

PETRONAS TECHNICAL STANDARDS

HEALTH, SAFETY AND ENVIRONMENT

GUIDELINE

WATER CONSERVATION GUIDELINE FOR ONSHORE FACILITIES

PTS 60.4301
DECEMBER 2011



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PTS 60.4301 – Water Conservation Guideline for Onshore Facilities (December 2011) has been developed to incorporate PETRONAS Lessons Learnt, Best Practice and new information issued by relevant industry code and standards.

The custodian of this PTS is: Manager - HSE Governance and Risk, GHSED.

Please direct any questions regarding this PTS to the above-mentioned.

Document Approval

	Name	Designation	Date	Signature
Prepared	Noor Suhailah Binti Othman	Principal, Environmental Management, Group HSE Division	2/02/2012	
Reviewed	Lee Tzee Wan	Custodian, Environmental Management, Group HSE Division	2/2/12	
Endorsed	Maureen Song Chai Kee	Head, HSE Strategy & Governance Group HSE Division	2/2/12	
Approved	Maureen Song Chai Kee	Head, HSE Strategy & Governance Group HSE Division	2/2/12	

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PREFACE

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They are based on the experience acquired during the involvement with the design, construction, operation and maintenance of processing units and facilities. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

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This document was jointly prepared with contribution from the following persons and their respective organisations:

- | | |
|----------------------------------|---------|
| 1. Wan M Sobri Bin Wan Abdullah | GTS |
| 2. Norliza Binti Zamhari | PP(M)SB |
| 3. Ruslan Bin Salleh | GTS |
| 4. Dr Norlinda Binti Mohd Zawawi | GHSED |
| 5. Islina Binti Kamaruzaman | GHSED |
| 6. M Anil Bin Carle Pun | GHSED |
| 7. Yap Wey Li | GTS |
| 8. Adriza Jazah Binti Jamil | GHSED |

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1.0 INTRODUCTION

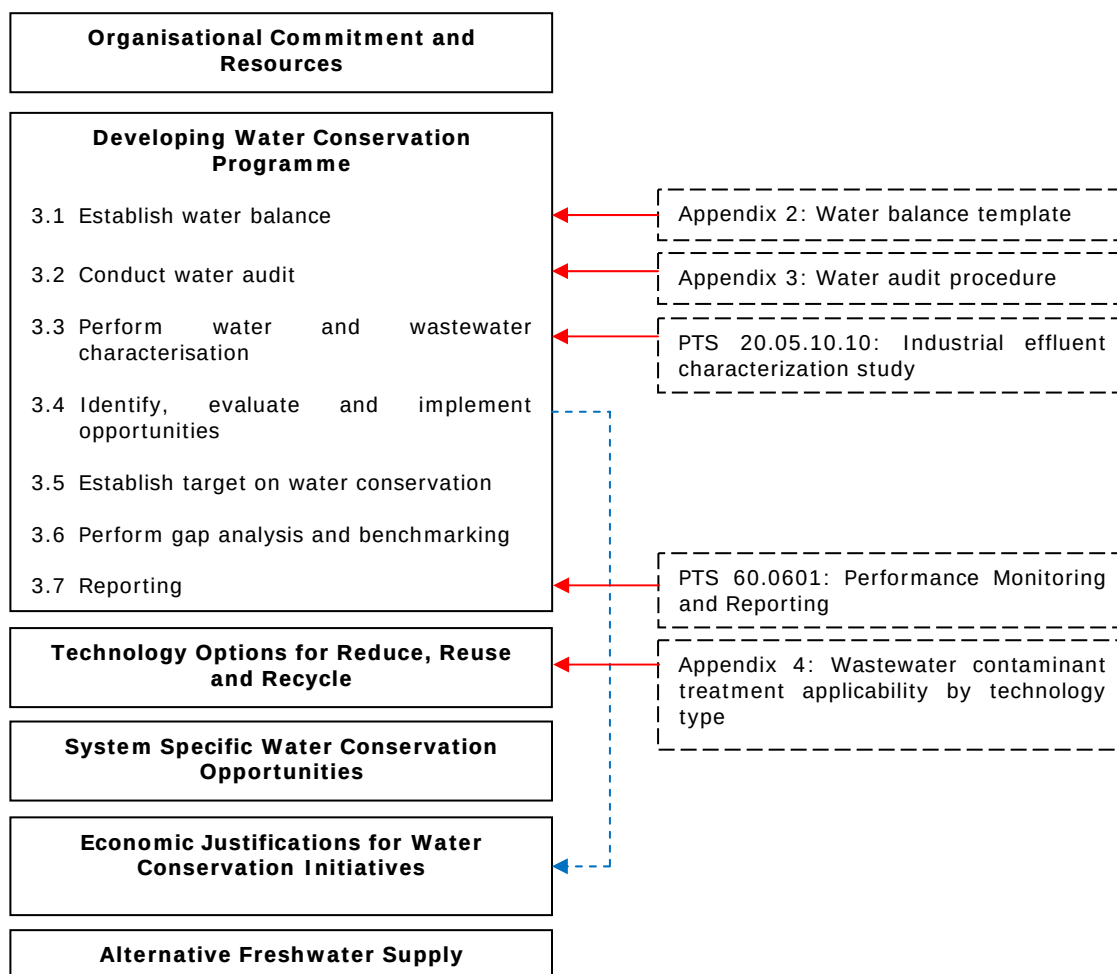
Water issues are often local, but may be influenced by large-scale trends. In the future, increased competition for fresh water will strengthen the need for optimal management of this resource. In addition, the projected impacts of climate change - including rising sea levels, the reduction of water storage in the form of snow, glaciers and ice caps, and an increase in droughts and floods – are likely to impact water supplies. Finally, many of the proposed methods of producing low carbon and renewable energies are water intensive and will increase competition for fresh water.

