GOOD PRACTICE GUIDE

AN INTRODUCTION
TO PRODUCED
WATER MANAGEMENT
Foreward

Produced water is a by-product of oil and gas production and with the increasing number of maturing fields water production is on the increase worldwide. Estimates of the amount of produced water vary but could be in the region of 250 million barrels per day. Once produced water is separated from oil (and gas) it is treated and then discharged to surface water or re-injected for either reservoir pressure maintenance or disposal. This document aims to provide an introduction to the management of produced water discharges; including the chemical make-up of produced water, the various separation and analysis technologies, together with current and future legislation.

Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreword</td>
<td>1</td>
</tr>
<tr>
<td>1 What is Produced Water?</td>
<td>2</td>
</tr>
<tr>
<td>2 Petroleum Hydrocarbons</td>
<td>2</td>
</tr>
<tr>
<td>3 What is Oil in Produced Water?</td>
<td>3</td>
</tr>
<tr>
<td>4 Down-hole Oil-in-Water Separation (DOWS)</td>
<td>4</td>
</tr>
<tr>
<td>5 Subsea Separation Systems</td>
<td>5</td>
</tr>
<tr>
<td>5.1 Gravity based</td>
<td>5</td>
</tr>
<tr>
<td>5.2 Cyclone based</td>
<td>6</td>
</tr>
<tr>
<td>6 Surface Treatment Technologies</td>
<td>6</td>
</tr>
<tr>
<td>6.1 Technologies for oil removal</td>
<td>6</td>
</tr>
<tr>
<td>6.2 Technologies for salt removal</td>
<td>7</td>
</tr>
<tr>
<td>Produced Water Re-injection (PWRI)</td>
<td>8</td>
</tr>
<tr>
<td>8 Oil-in-Water Monitoring</td>
<td>8</td>
</tr>
<tr>
<td>8.1 Officially approved methods</td>
<td>8</td>
</tr>
<tr>
<td>8.2 Bench top analysis methods</td>
<td>9</td>
</tr>
<tr>
<td>8.3 On-line monitoring</td>
<td>9</td>
</tr>
<tr>
<td>9 Oil in Produced Water Sampling</td>
<td>10</td>
</tr>
<tr>
<td>10 Oil-in-Water Legislation</td>
<td>11</td>
</tr>
<tr>
<td>10.1 History of the OSPAR discharge limit</td>
<td>12</td>
</tr>
<tr>
<td>10.2 Future legislation</td>
<td>12</td>
</tr>
<tr>
<td>11 Recommended Further Reading</td>
<td>13</td>
</tr>
</tbody>
</table>
1. What is Produced Water?

According to OSPAR (OSLO-PARIS) “Recommendation 2001/1” Produced Water means water which is produced in oil and/or gas production operations and includes formation water, condensation water and re-produced injection water; it also includes water used for desalting oil. Produced water is a complex mixture. It also has wide variations in composition within and between reservoirs as well as with the age of fields. The following materials are generally associated with produced water:

- Dispersed hydrocarbons – oil droplets mainly aliphatic hydrocarbons
- Dissolved hydrocarbons – aromatic and polycyclic aromatic hydrocarbons (PAHs)
- Soluble organics: phenols, fatty acids
- Salt content
- Production chemicals
- Heavy metals
- Radioactive materials

2. Petroleum Hydrocarbons

Common everyday petroleum products such as petrol and diesel, for example, are derived from crude oil. Crude oil is separated into constituent by a fraction distillation. The basic principle of this distillation process is that crude oil is separated into the hydrocarbon fractions which have similar numbers of carbon atoms which relate, in turn, to similar boiling points range. The most common petroleum fractions obtained from crude oil are given in the table below:

<table>
<thead>
<tr>
<th>Fraction</th>
<th>Carbon range</th>
<th>Boiling range (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petrol</td>
<td>C\textsubscript{4}-C\textsubscript{12}</td>
<td>25 – 200</td>
</tr>
<tr>
<td>Kerosene</td>
<td>C\textsubscript{10}-C\textsubscript{15}</td>
<td>150 – 300</td>
</tr>
<tr>
<td>Diesel</td>
<td>C\textsubscript{12}-C\textsubscript{20}</td>
<td>270 – 350</td>
</tr>
<tr>
<td>Lube Oil</td>
<td>C\textsubscript{20}-C\textsubscript{40}</td>
<td>350 – 500</td>
</tr>
<tr>
<td>Asphalt</td>
<td>C\textsubscript{40+}</td>
<td>&gt; 500</td>
</tr>
</tbody>
</table>

These petroleum products comprise a complex mixture of hundreds of individual hydrocarbons that are principally grouped into aliphatic, aromatic, and heterocyclic compounds.

