singapore are using conventional secondary treatment followed by highly advanced tertiary treatment using membrane filtrations. Membrane treatment technologies such as ultrafiltration (UF) pretreatment followed by reverse osmosis (RO) are being utilized.

The performance of the UF membrane process can be affected by operating conditions and feed water characteristics. Several key operational conditions that control the membrane performance include the operating flux, backwash interval and pretreatment processes, such as coagulation. Furthermore, UF performance can be significantly affected by membrane fouling (Laine et al. 1991), which results from the mass loading of solid, organic and microbial contaminants (Hofman et al. 1998) present in the feed water. The optimization of such conditions is essential in achieving the productivity and filtrate water quality necessary for water reclamation.

The main intent of this study was to assess the effects of various operating conditions on the performance of hollow fiber UF membranes during the reclamation of secondary treated wastewater. Specifically, a series of pilot experiments were conducted using a pilot-scale UF system to investigate the effect of operating flux, Backwash Interval (BWI) and pretreatment on membrane performance. In addition, feed and permeate water quality of the UF system was evaluated by measuring concentrations of solid (turbidity and particle counts), organic (TOC), and microbial (total coliform) parameters under varying operating conditions.

EXPERIMENTAL

Source Water

The source water used in this study was secondary treated domestic municipal wastewater obtained from the Seletar Water Reclamation Plant (WRP). This is one of the facilities treating sewage wastewater generated in Singapore with an activated sludge system consisting of the following unit operations: bar screening, primary clarifiers, aeration, microbial decomposition, and secondary sedimentation. In addition, the wastewater undergoes chlorination prior to being discharged. Source of water taken for the current study was prior to chlorination.

The microbial content of this wastewater was quite significant and offered adequate feed concentrations to assess the microbial impact on membrane fouling during this study.

UF Pilot System

A pilot unit Kristal 300 hollow fiber ultrafiltration module provided by Hyflux Ltd (Singapore) was used to perform all experiments pertinent to this study. The unit consists of eight identical 8" diameter by 2-meter length UF membrane modules arranged in parallel (4X2). Furthermore, the ability to operate each membrane at the same filtrate rate makes it possible to verify the reproducibility of membrane performance under specific operating conditions. The pilot plant is also designed to perform dead-end or cross flow filtration and is capable of producing filtrate flows ranging from 0.02 to $2.75m^3$. h^{-1} per membrane module. Lastly, the temperature corrected clean water specific flux of the Kristal 300 membranes is measured in the pilot studies. Each membrane module contains few thousands hollow fibers that provide a total membrane surface area of approximately 55 m^2. The membrane modules are designed with an outside – in flow configuration; that is, feed water enters the shell side of the capillary tubes, filters through the wall, and is collected in the lumen of the fibers. The capillary fibers have an inside diameter of approximately 0.7mm and an average molecular-weight cutoff (MWCO) of 35,000 Da. In addition, these membranes have several characteristics necessary for the treatment secondary/tertiary wastewater including the ability to withstand a wide pH range (2–13) and a high tolerance to free chlorine exposure (150 ppm). Such features allow for versatility in cleaning and backwashing procedures.

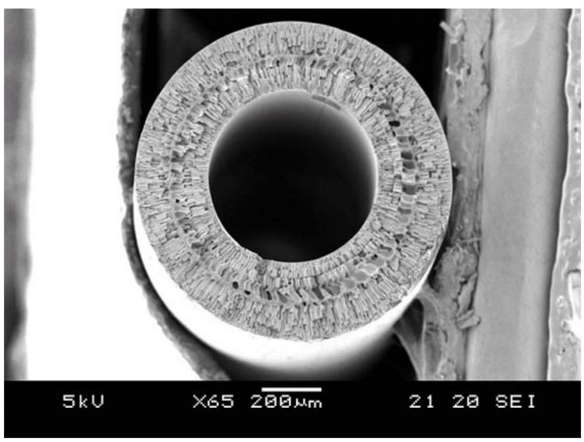

Fig. 1 Scanning Electron Microscopic Picture of the Cross Section of the Membrane Used in the Kristal-300 Modules

Table 1 Specifications of the Kristal 300

Type	UF
Pore Size	35000 MWCO (0.01 micron)
Fiber (ID)	0.7 mm
Fiber (OD)	1.3 mm
Module Length	2 m
Active Surface	Shell Side
Membrane area	55 m^2/module
Module Diameter	8 inch
Module Material	PVC

The pilot unit is also equipped with an automated membrane backwashing system and is capable of performing a fully automated membrane integrity test. The backwashing system acts to remove foulants accumulated on the membrane surface during filtration. The system initiates a series of steps during which backwash water is pumped under pressure through the filtrate side and across the outside of the capillary membranes. Furthermore, this system is designed to inject chlorine into the backwash water to promote chemical breakdown of foulants present on the membrane surface. The membrane integrity test system allows the operator to identify any breaches in integrity of the membrane fibers. Specifically, the test is a pressure-hold method, which applies air pressure to the outside of the membrane fibers. The pressure, when module is isolated, must hold for 10 mins. A confirmation of membrane integrity is by visual inspection of the filtrate flow meters. The presence of air bubbles in the flow meters indicates a possible break of a membrane fiber. Leaks are revealed by bubble emanating from the fibers at the end of the module.