Fresh water is both a socio-economic and an environmental issue and has multiple uses in the upstream and downstream business operations of oil and gas companies. Applications vary in complexity, scope and scale. The amount of fresh water used by large, global oil and gas companies is comparable to that used by large global mining and chemical companies. An overview of water management practices across oil and gas value chain is shown in **Appendix 1**.

As an essential resource for PETRONAS' operations, increasing water consumption trend due to population growth and rapid industrialization has put more stress on freshwater supply. This can be a potential threat to the sustainability of PETRONAS' operations.

In view of that, PETRONAS has been intensifying its effort to inculcate water conservation initiatives as part of its organisational culture in order to achieve a water efficient operation. This requires the establishment of clear guidelines and tools for water conservation.

An overview of the content of this guideline is illustrated in **Figure 1** below:



1.1 OBJECTIVE

The objectives of this document are as follows:

- To provide guidance on the development of site specific water conservation programme for existing operation.
- To provide guidance on design specification for water conservation in new project.
- To provide guidance in optimising water management for on-shore sites/facilities.
- To define roles and responsibilities of relevant personnel and departments for the implementation of the water conservation programme.

1.2 SCOPE

- This guideline is applicable for all PETRONAS new and existing onshore sites/facilities inclusive of non-process facilities i.e.: KLCC properties, MISC, PMTSB etc.
- This guideline is applicable to all types of freshwater intake.
- This guideline covers the optimization of water consumption and wastewater minimization.

PETRONAS sites refer to all OPU's or Joint Ventures, where PETRONAS has operational control.

1.3 REFERENCE

In preparing this guideline, references are made to the following documents:

- A Water Conservation Guide for Commercial, Institutional & Industrial Users, New Mexico Office of the State Engineers, July 1999, New Mexico.
- Industrial Water Management, A systems Approach, 2nd Edition, Centre for Waste Reduction Technologies, AIChE.
- IPIECA Overview of Freshwater Issues for the Oil and Gas Industry, Water 2010.
- IPIECA Petroleum Refining Water/Wastewater Use and Management, Operation Best Practice 2010.
- PETRONAS Project Management System, Project Management Standard, version 4.0, November 2009.
- PETRONAS Project Management System, Project Execution Plan Guideline, version 1.0 June 2009.
- PTS 20.05.10.10 Industrial Effluent Characterization Study
- PTS 60.0301 Performance Monitoring and Reporting

1.4 PETRONAS REQUIREMENTS ON WATER CONSERVATION

PETRONAS Corporate Sustainability Framework recognizes natural resource use as one of the key focus areas supporting PETRONAS' journey towards sustainable operation. The general direction for this focus area is to ensure the efficient and responsible use of energy and water.

1.5 CHALLENGES AND OPPORTUNITIES

There are several risks and opportunities listed in **Table 1** below that could be taken into consideration in formulating water conservation programme.

In locations where water tariff is relatively low, water conservation projects might not be economically viable. This is because the cost of water recycling will be more expensive compared to the cost of freshwater import.