**Aliphatic hydrocarbons** are those that contain alkanes, alkenes, and alkynes.

- Alkanes have carbons joined by a single bond, they are also called saturated hydrocarbons or paraffins. They can be straight chained, e.g. methane, branched, e.g. isobutane, or cyclic, e.g. cyclopentane
- Alkenes have carbons joined by a double bond, they are also called olefins, e.g. ethene
- Alkynes have carbons joined by a triple bond

**Aromatic hydrocarbons** are those that contain a benzene ring nucleus in their structure. They are grouped into two: the monoaromatic hydrocarbons and the polyaromatic hydrocarbons, PAHs, which contain three or more aromatic rings. Two ring aromatic hydrocarbons do not belong to either of them but in practice they are handled together with the PAHs.
2. Petroleum Hydrocarbons cont.

Monoaromatic hydrocarbons contain one aromatic ring. The most interesting and common ones include Benzene (C_6H_6), Toluene (C_6H_5-CH_3), Ethylbenzene (C_6H_5-C_2H_5) and Xylene, C_8H_10(CH_3)_2; often known as BETX by the industry. They are volatile as well as have relatively high solubility in water.

The Polyaromatic Hydrocarbons, PAHs, cover a broad range of compounds. In environmental investigations it is common to measure the sixteen PAHs defined by the list of Priority Pollutants from US EPA. These sixteen compounds are all full aromatic hydrocarbons without any substitutes. In crude oil the major part of the PAH will be of the alkylated type.

Within OSPAR three alternative selections of most relevant Polyaromatic hydrocarbons have been suggested:

- Naphthalenes (alkylated and non-alkylated)
- NPDs: naphthalene, phenanthrene, dibenzothiophene (alkylated and non-alkylated), which are 2-3 ring aromatic compounds
- US-EPA list of sixteen PAHs (naphthalenes, phenanthrenes are part of the sixteen US-EPA PAHs, dibenzothiophene is not)

When considering the aromatics, some, e.g. Oil and Gas Producers (OGP), have suggested the following grouping which seems to be clearer:

- BETX: monocyclic aromatic compounds
- NPD: 2-3 ring aromatic compounds
- PAH: Polyaromatic compounds represented by the sixteen US-EPA PAHs except naphthalene and phenanthrene).

These are 3-6 ring aromatics compounds.

It is generally accepted that the BTEX and NPD partition to a greater degree into the dissolved phase, whereas the PAHs (excluding naphthalene and phenanthrene) are associated predominately with oil dispersed in the aqueous phase.

3. What is Oil in Produced Water?

According to OSPAR “Recommendation 2001/1” (which was amended by “Recommendation 2006/4”), oil means the total hydrocarbons, which can be determined by the appropriate sum of analytical results obtained using the agreed reference methods for dispersed oil and aromatic hydrocarbons.

The agreed reference method for dispersed oil is the method detailed in “Agreement 2005-15”, which is based on using gas chromatography and flame ionisation detection (GC-FID).

Clearly it is crucial that one states precisely the definition and methodology used when referring to “oil”.

Dissolved - such as BETX (e.g. Benzene, Ethyl-benzene, Toluene, and Xylene), NPDs and / or some of the PAH (polycyclic aromatic hydrocarbons)
3. What is Oil in Produced Water? cont.

Dispersed - in the form of small droplets, say in the range from 0.5 micron to 80 microns, some time referred to as oil-in-water emulsion, which can be stable for a significant period of time.

Free oil- floating on the surface of water or in the forms of large droplets that will settle quickly.

4. Down-hole Oil-in-Water Separation

While water shut-off technology is used to prevent unwanted / excess water getting into the wellbore, it is almost inevitable that water will be produced with oil. DOWS offers a way to separate oil and water at the earliest possible stage and therefore reduces the costs associated with bringing water to surface or sub-surface for treatment. From the separation point of view it is also much easier to separate oil and water mixtures at wellbore conditions as the oil and water mixtures will not have gone through the mixing and shearing conditions that they otherwise will if the mixtures are brought to the surface. Separation also benefits from the lower oil viscosity (due to higher temperature) and relatively lower oil density (due to dissolved gas and the higher temperature).