Backwashing

Backwashing of the membrane modules was accomplished through an automatic sequence of steps controlled by a programmable logic controller, equipped on the pilot unit. The automated unit operations during backwashing included air flush, top backwash and/or final rinse. Accordingly, backwashing was initiated by an air flush of the modules in which compressed air was driven across the shell side of the capillary fibers to shear any foulants accumulated on the surface. Next, filtrate water was pumped through the lumen side of the membrane modules by the backwash pump and forced to exit the top of the membrane modules with air.

These steps were conducted with filtrate water containing 5-10 ppm NaOCl followed by a similar step in which the backwash water was removed through the bottom end of the modules without air. It should be noted that the pressure during backwashing was between 20–35 psi. In addition, during these steps, the chlorine pump was initiated and remained active throughout the backwash cycle. Accordingly, backwash water was pumped to the filtrate side of the membranes and exited to drain through the feed and concentrate lines. Each backwashing event lasted a total of 45-90 sec with the dosing rate provided a 5-25 ppm NaOCl concentration in the backwash water during bottom and top backwashing steps. The filtration time between backwashing events, defined as the BWI, ranged from 15 to 30 min.

Pilot Operation

The general sequence of steps followed during pilot operation included membrane cleaning, clean water flux analysis, membrane integrity testing, and filtration experiments. Prior to each experiment, the membranes were thoroughly cleaned using both acidic and basic solutions. To assess whether a given cleaning procedure adequately restored the specific flux capacity of the membranes, a clean water flux profile was developed for each individual membrane module.

Next, each membrane was tested for integrity using the fully automated pressure hold test equipped on the unit. The test was initiated by introducing approximately 10 psi of air pressure to the feed side of each membrane. A damaged membrane would allow the air to escape through the membrane and therefore can be detected by the presence of air bubbles in the filtrate valve. Following integrity testing, membrane filtration experiments were performed in dead-end filtration mode under various operating conditions. The feed water was collected in a 208 l (55 gal) storage tank equipped with a float valve to prevent overflow. Feed water was then pumped from the storage tank and passed through a pre-filter, prior to entering the bottom of the membrane modules. The operating flux was set between 25 and 50 LMH for each membrane module by adjusting the feed pressure and filtrate flow valves equipped on the unit. Throughout the course of a given experiment the membrane modules were backwashed (every 25–30 min) by chlorinated water. The filtrate produced was stored in 1.3 m^3 storage tanks and partially used during backwashing. The pilot operation was about 6 months.

Fig. 2 Photograph of the KRISTAL-300 Ultrafiltration Pilot Plant

Water Quality Analysis

Water quality analysis was also conducted during each filtration experiment to evaluate the performance of the UF membranes at rejection solid, organic and microbial foulants present in the feed water. Two water quality parameters were measured to assess each foulant group as follows: turbidity and particle counts for solids, TOC for organics, and total coliform and HPC for microorganisms. Each of the water quality parameters were measured in accordance to specific methods outlined in the "standard methods for the examination of water and wastewater" as identified in the measurement frequency of the above water quality parameters was established for a continuous filtration period.

RESULTS AND DISCUSSION

Innovative approaches are proposed both in terms of the reduction of energy consumption and optimization of pretreatment prior to reverse osmosis or nanofiltration. This is important when there is a need for advanced treatment due to regulation or because of specific applications (presence of salt content too high for use in irrigation, need for high-quality industrial water or aquifer recharge application). A major problem with RO and NF facilities is their susceptibility to fouling with suspended solids, colloidal material, organics, bacteria or scale from ions in the raw water. The implications of fouling are: irreversible membrane damage, reduced flux rates and increased operating costs from frequent chemical cleaning.

In reuse plants, the feed water to the pretreatment system is secondary sewage (biologically treated municipal wastewater). This can have a variable and at times high level of suspended solids load with a high proportion of colloidal material, organics and bacteria. These constituents can cause irreversible failure to the downstream RO system if not successfully removed during pretreatment.

Fouling of size exclusion membranes such as UF is attributed to the mass loading of solid, organic and microbial contaminant present in the feed water to the membrane surface. Fig. 3 presents average feed and average filtrate values of turbidity during experiments conducted at operating fluxes ranging from 25, 35 and 50 liters. m^{-2}. h^{-1} (lmh). As shown, the average filtrate turbidity concentrations measured during operation at the above experimental flux rates were all below 0.2 NTU. In a constant flux mode as solids accumulate on the membrane surface, the flow rate is maintained by increasing the driving force, i.e., transmembrane pressure (TMP) during the production period.

Fig 3 shows that the influence of feed turbidity on the TMP. The rise in feed water turbidity increases the TMP. These studies show that the fouling is completely reversed by properly designed cleaning methods. In order to maintain the TMP within the range of operating parameters, maintenance cleaning is carried out with every 2.5 days. The permeate turbidity is independent of the feed water.

During the entire operation of the pilot studies, the removal of bacterial indicators (i.e., total and fecal coliform bacteria) was measured to be within the allowed limit. The pore size (0.01micron) in a 35,000 MWCO membrane is an order of magnitude smaller than bacteria (0.2 micron). Therefore, a well-maintained UF system without membrane defects should preclude passage of most bacteria. At this phase of our analysis for E-coli was not positive as coliform counts <1 (mpn per 100 ml) in the permeate.