The importance of water conservation can only be realized if the actual cost of water which includes direct, indirect and intangible costs (risk, liability, potential HSE impact) **is** evaluated. The Total Cost Assessment (TCA)¹ is a powerful methodology for that purpose. The general approach of conducting a TCA is described in **Section 6.1**.

The universal drive towards sustainable development has resulted in increased motivation in water conservation projects. Technological advancement and the rising cost of freshwater is also making water conservation projects more technically and economically viable.

Risk	Opportunities
Social: Competition for fresh water resources could lead other users to challenge companies' 'license to operate'. Health: Poor access to clean water and sanitation can impact employee health, leading to lower capacity to perform their work, high absenteeism and increased staff turnover rates. Similarly, poor access to clean water and sanitation can impact community health. Regulatory: Governments may give precedence to agriculture, ecosystems, other industries or human needs by restricting water intensive industries or forcing them to use lower quality water sources. Governments may impose requirement for better water efficiency in industry and/or increase water tariff. Resource: Water scarcity and declining water quality. Reputation: Negative publicity related to water issues can impact corporate reputation, product brands and community acceptance.	Development and implementation of fresh water management: Sharing best management approaches across the value chain can optimize progress by leveraging information, technology and process improvements throughout a project or operation. Development of innovative technology: Process improvements that use less fresh water may lower costs and risks, and may provide competitive advantage. Dialogue and engagement with communities: Proactive communications will inform local people and encourage them to collaborate in the development of sustainable water policies. Promotion of partnerships: Water is a 'beyond the fence line' issue for businesses and should not be addressed in isolation. Partnerships can lead to optimal short-term solutions and long-term improvements in governance and policy that will reduce competition for resources and reduce tension between stakeholders.

Table 1: Risk and Opportunities

¹ Some of the information on TCA were extracted from "Industrial Water Management – A Systems Approach", 2nd Edition, Centre for Waste Reduction Technologies, AIChE.

2.0 ORGANISATIONAL COMMITMENT AND RESOURCES

2.1 LEADERSHIP AND COMMITMENT

Water conservation initiative, like any other initiatives, needs a common driver that plans and governs the whole chain of process starting from idea generation to the final phase of implementation.

OPUs management should be actively committed to water conservation by providing direction and resources to support its implementation. Resources include personnel, training, procedures, documentation, specialist support, materials and equipment, computer hardware and software, and finances.

2.2 ACCOUNTABILITIES AND RESPONSIBILITIES

Water conservation requires commitment and support at all levels in order to make it effective. **Table 2** describes the group of personnel in the plant/industry who are most likely to be the main drivers of water conservation initiatives in their own specific ways:

Group of Personnel	Description	Responsibilities
Business / OPU Head	The business leader of a group of companies / OPUs, who has overall accountability for the performance of the Group.	- Set direction on water conservation for the Businesses and OPUs. - Ensure development of actionable plan and clear target on water conservation. - Ensure availability of resources to support its implementation. - Develop benchmarking criteria for Businesses - Ensure benchmarking is carried out.
GSDD	Group Sustainable Development Department.	- Establish and review PETRONAS position on water conservation. - Develop benchmarking criteria for the Group. - Conduct corporate level gap analysis and benchmarking.
Utilities / Water Technologist	Utilities and water technologist supported by other technologists based in Technical Services Department / Division.	- Establish and update the water and wastewater balance. - Coordinate/conduct the water audit and wastewater characterization study with assistance from GTS where necessary. - Establish production cost of water and cost of treating wastewater. - Identify, coordinate, and implement plant-wide water 3R (Reuse, Reduce and Recycle) initiatives. - Establish water conservation target. - Prepare audit checklist - Lead/conduct water audit.
Water practitioner	Utilities asset manager.	Work with technologists in identifying