Two basic types of DOWS have been developed, they are Hydrocyclone-based and gravity based.
4. Down-hole Oil-in-Water Separation

In the Hydrocyclone-based DOWS production fluids are drawn into the pump, which drives the fluids through the separation module (cyclone). Oil and water are separated due to the centrifugal force; oil concentrate stream is then lifted to the surface while the water stream is discharged from the underflow into an injection zone separated from the production zone.

Gravity separation type DOWS are designed to essentially allow oil and water separation inside the well. Most gravity type DOWS are vertically oriented with two openings, one in the oil layer and the other in the water layer. Using rod pumps, oil is then lifted and water is injected. A schematic diagram of such gravity type DOWS with Rod Pump is shown in the figure above. Both dual-action pumping (DAP) and triple-action pumping systems (TAPs) have been reported. The triple-action pumping based systems achieve better water injection pressure compared to DAPs.

5. Sub-sea Separation Systems

A subsea separation system is designed to separate the multiphase fluids on the seabed and then send the oil and gas streams with a minimum amount of water either together or using separate lines to the surface for further treatment. Separated water may be re-injected back to formation either for disposal or for pressure maintenance. There are two main subsea separation types. These are gravity based three phase subsea separation systems and cyclone based two phase subsea separation systems.

5.1. Gravity based

A schematic diagram showing a gravity based subsea separation system is provided below.
5.1. Gravity based cont.

The basic design will include the following:

- A gravity (horizontal or vertical) separator
- Water injection facilities such as injection pump and injection Xmas tree
- A chemical injection system for treatment of emulsion, foam and corrosion etc
- A system for sand separation and removal
- A system for power transmission and distribution
- Instruments for injection water quality monitoring, detection of separator interface levels and emulsion composition monitoring, and of course measurement of pressure and temperature.

5.2. Cyclone based

Gas Liquid Cylindrical Cyclones (GLCC) have become well established in the past decade for separation of gas and liquid for the oil and gas industry. Cyclone based subsea separation systems use the same principle. One such system called VASPS (Vertical Annular Separation and Pumping System) was developed in the 1990’s. This system enables high capacity integrated separation and pumping equipment to be installed in a 30 to 36 inch conductor in a dummy well. In 2001 the world’s first VASPS system was installed by Petrobras in Campos Basin.

6. Surface Treatment Technologies

Once produced water is brought to the surface onshore and offshore, whether it will be discharged into the environment and or injected into underground for disposal and or reservoir pressure maintenance, treatment becomes critical.

There are two main categories when it comes to produced water treatment; these include treatment to remove oils (dissolved and dispersed) and treatment to remove salt. Salt removal becomes crucial if the treated produced water were to be re-used for e.g. irrigation, agriculture.

6.1. Technologies for oil removal

Oil in produced water exist in three forms; dissolved, dispersed and free oil as explained elsewhere in the guidance. Free oil is relatively easy to separate. It is the dissolved and dispersed oil that is more difficult to remove.

There are many treatment technologies available for removing dispersed and dissolved oil from produced water. These technologies include:

- Mechanical (gravity, enhanced gravity, gas flotation, filtration, membrane etc)
- Absorption / adsorption / extraction (Granular Activated Carbons – GAC, Macro Porous Polymer Extraction – MPPE; C-tour etc)
- Advanced Oxidation Process (AOP)
- Biological (bio reactors, wetlands etc)
- Hybrid (combination of various technologies, e.g. Compact Flotation Units – CFUs)
6.1. Technologies for oil removal

For the removal of dispersed oil, mechanical methods are most commonly used and can be effective. The table below provides an indication of the kind of oil droplets that can be separated by typical mechanical methods.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Minimum size of droplets removed (μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>API gravity separator</td>
<td>150</td>
</tr>
<tr>
<td>Corrugated plate separator</td>
<td>40</td>
</tr>
<tr>
<td>Induced gas flotation (no flocculant)</td>
<td>25</td>
</tr>
<tr>
<td>Induced gas flotation (with flocculant)</td>
<td>3-5</td>
</tr>
<tr>
<td>Hydrocyclone</td>
<td>10-15</td>
</tr>
<tr>
<td>Mesh coalesce</td>
<td>5</td>
</tr>
<tr>
<td>Media filter</td>
<td>5</td>
</tr>
<tr>
<td>Centrifuge</td>
<td>2</td>
</tr>
<tr>
<td>Membrane</td>
<td>Sub micron, even 0.01</td>
</tr>
</tbody>
</table>

It can be seen from the table that oil droplet size plays a critical role in determining whether such an oil droplet can be separated by a particular mechanical method.