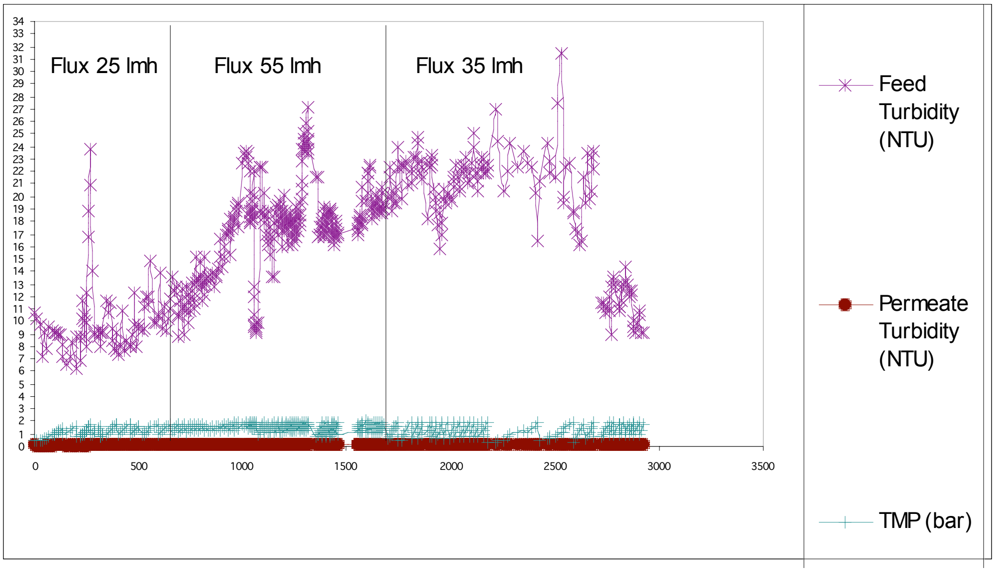

Fig. 3 the Effect of Feed Water Turbidity on Permeate Turbidity and Trans-membrane Pressure

Table 2 Summary of the Treatment Results

Water Quality	Influent	UF treated
Turbidity, NTU	3-26	<0.2
Suspended solids, mg/l	5-40	<2
Total organic carbon, mg/1	120 –250	16-160
Silt Density Index	>6	<2
Bacteria, CFU/100 ml	10^5-10^6	5-6 log Reduction
Coliform mpn/100ml	-	<1

CFU= Colony Forming Units, MPN= Most Probable Number.

Table 2 summarizes the range of feed water quality and the UF permeate water quality. From these results we can observe that the SDI value is always less than 2, which is well below the requirements of the downstream RO feed water.

CONCLUSIONS

Hyflux Kristal 300 ultrafiltration system has excellent resistance to fouling components found in the secondary effluent. The fouling can be fully reversible by simple cleaning methods, which show that there are no irreversible fouling effects. The effectiveness of UF systems was evaluated in terms of the quality and variability of the feed water, the capacity of the system and the space available. These studies also show the quality of the UF product water is largely independent of the feed quality.

Reclaimed water, as shown in this paper, can be a competitive water resource to satisfy growing, and predominantly non-potable, urban and industrial water demands. Besides generating a new water resource, and limiting effluent discharges to the environment, water reclamation and reuse conserves freshwater resources for the highest quality need, i.e., drinking water.

The Full scale Seletar WRP using Hyflux Kristal 300 membrane will be operational at the end of this year.

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REFERENCES

Ammerman. D. K. (1998). Water reclamation takes hold, Water Environ. Technol. 10(5) 67–72.

Crook. J., Surampalli. R. Y. (1996). Water reclamation and reuse criteria in the US, Water Sci. Tech. 33(10/11) 451–462.

G. Tchobanoglous, J. Darby, K. Bourgeous, J. McArdle, P. Genest, M. Tylla. (1998). Ultrafiltration as an advanced tertiary treatment process for municipal wastewater, Desalination 119, 315–322.

Hofman, J. A. M. H., Beumer. M. M., Baars. E. T., Van der Hoek. J. P., and Koppers. H. M. M. (1998). Enhanced surface water treatment by ultrafiltration, Desalination 119, 113–125.

Laine. J. M., Jacangelo. J. G., Patania. N. L., Montogomery. J. M., Booe. W., Mallevialle, J., and Eaux-Dumez. L. D. (1991). Evaluation of ultrafiltration membrane fouling and parameters for its control, in: Proceedings of the AWWA Membrane Technologies in the Water Industry, Orlando, FL, pp.253–274.

Madaeni. S. S. (1999). The application of membrane technology for water disinfection, Water Res. 33 (2) 301–308.

Randles. N. (1996). Large scale operating experience in membrane systems for water and waste water reclamation, Desalination 108, 205–211.

Reith C., and Birkenhead. B. (1998). Membranes enabling the affordable and cost effective reuse of wastewater as an alternative water source, Desalination 117, 203–210.

Van der Graff. J. H., J. M., Kramer. J. F., Pluim J., de Koning J., and Weijs. M. (1999). Experiments on membrane filtration of effluent at wastewater treatment plants in The Netherlands, Water Sci. Tech. 39(5) 129–136.

Wiesner. M. R., and Laine. J. M. (1996). Water Treatment Membrane Processes, AWWA Research Foundation, Mcgraw-Hill, New York, (Chapter 16).