Group of Personnel	Description	Responsibilities
	- Utilities operator. - Utilities operation engineer.	- and implementing water 3R initiatives in utilities. - Implement water conservation in day-to-day operation (optimization of blow-down, backwash, etc.). - Ensure adequate and reliable water supply (quantity and quality) - Be familiar with water cost.
Water users	- Process water users in the process areas or off-sites who uses freshwater, cooling water, demineralised water, boiler feed water, steam, and condensate. - Non-process water users who uses freshwater for sanitation, gardening, water fountains, etc.	- Conduct routine checks to detect and stop water losses, e.g., once-through cooling of equipment, passing steam trap, water pipe leaks, passing cooling water RVs, water curtain, steam blanket. - Review operational practices that involve wastage of water. - Avoid non-essential use of water, e.g., flushing, cleaning, gardening. - Work with technologists in identifying and implementing water 3R initiatives in process, off-sites and non-process areas. - Be familiar with water costs.
Wastewater generators	Producers of wastewater either from utilities or process areas e.g. blow-down water, demin regeneration waste, sourwater, crude tank water-draw.	- Aware that the individual discharge from each unit/system has an impact on the water and wastewater balance and water 3R opportunities: - Optimize operation to minimize discharge flow. - Ensure each discharge is in-compliance to the discharge specification (effluent treatment system feed quality, stormwater quality, etc.). - Contain the discharge when severe contamination is suspected. - Avoid batch discharge. - Ensure the correct route for discharge as per design.
Project teams/designers	Group of people responsible for detailed planning, design, and successful completion of capital projects (plant modifications, revamp, etc.).	- Adopt design specification on water conservation for all new projects. - Ensure water 3R strategies and efficient water usage practices are embedded in the facilities design and equipment selection.
HSE Manager	A person that manages HSE matters or provides advices on environmental management including benchmarking to international and industry	Maintain water consumption database, verify data and report performance.
Environmental TP		Advise on water conservation plan and target setting.

Group of Personnel	Description	Responsibilities
	standards.	
Water TP	A person that manages water related matters or provide advices on water management including benchmarking to international and industry standards.	- Prepare audit checklist. - Lead/conduct water audit. - Guide on water conservation plan and target setting.

Table 2: Roles and Responsibilities

3.0 DEVELOPING WATER CONSERVATION PROGRAMME

The following sections describe the typical steps to be undertaken in implementing water conservation.

3.1 ESTABLISH WATER BALANCE

3.1.1 Purpose

- Monitoring and tracking of water usage and identification of deviation from normal operating range.
- Identification of water 3R opportunities.
- Visualization of different scenarios on water minimization.

3.1.2 General Requirements

- System boundary (i.e. the start and end point of water balance).
- Monthly total water consumption in m^3 .
- All sources of water (e.g. JBA, CUF, stormwater, groundwater, process water, river water)
- All water users (e.g. process, steam system, cooling water, firewater, potable water, export streams, cleaning).
- All water discharges and loss (i.e. wastewater generated from utilities systems, wastewater from process systems, and the wastewater collected from bund areas, and collection systems within the facility).
- All reuse/recycle water streams.
- Flow rate (in m^3/hr).
- Mode of flow (continuous, batch or normally no flow -NNF).
- Indications of where flows estimation are made (due to unavailability of flow meters).

3.1.3 Methodology

- Identify major processes and equipment between the water intake and discharge to the environment. Typical processes and equipment are:
 - a. Water treatment or purification system such as filtration, softener, demineralization, membrane.
 - b. Cooling water system.
 - c. Steam raising system.
 - d. Wastewater treatment system.
 - e. Processes which utilizes or generates water.
 - f. Potable water system.
 - g. Firewater system.
- Identify the flow and type of water flowing in and out of each system. Water bills are considered accurate and verifiable source for main water intake. For intermediate streams, data from control room, meters and any other available data can be used. If actual data is not available, estimates can be made based on design values or assumptions. Ultrasonic flow measurements can be used to verify the estimation or assumptions.
- For batch flows, the flow needs to be translated into average hourly (m^3/hr) basis by determining the total volume discharged over a specific period.

- Balancing around a process or equipment is to be done to ensure that all flows into and out of the process or equipment are accounted for. For example, water balance around the purification system shall be done as follows:
 - a. Input: raw water from raw water tank
 - b. Output: demineralised water
 - c. Losses: Backwash, regeneration water, dilution water, rinsing water
- The difference between total inlet and outlet flows from the identified system boundary shall not exceed 10%. If more than 10%, re-evaluation of the water balance shall be considered.
- Water balance should be prepared and updated on a monthly basis by Water Technologist. Sample of generic water balance template is available in **Appendix 2** for reference. Process flow diagrams (PFDs) and piping and instrumentation diagrams (PIDs) shall be referred to during the establishment of the water and wastewater balance.

3.2 CONDUCT WATER AUDIT

3.2.1 Purpose

- Verification of the water balance.
- Identification of unaccountable water losses within and around the facility.
- Identification of unnecessary water usage.
- Identification of 3R opportunities.
- Verification of water systems performance.