Most of the mechanical methods are now well established. Technologies such as hydrocyclones and gas flotation units with and without the use of chemicals are well applied offshore and onshore for produced water treatment to meet typical produced water discharge standards, such as 30 mg/l in the North Sea and 29 mg/l in the Gulf of Mexico (GoM).

For the removal of dissolved oil in produced water, non-mechanical based methods are often required. Absorption / adsorption / extraction are the current state of the art while oxidation and biological based methods are emerging, in particular for an example, the use of constructed wetlands / reed beds for the treatment of produced water.

6.2. Technologies for salt removal

In order for produced water to be re-used for agriculture, irrigation use purpose, in addition to the removal of oil (dispersed and dissolved), salt content of the produced water needs to be reduced. There are several methods with which salt content or dissolved solids can be removed. These may include:

- Electrodialysis
- Reverse osmosis
- Ion exchange
- Capacitive deionization
- Evaporation

Electrodialysis and reverse osmosis have been commonly used for sea water desalination purpose. There are now by far the two technologies that have been considered for removing salts from produced water. However for both technologies, it is extremely important to remove oil and solids as a pre-treatment.
6.2. Technologies for salt removal cont.

With an increasingly stringent regulatory requirements worldwide and an emphasis on water re-use in particular in places where water is increasingly becoming scarce, oil and gas producers around the globe are increasingly having to treat produced water to remove dissolved oil, dissolved solids on top of dispersed oil.

7. Produced Water Re-injection (PWRI)

PWRI is a very important produced water management option. It offers the following advantages:

- Achieve zero discharge to sea in a physical sense
- Play a significant role in meeting regulatory requirements of produced water discharge to sea
- Possibly be used for reservoir pressure maintenance

PWRI has been in practice for many years; however, North Sea has one of the lowest ratios of re-injection water to the total produced water in the world. In 2003 while most of offshore produced water is re-injected in the Middle East, and almost half in North America, and 45% in Africa, only 12% of offshore water produced in oil and gas production was re-injected by around forty installations or 18% of total number of installations that are permitted to discharge produced water. PWRI is a truly transverse topic between reservoir, process and well engineering. There are many aspects that one needs to consider in making PWRI reliable, effective and economical.

8. Oil-in-Water Monitoring

Oil in produced water is by far the most important parameter that has been commonly used for regulating the discharge of produced water offshore. Therefore analysis and monitoring is extremely important for both offshore operators and regulators. From the operators’ point of view the monitoring of oil in produced water is not only important in terms of meeting the discharge limit (30 mg/l currently in the North Sea), but also in terms of process control and management.

8.1. Officially approved methods

Details of the OSPAR approved reference method can be found in the OSPAR agreement 2005-15. The method was implemented from January 2007 across the North Sea countries. Essentially, the method involves n-pentane to extract oils from a produced water sample. This is then followed by a clean-up with florisil to remove polar components in the pentane extract, and then analysing using GC and FID. The measured dispersed oil by the method is defined as the sum of concentrations of compounds extractable with n-pentane, not absorbed on florisil and which may be chromatographed with retention times between those of n-heptane (C\textsubscript{7}H\textsubscript{16}) and n-tetracontane (C\textsubscript{40}H\textsubscript{82}) excluding the concentrations of the aromatic hydrocarbons of toluene, ethlybenzene and the three isomers of xylene.
8.2. Bench top analysis methods

For routine offshore oil-in-water analyses, simple bench-top analysis methods are very useful. There are a good number of methods/techniques that are available. These may include:

- Colorimetric Method
- Fibre Optic Chemical Sensor
- Infrared Analysis Based on Internal Reflection
- UV Absorbance
- UV Fluorescence
- Supercritical Fluid Extraction (SFE) and IR
- Solid Phase Extraction (SPE) with IR / GC-FID/ GC-MS

Currently in the North Sea both IR absorption with internal reflection and UV fluorescence methods have been used. In Norway and Denmark IR absorption with internal reflection method is now permitted by the authority for reporting. In UK both methods have been tested or are under test offshore. A new method based on using Supercritical Fluid Extraction and Infrared (SFE-IR) has been recently developed for the analysis of oil-in-water. The method effectively allows the continuation of the old IR method but without the use of the banned solvents such as Freon.