Panel Discussion IV for Track 3

Moderator: • **Wendy Nero,** CH2M HILL, Tampa, Florida, USA

Panelists: • **Dee Dee Ng,** Hyflux Ltd, Singapore

• **Jian Lin Liu,** SUT Sakra Pte Ltd, Singapore

• **Key Wee Ong,** Public Utilities Board, Singapore

• **Paul Tan,** Public Utilities Board, Singapore

• **Sugimura Yokito,** Japan Water Agency, Japan

• **Totaro Goto,** Water Re-use Promotion Center, Japan

Moderator: We are coming to the end of two days of excellent work and presentations. Now I would like to invite the participants here today to ask whatever remains of questions they have to the panel and challenge them with the same difficult questions that you have been drilling me for the last two days. Are there any questions or comments?

Question: I am from Sri Lanka. My question is to Dr. Goto. In your presentation, you mentioned the process of desalination of seawater is very expensive. I would like to know whether there are any studies done on the economic viability of this process. Thank you. What I mean is whether you have compared with other alternatives?

Totaro Goto: The cost of the natural water depends on the location. I just mentioned a few for discussion. The figure for desalination ranges from half a dollar to 1.2 dollar per cubic meter. However, natural water is expensive if you want to transfer water from original place to use point. Take the case of Kuwait for example; they wanted to import fresh water from Iran across Arabic Gulf to Kuwait. In this case, they estimated the cost of transportation of water as 50 cents per cubic meter. This is just equivalent cost to natural water transportation. We expect that in the near future, the cost will be lower than 50 cents. In this stage, we have to compare the natural water and seawater desalination. Is this the answer to your question?

Moderator: One of the examples that Dr. Goto mentioned was the Tampa Bay water. I think there are few things that make that original costs proposal. At the costs proposal at this point right now, we have some problems with the developers currently and before. The plan is not operational. They co-located the facility with the power plant so they are producing the power at a lower and buying at a much lower cost they would not have otherwise. Secondly, their intake was in the hot water discharge of the same power plant so the TDS was considerably lower than gulf water a few hundred yards away. The third arrangement they made is that relatively low cost was a public-private partnership and design-build-operate contract structure. Now that the plan is not operational yet, but with those of three strategies that allow the initial cost to be lower, we will find out here and another 45 days what the outcome will be of Tampa Bay water facility.

Totaro Goto: I might add one thing, the cost of water includes technology, building and financing. The financing is getting more and more important. If you get good finance system, the cost will go down. That is another point I might add.

Question: I have a couple of questions. What I do is to ask question one by one and sit down, then you can answer.

Moderator: Will you please name the person you are questioning so they can be preparing their answers?

Question: Since it is very difficult to remember all their names. But I will try to do that. We were discussing on the cost of the treatment of water. Because the cost of water depends on the type of water we study. If it is high saline 40000 ppm, it will have different price type. If it is 50000 ppm, it will be different because of the type of the membrane we are going to use. My first question is for Dr. Goto. He said that the RO plant was successful in European countries and America. It was not successful in Middle-East countries. I wonder why they were not successful there. The second part of this question is what they are doing with the brine disposal. I would imagine that tons of salt would be taken from this process when they are using the RO desalination process. What are they doing with the disposal of the brine water? Are they throwing it into the sea nearby again or dry it and reuse it at somewhere else?

Totaro Goto: Brine disposal is a headache for desalination. There is no essential solution for brine discharge. Now, in the case of Tampa Bay, they dilute concentrated seawater with cooling water. In the case of Popoka, they mix with sewage to reduce concentration. In the case of Okinawa, they discharge the brine to open sea but they made many experiments before that. They measured the temperature, water quality around the seawater during 2 years. Then they got the data of water quality with seasonal fluctuation. Then they designed a discharge system. The discharge system is just like a jet diffuser from the bottom to the surface. The arm is about 54 inches. This is a longest distanced discharge. Then they calculated the dilution ratio. If the discharge brine reaches to the bottom, it goes up and down. The salinity is within the fluctuation of all the seasons. This is their method to fight against the discharge of brine. This is one of the typical examples, if you have open sea. The capacity of Okinawa desalination plant is 40000 cubic meters per day. Now they succeeded. Okinawa area is famous for corn. We are afraid of damaging the corn. They have operated the plan for more than 5 years and have not observed any damage to the corn. This is one successful story.

Question: On this brine thing, if you throw it back into sea, I would understand that there is fish habitat in the sea also. I know fishes grow up to the salinity of 40000 ppm. It is saline fish. If you dump back tons of salts, I am wondering what could be happening to the fishes in the sea there.

Totaro Goto: Fish can move. But the most serious problem is seaweeds, they cannot move. When we think about power station, they discharge a lot of elevated temperatures in cooling water. In this case, we sacrifice some limited areas that we called it as “Mixing zone”. Temperature is higher in these mixing areas. Seaweeds are damaged to some extent in these areas. But we have to control the limit of mixing zone. This is the fundamental concept for discharge in a power plant case. This is my personal opinion, if we have no choice but to discharge brine around there, we have to limit the damage as much as possible. There is no way right now. If you have blackish water in inland apart from several kilometers each side, in this case, you have no way but to discharge brine, maybe digging in the ground is a choice.

Question: Why can't you collect this (water) in big tanks and evaporate this and take the salts and use them in industries, for example, ice factories?