3.2.2 General Requirements

- Water consumption inventory.
- Water balance.
- Water quality data.
- Information on operations and maintenance of water system.

3.2.3 Methodology

Water audit should be carried out on yearly basis, or whenever there is major change in process or equipment. The audit team shall be led by OPU's focal person preferably, Senior Water Technologist/Water TP with involvement from related department at OPUs. The step-by-step approach to conduct an accurate and thorough examination of current water usage is shown in **Figure 2**.

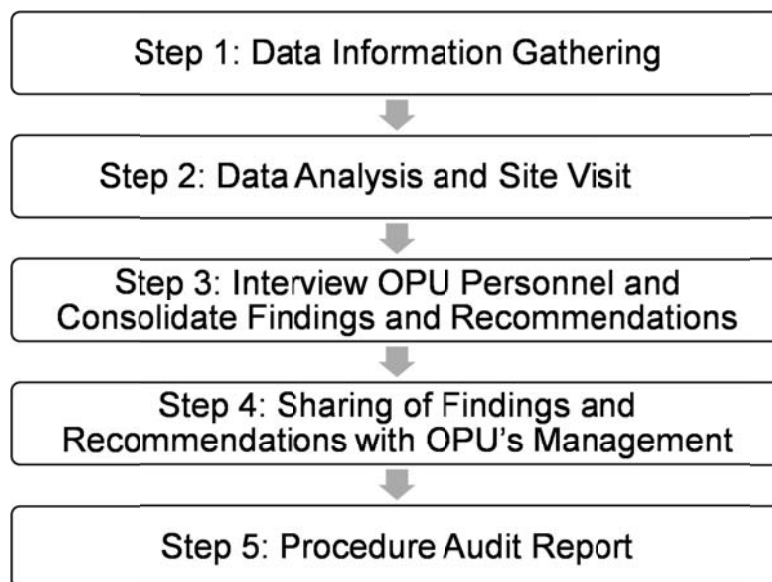


Figure 2: Water Audit Steps

The details of each step are described in **Appendix 3**.

During the audit, audit team shall be guided by using audit checklist developed by Senior Water Technologist/Water TP.

3.3 PERFORM WASTEWATER CHARACTERIZATION

3.3.1 Purpose

- Determination of loading (i.e. physical, biological, and chemical constituents of the wastewater).
- Performance evaluation of water systems.
- Identification of contaminant source.
- Verification of potential reuse and recycle opportunities.
- Wastewater characterization needs to be done to evaluate the suitability and pre-treatment requirement for the identified water reuse/recycle opportunities.

3.3.2 General Requirements

- Identified sampling points.
- Proposed testing parameters.
- Frequency of sampling and number of data sets required.
- Sampling and testing method.
- Flow data and mode (continuous/intermittent).
- Operational activities which might affect effluent composition.

3.3.3 Methodology

Refer to PTS 20.05.10.10 Industrial Effluent Characterization Study.