8.3. On-line monitoring

One of the key advantages for using an on-line oil-in-water monitor is that it can provide oil-in-water information continuously. Therefore, from the process control and management point of view it is extremely useful.

There are many techniques that may be used for constructing an on-line oil-in-water monitor. These techniques include:

- Focused ultrasonic acoustics
- Fibre optical chemical sensor
- Image analysis
- Light scattering and turbidity
- On-line solvent extraction and IR analysis
- Infrared attenuation total reflection
- Photo acoustic sensor
- Laser induced fluorescence
- Spectral fluorescent signatures
- UV fluorescence
- UV absorption

Most of on-line oil-in-water monitoring instruments that are currently used or are under trials in the North Sea are based on light scattering and UV fluorescence. Light scattering based instruments measure the dispersed oils. They are also widely used as oil content meters for monitoring ship bilge water discharges. The main disadvantages associated with this type of instruments include its sensitivity to gas bubbles, solids and also fouling of the sample window. For UV fluorescence based instruments, it is vital that the ratio of aromatic to the total hydrocarbons in the produced water remains relatively constant. Overall the use of UV fluorescence based instruments is on the increase. This is partly as a result of instrument suppliers being able to use the most appropriate detection wavelength that is specifically linked to the Polycyclic Aromatic
8.3. On-line monitoring cont.

Hydrocarbons (PAH), which can be unique for specific installations. The content of PAHs is now well known to be closely related to the dispersed oils.

With the recent OSPAR decision to recommend a new reference method based on a modified version of the ISO 9377 GC-FID and the fact that such a method for direct offshore use is practically difficult. It is recognised that alternative methods such as on-line monitoring and bench top methods may need to be widely allowed for the analysis of oil-in-water for the purpose of reporting.

9. Oil in Produced Water Sampling

In many parts of the world, oil in produced water is a key parameter that is used for compliance monitoring. It is also a parameter that is used by operators for process control. Provision of accurate oil in produced water data is therefore very important for both regulators and oil and gas producers.

To obtain accurate oil in produced water data, an important step of the process is to withdraw a representative sample from the main produced water pipeline. Without a representative sample, even with the best sample handling procedure and fully complied analysis method, the results can be erroneous.

To obtain a representative oil in produced water sample care has to be taken in relation to the following:

- **Selection of a sample point location**: This will depend on whether the samples to be taken will be used for operational or regulatory compliance monitoring purpose. In the case of regulatory compliance, this must be chosen at a location immediately after the last item of the produced water treatment equipment in or downstream of, a turbulent region, but before dilution.

- **Design of a sample point**: Ideally a sample point is installed on a vertical up-flow pipe with the probe facing upstream. The probe should be of a centre line pitot, which should be made using stainless steel tubing or other suitable material. The pitot should be of at least ½” bore with the edges of the pitot smoothened. If a sample point is fitted into a horizontal pipe, the probe should ideally face upstream.

- **Flow mixing conditions**: This is particularly important if the sample point is installed on a horizontal pipe. Adequate mixing that will result in good dispersion across the pipe cross section needs to be provided prior to the sample point.

- **Isokinetic sampling**: Due to a density difference between oil and water, it is important that the samples are taken iso-kinetically. Isokinetic sampling means that samples are taken where the linear velocity of fluids in the sampling tube (probe) is the same as that in the main pipeline.

- **Other points**: When taking a sample, if the sample point is not in continuous use, then adequate flushing is carried out prior to taking a sample. As a minimum, it is advised that the sample point should be flushed for one minute. For external valving at the sample point, there will normally be a requirement for double block and bleed valving. Also the distance between the sample probe and the sample valving should be kept at a minimum.