Totaro Goto: Maybe. But still, we have sort of damage to the land.

Moderator: Do we have any other panelists who want to respond to these questions?

Jian Lin Liu: Maybe I can add on this brine issue. We have encountered the same issue. We are running a water recycling plant. It is recycling water from municipal effluent. The effluent basically contains the high COD and also salt. If you want to increase the recovery, you will have very concentrated brine water. Disposal of that water is our headache because theoretically we cannot treat that water. We can use certain technologies to treat the water, but eventually the problem to us is the cost. Just like what you mentioned, we can evaporate that water. But if you look at the total production cost, it will make the production not viable. I think this is a concern, for the water recycling. If you recycle the secondary effluent, it is not only the TDS, the salt, but also the organic contents. In our case, we have recycled it in our plant. We have a recovery rate of 86 percent. That means that the incoming water will be concentrated 6 to 7 times to come to brine. For example, if the COD of the incoming water is around 20 to 30 ppm, the COD of the brine will be above 100. You know the environment standard in Singapore; Discharge COD should be less than 100. This is a big issue for us, but there are some arguments because eventually if we do not do the recycling, the total mass of COD will go to the sea. That means in the case of desalination, we take the source from the sea and return the mass to the sea. This is one of the arguments.

Moderator: Dr. Goto, how about the first part of the question that why RO is not successful in Middle-East countries?

Totaro Goto: In 1950s, a professor in the University of Glasgow got an idea of MSF and they tested the pilot plan of MSF and they succeeded. Since then, MSF dominated in the Middle-East. They used MSF desalination process in the Middle-east. The RO process appeared in 1970s but it was about 1980s when we could apply the Reverse Osmosis to seawater. Before that, we could only use it to blackish water. The RO process appeared in the market, they tried it in Gulf area. As I told you in my presentation, two major projects failed. Then the Arabic countries rejected the RO process even though the cost and energy consumption are favorable. It is a very complicated question to answer, but the only thing clear to me is that the applied measure was not so suitable for seawater quality. There are hollow fine fibers made by Du Pont. Unfortunately, the site water has much salt and salinity fluctuates, so they failed. If they could use suitable RO module, they may succeed. Unfortunately, at that time technology could not catch the requirement. That's the reason I think.

Dee Dee Ng: I am trying to avoid answering the question because I am currently dealing with the desalination plans for Singapore. I cannot answer a lot of questions. The reason is because it is sensitive politically. I would comment and I think it is historical. If we look at the history of desalination and timeframe, a lot of technologies and costs have not caught up. I would like to share with you four things for really viable desalination projects. They are technology, financial modeling, energy costs, as well as some of the legal structuring. A lot of these projects are far more sophisticated and complicated than they actually looked. If you are in the country where energy is not a concern, the case is different. I would say if energy is surplus, desalination can actually win the day. But if you look at Singapore, you will find nothing is free, from land to electricity. One thing I would share with you that the desalination bid in Singapore was a global search. I believe there are over 20 companies that have applied for it, of which 11 companies were pre-qualified. After we talked to each of them, it ended up 4 bidders. Of the 4, three lowest will be using our technology. The 4th will use our higher bid system or our MED. MSF did not feature. I think that states a lot in terms of costs because you really have an open market here. There is more rather than MSF works or RO works. Thanks.

Question: I want to ask a bit more for the discharge of high salt water after desalination. I want to question Mr. Ong from PUB. This morning you mentioned Singapore will have its first desalination plant in 2005. What is the practice in Singapore? How you study and how you review these things?

Key Wee Ong: Sad to say, I am not the prepared person to answer that. Although I am from PUB water department, I am not directly involved in this particular project. I do not know whether Dr. Ng can highlight that because Hyflux is the company that will be doing that project.

Dee Dee Ng: I think all of your comments are relevant. I would say that environmental impact studies are very expensive. We studied before the bid and we are still proceeding. There is one thing I want to tell you that this project is a finance project. Everyone will sit on you and make sure that there is an open seat. I don’t want to go in details as currently we are doing our summations. But yes, there are a lot of environmental studies going on.

Question: I will move to Mr Ong and Mr Tan. We have made comparative study of making new water from seawater and using rainwater. If we can use rainwater, the process cost will be much lower than taking the water from sea or using the RO technology. Our preference should be to use rain water that is much clearer and purer. The second part of this is you are throwing water after treating it in water plant process. Why are you doing that? Why can’t you supply it directly to the people if they want drink it? This is much cleaner water, even the rain water will have bacteria and everything. But once you treated the water with RO, it is bacteria free. And you have also treated with ultraviolet, by which you have killed all the bacteria essentially. So if you add it again to reservoir, there are chances that there will be more bacteria again?