3.4 IDENTIFY, EVALUATE AND IMPLEMENT OPPORTUNITIES

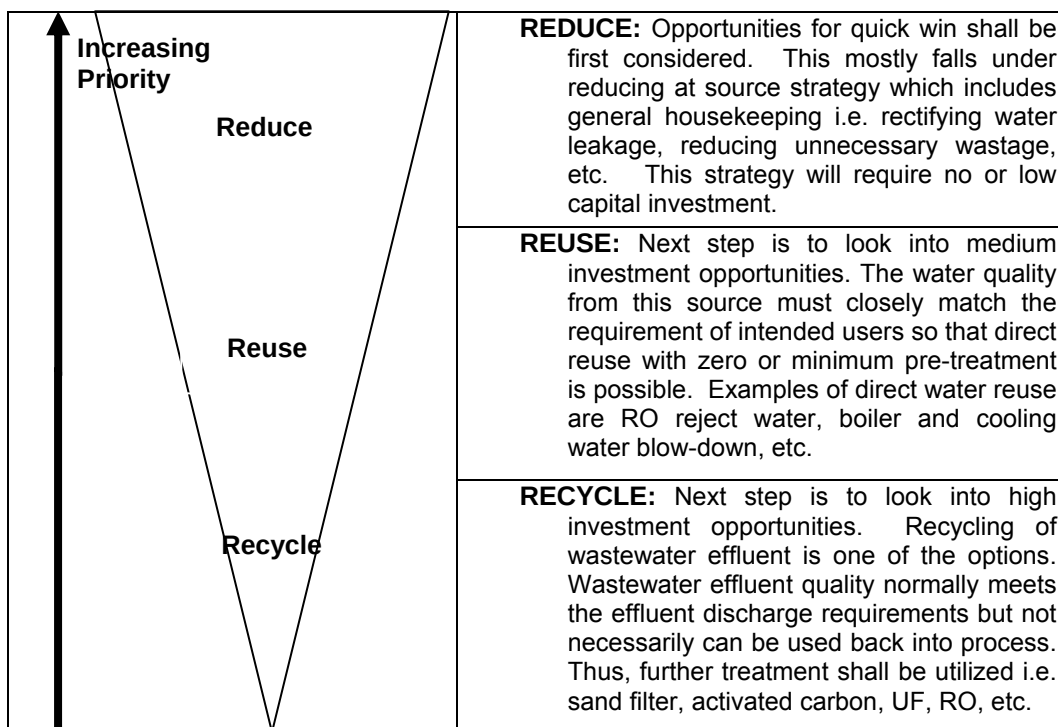
3.4.1 Purpose

- Evaluate water conservation opportunities in terms of potential annual water savings, estimated investment and operational cost together with internal rate of return (IRR), net present value (NPV) and payback period. Refer to **Section 6.0** for details in performing the economic analysis.
- Evaluate operational risks associated with the identified opportunities (e.g. more concentrated effluent discharge, effect of RO reject water on cooling water quality) and identify operational adjustment requirement (which may incur higher operating cost).

3.4.2 General Requirements

- Options on treatment technology with cost estimate.
- Operational cost estimate.
- Current and projected water cost.
- Determination of actual cost of water which includes indirect and intangible costs (risk, liability, potential HSE impact). Refer to the TCA approach in **Section 6.1**.

3.4.3 Methodology



Where capital investment is required, the initiative shall undergo the standard management of change process, including getting the budget and project sanctions. Some initiatives may result in higher energy or chemical consumption and therefore, a proper risk review and economics study shall be conducted to ensure a wholesome and balanced approach in the implementation of water conservation projects.

3.5 ESTABLISH TARGET ON WATER CONSERVATION

3.5.1 Purpose

- Development of site or organisational level target on water conservation.
- Tracking and monitoring the impact of water conservation initiatives.
- Continuous improvement of water conservation programme.
- Communicate on success and lesson-learned of water conservation initiatives.

3.5.2 General Requirements

- Water inventory data for at least 2 years.
- Projection on future water demand (at least for next 10 - 15 years).
- Cost-benefit analysis of a proposed target.

3.5.3 Methodology

- Development of water conservation target based on previous trend is carried out in consultation with water technologist and asset owners.
- The water reduction targets, like any other KPIs, should be specific, measurable, achievable, realistic and timely (SMART).
- The water conservation targets and KPIs shall be in relative value or intensity. Examples of targets and KPIs are as follows:
 - i. Steam trap failure rate (%)
 - ii. Condensate recovery rate (%)
 - iii. Steam venting loss rate (tonne/hr)
 - iv. Closed cooling water loss rate (m³/process output)
 - v. Reduction intensity of freshwater make-up to cooling tower (m³/process output)
 - vi. Compliance of discharge stream (% in compliance of critical parameters)
 - vii. Cooling water blowdown rate (m³/process output)
 - viii. Reject water recovery rate (m³/process output)
 - ix. Total freshwater reduction intensity (m³/no of people or m³/production output)

3.6 PERFORM GAP ANALYSIS AND BENCHMARKING

3.6.1 Purpose

The purpose of gap analysis and benchmarking is to achieve continuous improvement in water conservation.

The Gap Analysis and Benchmarking are normally conducted by Business Division or Corporate Office. Benchmarking is normally done against design requirements or 'Best-in-class' industry/companies practices.

3.6.2 General Requirements

- Updated water balance.
- Water audit report.
- Group water inventory.

3.6.3 Methodology

- Analysing trend on water consumption and performance against water conservation target.
- Identifying operational performance gaps and opportunities for improvement.

- Establishing new targets, if necessary.
- Gap analysis and benchmarking practice can be conducted on yearly basis.
- The benchmarking criteria to conduct gap analysis will be determined by GSDD for consistency throughout the Group.
- OPU shall submit all relevant information and performance analysis of water systems to Business Units and GSDD.