Online oil in produced water monitoring is increasingly used for process trending and optimisation. Online monitors may be fitted inline or onto a side-stream depending upon the instrument supplied and or space available. If such an instrument is fitted inline (no by-pass), then it is important that the location chosen must have adequate mixing.

When such a device is fitted onto a by-pass stream, the feed to the monitor should have a dedicated sample connection. A centre line pitot together with isokinetic sampling should be used to ensure samples taken are representative.

Until recently, there has been little information and emphasis on oil in produced water sampling due to the fact that produced water has been considered as a waste stream which generates no revenue. The publication of OSPAR and UK guidance on the subject, for which NEL played a very important role in drafting up, has helped the North Sea oil and gas industry a great deal in terms of a harmonised sampling and measurement approach, to obtain more accurate oil in produced water data.

10. Oil-in-Water Legislation

International Law recognises four categories of water discharges associated with the operation of offshore platforms:

- Platform drainage from machinery space - including generators, fuel tanks and pumps etc
- Offshore processing drainage - open and closed drainage from oil and gas processing activities
- Produced water discharge - separated from production fluids
- Displacement discharge - used and separated from separation storage

The first of these is regulated under the provision of the International Convention for the Prevention of Pollution from Ships 1973, as amended 1978 (MARPOL 73/78). The UK is a signatory to the Convention and implements its provisions through the Merchant Shipping (Prevention of Oil Pollution) Regulations 1983. These regulations, as amended, will require that all installations meet an oil-in-water concentration of 15 ppm for platform drainage discharges, and that they be fitted with the appropriate monitoring and separation technology to ensure compliance. The three remaining discharges are regulated under the provisions of the OSPAR Convention for the protection of the marine environment of the North-East Atlantic, which entered into force on 25 March 1998. This is implemented under UK law by the Oil Pollution Prevention and Control (OPPC) Regulations 2005. These regulations have been designed to encourage offshore operators to continue to reduce the quantities of hydrocarbons discharged during the course of offshore operations. The Regulations give the definition of oil, introduce a permitting system for oil discharges and strengthen powers to inspect and investigate oil discharges.

With regard to the discharge of oil in produced water in the UK, it was stipulated that the monthly average concentration of dispersed oil in produced water did not exceed the 40 mg/l during the period between permit issued on 31 December 2005, and did not exceed 30 mg/l after 1 January 2006. The maximum concentration of dispersed oil in the discharge should not exceed 100 mg/l. In terms of sampling requirements, for installations that discharge no greater than two tonnes of dispersed oil per annum, samples should be collected at least once a month at approximately equal intervals of time. For the installations that discharge more than two tonnes per annum, at least two samples are required to be taken at equal intervals of time. Oil concentration should be determined by a method as prescribed by the UK Department of Energy and Climate Change (DECC) (solvent extraction and GC-FID analysis) or an alternative method approved by DECC.
10.1. History of the OSPAR discharge limit

The Oslo-Paris (OSPAR) Convention was adopted on 22 September 1992, primarily in order to merge the 1972 Oslo Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft and the 1974 Paris Convention for the Prevention of Marine Pollution from Land-based Sources.

Currently the signatories to OSPAR are:

- Belgium
- Denmark
- European Community
- Finland
- France
- Germany
- Iceland
- Ireland
- Luxembourg
- The Netherlands
- Norway
- Portugal
- Spain
- Sweden
- Switzerland
- United Kingdom


10.2. Future legislation

With OSPAR clearly decided on the new reference method for the determination of dispersed oil in produced water, detailed legislation on how to implement the new reference method at both OSPAR and national levels will be made available. Also with the new reference method of having limited practicality for offshore applications, it was clear that an alternative method for both on-line and laboratory bench-top instruments would need to be developed. Acceptance criteria for such alternative methods were developed and made available with the assistance of NEL.

While oil-in-water will remain an important parameter for the management of produced water in the North Sea, a risk based approach is now being established by OSPAR. It is likely that such an approach based on whole effluent assessment will be in place in 2011.
11. Recommended Further Reading

- “OSPAR Recommendation 2001/1 for the management of produced water from Offshore Installations”, www.ospar.org
- OSPAR Agreement 2006-6, “Oil in produced water analysis – guideline on criteria for alternative method acceptance and general guidelines on sample taking and handling”, www.ospar.org
National Measurement System

The National Measurement System delivers world-class measurement for science and technology through these organisations