Paul Tan: Thank you for your question. I will answer the second question first. That is in fact it is an easier question. In the presentation earlier on, I mentioned there are two main uses of Newater. One is direct it into industries for the non-potable industrial process uses; the other is indirectly potable use when we put the Newater back into the reservoir. What you are asking is since the Newater has passed through the UF, MF, and RO, why do we have to put it back into the reservoir again? There are a few of reasons we do so. Number one, the government is prudent in implementing this indirect potable use of the NEWater in Singapore. Basically, we follow the examples from the US. The most famous one is Water Factory 21 in Orange County. A lot of other water reclamation examples and projects in the US were studied two years ago. They were also going along the lines of indirect potable use, which means the reclaimed water was either put back into the aquifers or ground water. We have been prudent in the same way of putting a little bit of NEWater, which is less than 1 percent back to the reservoir. The second reason is that you yourself have said the reclaimed water is too clean. If we use it directly, one group of people on one end of the spectrum will say: “Hey, NEWater is too clean, there is no mineral inside, what happens if I drink too much of it? Will I get anemia? Will my teeth start to drop when I grow old because there is no fluorine inside?” By piping back the NEWater into the reservoir, we allow the NEWater to regain the minerals. When it comes to the tap, although it is one drop in one hundred drops, it is still the same PUB water that consumers have been drinking for so many years. The third reason is still the psychological reason. There will always be a small percentage of population on the other end of the spectrum who may not be able to truly accept the concept of direct drinking, because the source of NEWater is from the treated water. By putting back the NEWater into the reservoirs, we allow it to lose its identity in one sense, regain the mineral contents in the other sense to satisfy the other end of the spectrum of people. When it eventually comes to this glass of water, it is the same thing. That is the main reason why we decided to put the NEWater back into the reservoir, rather than to get into the serious discussions with these two groups of people about whether the water is too clean or it can not be used for direct drinking.

Question: I would just give a belief comment on this. On these companies who are preparing this bottle water, what they are doing is using two methods, one is this RO method you have mentioned, and the other is the desalination process where they evaporate and condense the water and use it. In both cases, the water is free of mineral, it is pure water. What they do is that they come back and add a few minerals, 3 or 4, at most 4 minerals. But there are 58 plus minerals, which are useful minerals, starting from Copper to Zinc. These are mineral elements that are very important for health. But all of this bottle water in the market does not contain that. They only contain 3 to 4 minerals, such as calcium, barium and potassium. In your case, it is much easier to mix a few minerals there rather than throwing the entire thing in reservoir and start doing it again.

Totaro Goto: I have a comment on this. In the Middle-East countries, there are fresh water comes from MSF. As I mentioned, there is no mineral in it. They evaporate water to add mineral in it. In the case of Kuwait, they imported about 80 percent of the desalinated water from Algerian plant. They have ground water around the other city. This contains minerals and they blend it with desalinated water and distributed it in the city of Kuwait. In the Middle-East countries they pump up ground water and blend it with desalinated water. You don’t need to worry about the mineral balance when you visit the Middle-East countries. The water is safe.

Comment: I don’t think it is that simple if you go ahead and take some ground water and mix it. Before you mix it, you need to make sure what kind of ground water you are taking because there are many ground waters that have poisonous things like arsenic, lead and many bad things. You’d better make sure what you are going to mix in the purified water will contain good and useful minerals, not bad minerals. So it is not easy to just go ahead and mix with any kinds of water.

Moderator: Would you like to take on the first part of the question, which was the cost comparison between rain water and NEWwater?

Paul Tan: I think the first part of your question you are asking is why don't we use rainwater into NEWater process to produce NEWater, isn't it? The term of NEWater is actually referring to the reclaimed water. As of the use of rainwater, I would not say that using rainwater is a stop of producing NEWater. PUB has begun to utilize membrane technology essentially in water treatment, which means that it is essentially to replace the sand filter in conventional water treatment plants. I don't think we need to go to the extent of using RO or even nano-filtration (NF) to produce the kind of water that is so pure for drinking purpose yet. PUB is starting to upgrade or to build plants with Micro-Filtration or Ultra-Filtration in potable water treatment plants. That is the use of the rainwater as the feed source.

Question: If you use rainwater, you would require a much simpler process to clean it. You might only need a few percent of the cost that you use for carbon filter. You don't have to go to the very complicated kind of treatment also. You definitely need to look into that option. In the whole story of RO, we are shy of mentioning the cost of these membranes. I think what we need to do is we need to find the life of these membranes which we expect to the type of use for treatment. If we use pre-treatment, the life of these particular membranes would last so many years, or so many gallons. If we do not use pre-treatment, the life of these particular membranes would last for a number of years. This kind of data will be very useful for future work for these RO membranes. We should not be shy about the cost of these membranes because there are places where we do not have other options. You have to spend money to take water. Certain areas would be cheaper and some will be expensive. It all depends on where you are and in what situation you are. In the Dr. Liu's treatment case, it is slightly better because his water is from domestic sewage water. It does not have too much TDS and too many salts. If it is house water, it won't have heavy metals in it. It is simple BOD, COD stuff. If you pass it into filters and things like that, it would be good enough for the use for industries because for the water for industries all you need to worry about is calcium and magnesium. You don't have to worry about the bacteria there, such as E.coli or coliform, which you are trying to remove by ultraviolet and RO. In that case you can cut down your process very simply. The last question is to my Japanese friend, a very interesting study he has tried to reach on the effect of rice paddies on the ground water recharge. I could see the figure here. There was a change in the water level from 70 meter to 250 meter where the paddies were grown. You data show that the growth of the paddies would have to recharge the aquifer, which makes sense because if you pump water onto surface, there are two ways it is going to go, one is to evaporate, and the other is to go into the ground. So it would depend on what type of soil layer it is. That is the information missing here.