3.7 Reporting

OPUs shall report their monthly freshwater consumption on a quarterly basis through iHSE as required by **PTS 60.0601: Performance Monitoring and Reporting**. The data that shall be reported by each OPU is shown below:

OPU'S BUSINESS SECTOR	UNIT	FREQUENCY OF REPORTING
E&P/G&P/DOD/Other Businesses	Cubic Meter (m ³)	Quarterly

OPUs shall report any water conservation initiatives done in their premises to the respective BUs and GSDD.

4.0 TECHNOLOGY OPTIONS FOR REDUCE, REUSE AND RECYCLE

4.1 REDUCE

This is the simplest form of water conservation strategy whereby immediate improvement can be seen with minimum resource and capital requirement. It involves the reduction of wastages and optimization of water consumption at source.

The following briefly describes the six general approaches for water reduction. The last three approaches (retrofitting, re-engineering and alternative technologies) are best applied during design stage of new facilities and should be considered in the rejuvenation or revamp of existing facilities.

4.1.1 Housekeeping

Housekeeping means avoiding wastages and keeping systems in place to ensure it is working as per design intent. This encompasses the following:

- Detection and repair of piping, valve leaks, etc.
- Efficient management of steam traps.
- Controlled usage of water for flushing and cleaning.
- Elimination of improper or non-essential water usage.

Housekeeping shall be a continuous and frequently conducted activity. For that, plant walkabout has to be conducted by operators on a regular basis. Any abnormal condition with regards to water usage in plant area has to be reported and attended to immediately.

4.1.2 Operational Adjustment

Typical water losses from processes are from blow-down, backwash, regeneration, venting, stripping, quenching, water washing, etc. It is important to ensure that these losses are kept to a minimum to avoid wastages.

Adjustment of the system's operating condition is one of the methods to achieve this. For example, controlling filter backwash by pressure drop across filter is a better alternative than timed backwash. Adjustments in operating condition shall only be done if it is not jeopardizing process requirements and performance.

4.1.3 Management of Non-Essential Water Use

Non-essential water use refers to usage of water for activities other than those supporting plant productions. Examples of non-essential water use are:

- Washing/pressure cleaning of walkways, parking lots or any other paved areas or building exteriors (unless necessary for maintaining public sanitation/safety).
- Water fountains, fish ponds and pools.
- Frequent and inefficient irrigation of lawns, fields and plants.

As much as possible, non-essential water use shall be avoided or kept to a minimum.

4.1.4 Engineering Modification

There are water losses which can be totally avoided through improvement in engineering design. Examples are use of fresh water for once-through cooling, water-bath, water curtains, and in some extreme cases for cooling down of waste streams. These non-efficient water usage features shall be avoided in any new facility design; while in existing facilities, modification for better alternatives is recommended at available opportunities.

4.1.5 Retrofitting

Retrofitting refers to the addition of new technology or features to older systems in order to increase water-efficiency. Older systems in plants were built with little consideration on water conservation. Retrofitting involves making improvement to older fixtures or equipment to optimize water consumption. Examples are installation of infrared and ultrasonic sensor faucets, flow restrictors, dual flushing system, etc.

4.1.6 Alternative Water-Efficient Technologies

Water-efficient equipment are increasing in number and becoming less expensive with recent advancement in technology. Awareness on these new or alternative technologies needs to be constantly acquired by water technologists and practitioners for potential application.

Examples are:

- Mechanical disc filter vs. the conventional sand filter for cooling water and raw water systems.
- Closed loop cooling system vs. open evaporative cooling system.

4.2 REUSE

Reuse involves direct usage of water from one service to another service without the need for extensive treatment. This method is suitable especially for plant wastewater which is still in the acceptable quality range to be re-used for other applications.

Small to medium level of investment may be required in the form of collection pit, pump and piping. In some cases, basic physical treatment such as strainer may be required.

Many opportunities exist for reuse of non- contaminated wastewater and storm water. Some examples of applications are described in **Table 3** below.