Totaro Goto: From a preliminary report conducted in the United States, for the last 15 years, the membranes cost reduced about 10 percent. Concerning the life of membranes, one membrane manufacturer who supplied membranes to the plant complained about membrane life. They expect 5 years of membrane's life, which means 20 percent will be replaced by new membranes each year. 5 years has passed, but there is no replacement, no order from the plant. So the membrane manufacturers complained about that, they are losing their businesses.

Jian Lin Liu: Maybe I response to what he mentioned about the bacteria. It is easier for us because our industry does not appear about the bacteria. In terms of treatment process, if you look at our process, it is basically 2 membranes that have two mechanisms to remove the impurities. One is by diffusion mechanism. The second mechanism is based on the particle size. If we look at the bacteria, the size is quite huge compared to the membrane pore size. The normal pore size of our membrane is 0.5 nanometer, it is quite a small size. Theoretically no bacteria can pass through this membrane. But of course there are some concerns on virus, which has smaller size and can possibly pass through the membrane. We think the bacteria are not the issue for our case, i.e., application to industrial water. But definitely some chemical companies, who use our water, questioned us about the bacteria. Sometimes they use the water as the process water. If the bacteria quantity is high, it will affect their products. The second point is that if that water is used for the demineralized plant, which has ion exchange and resin, to produce ultra pure water, the bacteria growth will affect the life of the resin. That means it will cause the biological fouling to the resin. So it is not so straightforward or simple that the bacteria are not an issue for our application.

Moderator: Thank you. Dr. Yokito?

Sugimura Yokito: I am sorry. I have no comment on what he mentioned to me.

Moderator: Thank you. Any other remaining questions for panels?

Question: My question is to the panel, not to a particular person. What is the possible cost of one MGD of RO-based plant? Nobody has mentioned or highlighted on the maintenance part. Another question is what is the cost of possible maintenance part? What will be the problems faced during the maintenance and running of these plants? When we combine the two treatment methods, the conventional and RO or the other newer technologies, what will be the impact on the cost and the quality of it? What might be the possible side effects that we might face using RO and membrane filtration? What are the pollutants that could not be treated in RO process and other technologies you have mentioned?

Moderator: Thank you. Can we have short answers, as there are 6 questions? Anybody wants to take the first one?

Paul Tan: I will take the first question because it is easier. We just give you an idea. The Bedok Water Reclamation Plant is about 7 MGD. This includes not only RO but the whole plant. And we are talking about the process equipment. The feed water is secondary treated effluent. Besides RO, we have Micro-filtration and UV. The process equipment alone was about 16 million Singapore dollars.

Moderator: Thank you. And second question on costs of operation and maintenance?

Jian Lin Liu: I want to make sure whether this maintenance cost is only for the maintenance. If we look at the cost of the sewage water recycling plant, we actually look at the operating cost, which is the major cost. That means we look at the chemical cost, power cost and membrane replacement cost. The maintenance cost is a separate cost by which we maintain the plant and mechanical equipments. If we define the maintenance cost in this way, I would say the maintenance cost is not a huge cost. This is the case like other normal plants. If we define the maintenance cost that includes the operating cost, chemical cost, power cost and membrane replacement cost, that will take a major part of the cost to run a water reclamation plant. The power cost contributes to more than one third of the cost, and the membrane replacement cost contributes to more than one third also.

Question: I have been asking about the operation maintenance part. What is the percentage of operation maintenance cost of the total cost which you have illustrated? Normally they have about 5 percent or so for these sewage treatment plants. Or 2 percent? It has to be more because we have one plant in this industry. There are a lot of problems facing the maintenance and operation part of it. They have a lot of problems running it successfully. The maintenance cost is very high and there are frequent breakdowns.

Comment: When I said 2 percentages, cost of maintenance could be anything from 1 to 6 percent. It highly depends on what kind of management is going on and what kind of water you are using for this system. It varies, nobody can give you a figure. Any figure could be ok.

Moderator: Final question is which pollutants cannot be treated.

Jian Lin Liu: Maybe this is a theoretical question. This is associated with the mechanism of the membrane. As I mentioned, there are two mechanisms for the membrane. One is by solution-diffusion mechanism, which means the ions or salts pass through the membrane based on this solution-diffusion mechanism. You need to take account for the osmotic pressure. If the component in the water is ionized, it would be easy to be removed. The higher it is charged, the higher removal efficiency you will get. The second mechanism is based on the size of the component in the water. That is related to the organic component. If the molecular weight of the organic component is higher, you will get the higher rejection rate and vice versa. Especially when the component is volatile, the removal efficiency will be lower.

Moderator: Thank you. Any questions in the back?

Comment: Actually I do not have questions but I am going to try to help answer the earlier questions about what the problems we might anticipate in the future. Dr. Liu has touched the point of some of the trace organisms that might pass through the RO system. There are some technical problems when it comes to detecting the trace organisms. Right now we are probably limited by the technology at detecting very low level of these organisms. As our technology for measuring these trace organisms becomes better, we might be able to see them coming out in the future. That is something we do not know right now. Perhaps if we look back at the data, (we found) there are still some TOC at a small amount coming out. We have not been able to characterize what is in that TOC. It could be pharmaceutical residues; it could be hormones. These are some issues that future research will have to look into.

Totaro Goto: Yes, I agree with you 100 percent. Just recently, one paper appeared which is concerned with rejection of low molecular weight organic compounds with membrane. This is related to the chemicals from pharmaceutical compounds. We are afraid of some effects of them on our bodies. Right now, our knowledge is limited. We have to think about such danger in the future. So I always say the nature beyond our brains, it is not 100 percent known about the nature.