Source of Wastewater	Cascade Reuse Application
Cooling tower blowdown	• Wash water • Utility water • Flare drum seal water • Pump coolant • Tank field waste • Scrubber water makeup • Landscape irrigation water • Log deck watering • Cooling for boiler blowdown
Boiler blowdown	• Lower-pressure boiler makeup water
Once-through rinse water	• Counter-current rinsing
Once-through cooling water	• Cooling pond • Compressor cooling water • Non-contact cooling water • Process water • Wash water
Condensate from tanks or processes	• Boiler makeup water
Storm water	• Process water • Non-contact cooling water • Firewater • Cooling tower make up (with chemical

Source of Wastewater	Cascade Reuse Application
	treatment) Wash water
Reverse osmosis reject water	- Cooling tower make up (with chemical treatment) - Wash water

Table 3: Potential Water Reuse Applications

Some examples of applications for contaminated wastewater and storm water are described in **Table 4** below.

Water Category	Contaminant Specification	Potential Source Of Re-Use Water
Desalter makeup	- Sulphide: < 10 mg/l - Ammonia: < 50 mg/l - Total dissolved solids (TDS): < 200 mg/l	- Stripped sourwater - Vacuum tower overhead - Crude tower overhead
Coker quench water	- Total suspended solids: < 100 mg/l - Biological solids: none - H₂S and other odorous compounds: none	Stripped sourwater
Coke cutting water	- Total suspended solids: < 100 mg/l - Biological solids: none - H₂S and other odorous compounds: none	Stripped sourwater
Boiler feedwater makeup (quality required is highly dependent on the pressure of steam being produced)	- Conductivity: < 1 µS/cm - Hardness: < 0.3 mg/l - Chlorides: < 0.05 mg/l - Sulphates: < 0.05 mg/l - Total silica: < 0.01 mg/l - Sodium: < 0.05 mg/l - Dissolved oxygen: < 0.007 mg/l	Treated and upgraded wastewater
Cooling tower makeup	- Conductivity: < 6,000 µS/cm - Alkalinity: < 3,000 mg/l - Chlorides: < 1,500 mg/l - Suspended solids: < 150 mg/l	Treated and upgraded wastewater

Table 4: Potential Water Reuse Applications for Contaminated Storm Water

4.3 RECYCLE

For some industry, make-up water for cooling tower can account for up to 50% of the total plant freshwater demand. At the same time, the amount of wastewater discharged from the facility is also significant. In this situation, water recycling should be an attractive option for reduction of freshwater consumption and reduce dependency on freshwater supply.

Recycle involves reuse of wastewater either from final discharge or those generated from specific unit operation. This recycled wastewater (after going through treatment) can be diverted either to the front end of water system (intake point) or upstream of specific unit operation as feed depending on suitability. Entry into the potable water system should only be allowed if the treated water meets the drinking water standard. Major types of technological processes applicable to water recycling, along with their applicability are listed in **Table 5**.

Treatment	Inorganic Contaminant	Organic Contaminant	Dissolved Contaminant	Suspended Contaminant	Biological Contaminant
Bio-oxidation and Bio-treatment (anaerobic, aerobic, nitrification, other)	√	√	√	√	√
Carbon Treatment (sorption or adsorption)	√	√	√		
Centrifuge separation				√	
Chemical Oxidation (ozone, wet air, peroxide, supercritical, other)	√	√	√		√
Crystallization	√	√	√		
Electrodialysis	√		√		
Evaporation (mechanical, ponds, distillation)	√	√	√		
Filtration (granular bed, vacuum drum, press, belt filter, other)	√	√		√	√
Flotation	√	√		√	
Gravity Separation or Settling (coagulation, flocculation, or clarification)	√	√		√	√
Ion Exchange	√	√	√		
Membrane Separation (reverse osmosis, ultrafiltration)	√	√	√	√	√
Precipitation	√	√	√	√	
Solidification or Stabilization	√	√	√	√	
Solvent Extraction	√	√	√		
Stripping (steam, air, other)	√	√	√		
Thermal Treatment (drying, incineration, spray drying, other)		√	√	√	√

Table 5: Wastewater Contaminant Treatment Applicability by Technology Type

Water recycling will require major capital investment due to installation of treatment system. It is recommended that a pilot plant study to be conducted prior to full scale implementation. This is to ensure high success rate which addresses operability of the treatment unit and the impact on the receiving unit. The recycling/reuse options and technologies discussed herewith may result in the need to discharge a concentrated brine stream that comes from the reverse osmosis / nanofiltration reject. This reject stream shall be channelled to dewatering unit prior to disposal as hazardous waste.

Further explanation regarding wastewater contaminant treatment applicability by technology type is available in **Appendix 4**.