Question: I have a simple question for Mr. Ong. I would like to know the water tower for NEWater. You have separated lines to industry. Who covers those costs? Is it PUB or cost sharing?

Key Wee Ong: The NEWater pipelines supplied to Wafer Industries are lead by PUB. These are the delicate pipelines that we only carry NEWater. The way we do it is that PUB will go to each one of our customers. It actually starts with industries. We will sign separate agreements with them. The prices are very competitive compared with PUB tap water. That means NEWater will always be price-competitive to PUB tap water. Yes, PUB will cover the cost for the pipelines.

Moderator: We will take one more question.

Question: I would like to ask a question to Dr. Yokito. From your slides, you showed that urbanization causes frequent flood damage. Do you have any recommendations to solve the problem?

Sugimura Yokito: I think one of the most important things is to eliminate the flood damage. All people living in cities have to cooperate to mitigate the flood damage. 10 or 20 years ago, only the local governments execute the plan of how to mitigate the flood damage. However, it is not an easy job to mitigate flood only with structure, especially in the urban area. In fact, we can contribute to the reduction of the damage. For example, in your house, if you install a small tap with 2 cubic meters, you can decrease the water using from the rainfall. Such kind of cooperation may be important and contribute much to the mitigation. Now the ministry of land, infrastructure or transportation tries to find out the consensus about the participation of individual and government on how to cooperate about the flood control.

Moderator: Historically, that was just the government that took the responsibility for preventing the flood damage. Now you are saying that the cooperation and personal responsibility to do what the property owner cannot do is a part of the solution. I think your research demonstrated in that comparative study shows the amount of decrease in the storm runoff as the result of the changes of pavement, the retained area with land retention area and other kinds of things. The consensus-based approaches are very important in getting the participation of the public. Ok, with that I would like to go ahead in the close of the afternoon panel discussion. And I want to thank each of our speakers for their excellent work on presentation and responding to the challenging questions. Thank you very much for staying in the symposium.

APPENDICES

1. LIST OF PARTICIPANTS, RESOURCE SPEAKERS AND SECRETARIAT

International Symposium on Water Resource Management and Green Productivity, Singapore, 7-9 October 2003

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B. RESOURCE SPEAKERS

Ms. Wendy L Nero	Vice President CH2M HILL United States
Mr. Santosh Raghunath Gondhalekar	Gangotree India
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Professor Tay Joo Hwa	Head (Div of Environmental and Water Resources Engrg) & Director (Environmental Engrg Research Centre) School of Civil & Structural Engineering Nanyang Technological University Singapore
Dr. Totaro Goto	Managing Director Water Re-use Promotion Centre Japan
Mr. Ong Key Wee	Senior Manager (Bedok Water Reclamation Plant) Public Utilities Board Singapore
Mr. Paul Tan	Seior Manager (Facilities) Systems-on-Silicon Manufacturing Co. Pte Ltd. Singapore
Dr. Jerry Liu Jianlin	Assistant Principle Engineering (Process & Technology) SUT Sakra Pte Ltd. Singapore
Dr. Yokito Sugimura	Director, Management and Operation Department Japan Water Agency Japan
Dr. Dee Dee Ng	Chief Operating Officer Hyflux Ltd. Singapore

2. PROGRAM OF ACTIVITIES

International Symposium on Water Resource Management and Green Productivity, Singapore, 7-9 October 2003

Date/Time	**Activity**
Tue., 7 Oct.	
Forenoon	Opening Ceremony Keynote Address by Mr. Lim Swee Say, Singapore Minister for the Environment
	Track 1: Global Perspectives on Water Resources Management
	Presentation on *the Water Scenario: Practice and Optimization of Water Demand and Supply* by Ms. Wendy L. Nero. Presentation on *Strategic Water Resource Management and Water Resource Assessment* by Mr. Santosh Gondhalekar
Afternoon	Panel Discussion I for Track 1, Part 1
	Presentation on *Watershed Management* by Ms. Wendy L. Nero Presentation on *Integrated Urban Water Management* by Dr. Chizuru Aoki
	Panel Discussion II for Track 1, Part 2
Wed., 8 Oct.	
Forenoon	**Track 2: Demand Management**
	Presentation on *Managing Singapore's Water Demand for Sustainability* by Mr. Ng Han Tong Presentation on *Clean Water Program (including Pollution Prevention and Control) and Green Productivity* by Professor. Tay Joo Hwa Presentation on *Water Conservation and Efficient Use of Water* by Ms. Wendy L. Nero
	Panel Discussion III for Track 2
Afternoon	**Track 3: Water Reclamation**
	Presentation on *Sea Water Desalination* by Dr. Totaro Goto Presentation on *NEWater and Water Reclamation: Singapore Experience and Application* by Mr. Ong Key Wee and Mr. Paul Tan

Presentation on *Water Recycling—An Industrial Case Study* by Dr. Jerry Liu Jianlin
Presentation on *Recycling of Non-Industrial Water in Japan* by Dr. Yokito Sugimura
Presentation on *Use of Membrane Technology for Water Reclamation* by Dr. Dee Dee Ng

Panel Discussion IV for Track 3

Thu. 9 Oct.	
Forenoon	Site Visit
Afternoon	Summing-up Session Closing Session