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D66: A Best Practice Guide for Water Body Monitoring

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Water Monitoring with Screening Methods and Emerging Tools- A Best Practice Guide

STATUS, CONFIDENTIALITY AND ACCESSIBILITY										
Status				Confidentiality					Accessibility	
S0	**Approved/Released**	X		R0	**General public**	X			**Work-space**	
S1	**Reviewed**			R1	**Restricted to SWIFT-WFD members**				**Internet**	X
S2	**Pending for review**			R2	**Restricted to European. Commission**				**Paper**	X
S3	**Draft for comments**									
S4	**Under preparation**									

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Icon Key	Explanation
🕮	More information can be found in a SWIFT-WFD Deliverable. All deliverables can be viewed on the www.swift-wfd.com site.
	Refers to experiences, practical conclusions and situations during the SWIFT-WFD national field case studies.
☑	Best Practice conclusion based on empirical experience carried out during the SWIFT-WFD project.

1. Executive Summary

The growing range of anthropogenic threats to water bodies result in increasing needs for water assessment and management to detect, identify and quantify existing and emerging stressors.

The Water Framework Directive, WFD, (2000/60/EC) aims to maintain, improve, protect and prevent further deterioration of the aquatic environment in the European Community. The success of the implementation of the WFD will rely on the availability of appropriate, comparable and reliable data and therefore, improvements in water quality monitoring technology and methods need to occur and be applied within monitoring programs. New screening methods and emerging techniques (SMETs) can assist in gathering information about the water status and to achieve the aims of the Directive.

The SWIFT-WFD Project was initiated with the goal of investigating how Screening Methods and Emerging Tools may assist the implementation of the Water Framework Directive. As part of the SWIFT project, a Best Practice document has been prepared by collecting all the lessons learnt and conclusions of the SWIFT-WFD project. The purpose of the SWIFT-WFD Best Practice Guide is to help improve water onitoring programmes through the integration and utilisation of Emerging Tools and Methods (SMETs) into water quality monitoring. The Best Practice Guide supports the WFD Article 8 Requirements, which focuses on the establishment of programmes for monitoring the water status.

The Best Practice Guide proposes a general approach due to the diversity of the water bodies across Europe whilst still trying to provide a complete overview of the Screening Methods and Emerging Tools (SMETs) and a practical approach in implementing SMETS.

2. Introduction and Background

Water is a crucial resource for human beings and the environment. We interact with water in a wide variety of ways and uses i.e. agriculture, fishing, industry, domestic, recreational and we influence its sources (i.e. drainage, dams, urban development, flood management, pollution). Water management is vital for water sustainability and for assuring its quantity and quality. The European Water Framework Directive (WFD) is the most important and holistic water legislation to date. Its successful implementation will strongly rely on the availability of sufficient solid and comparable water monitoring data for achieving an effective water management. In this context, the SWIFT-WFD Project involving more than forty institutional, public and private enterprises from several European member states was initiated. The project's goal was to assist the Common Implementation Strategy (CIS) of WFD and to contribute to the further development of the European Union's water monitoring activities through water screening methods. The SWIFT-WFD objectives were to:

1. To review existing Screening Methods and Emerging Tools (SMETs) for chemical water monitoring under WFD.
2. Prepare a set of good practices, including the production of reference material, for screening methods at laboratory scale.
3. To assess the quality of the information obtained from the implementation of these tools in field conditions based on comparison of their output with results collected from other currently used methods. To identify the main constraints concerning their application.
4. Professional training based on the dissemination of results.
5. To develop and to apply robust quality control and validation methods for these methods/tools.
6. Assessments of the socio-economical impact using SMETs.
7. Identify a set of good practices for assessing SMETs and to provide recommendations for the optimal use of SMETs in the WFD.

What does the Best Practice Guide provide?

The WFD requires new types of information concerning the status of each water body. In order to check compliance with the requirements of the WFD and in order to be in a position to report information at an EU level to the European Parliament and the public, the Commission needs Member States to provide them with data and information on the monitoring programmes required by the WFD in a consistent format and in sufficient detail[1]. This means that WFD requires Member States to report water status information in a holistic manner.

The purpose of the SWIFT-WFD Best Practice Guide is to assist in improving the water monitoring programmes by providing new information concerning the water status and monitoring through the selection and utilisation of Screening Methods and Emerging Tools (SMETs). The Best Practice Guide is related to the WFD Article 8 requirements, which focuses on the establishment of programmes for monitoring the water status. It also links to the WFD Guidance CIS documents 7 and 11[2].

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[1] EU CIS: Monitoring-reporting Guidance- V5.0

[2] WFD Guidance CIS documents 7 and 11:
http://ec.europa.eu/environment/water/water-framework/facts_figures/guidance_docs_en.htm

The Best Practice Guide provides and approach for considering SMETs in water monitoring. This approach builds on the experience and lessons learnt during the SWIFT-WFD project case studies. This document is not a comprehensive knowledge resource, but a practical document providing best practice examples and links for further reference.

The Best Practice Guide focuses primarily on water chemical quality monitoring, but certain biological methods, which provide a wider assessment of the status of the aquatic ecosystem status, have also been addressed.

The Best Practice Guide's main goals are:

- To provide a concise overview of SMETs in respect to the WFD information quality requirements;
- To address issues facing the water manager in selecting and utilising suitable SMETs depending on the monitoring purpose for implementing WFD compliant water monitoring programmes;
- To share lessons learnt from the SWIFT-WFD surveys and case studies concerning SMETs.

What is excluded from the Best Practice Guide

The Best Practice Guide summarises in a practical manner the findings and conclusions of the SWIFT-WFD project without going in detail. References are provided to all the SWIFT-WFD documents. The reader may consult the www.swift-wfd.com website for further information. This website is available to the public until August 2008.

Furthermore, it is assumed that the reader is already familiar with WFD and the WFD Common Implementation Strategy (CIS) documents.

Audience addressed

This guide is for water authorities in charge of water policy, monitoring experts involved in implementing WFD, advisers on WFD, applied researchers and technical specialists responsible for water quality monitoring programmes. Enterprises and individual people interested in undertaking a water quality monitoring programme are strongly urged to consult with water quality specialists or resource managers to assist with any individual program development.

The reader must note that the document is based on the activities and results of the SWIFT-WFD project and the work undertaken by the SWIFT-WFD consortium. The practices and views expressed in this document may not in any circumstances be regarded as stating an official position of the European Commission or individual Member States. Neither the European Commission nor any person acting on behalf of the Commission is responsible for the interpretation and use of the information contained herein.

Since different methodologies or techniques measure different pollutant fractions (absorbed and/or dissolved phases, species-specific), and may be field or lab-based, based on spot sampling, on-line, continuous measurements or passive sampling, their applicability to surveillance, operational and investigative monitoring may differ significantly. It is the responsibility of the water monitoring manager(s) to decide which tools/ methods are to be used depending on the particular type of monitoring as this is highly dependent on situation- and site-specific information, morphology, water status and costs.

Structure of the Document

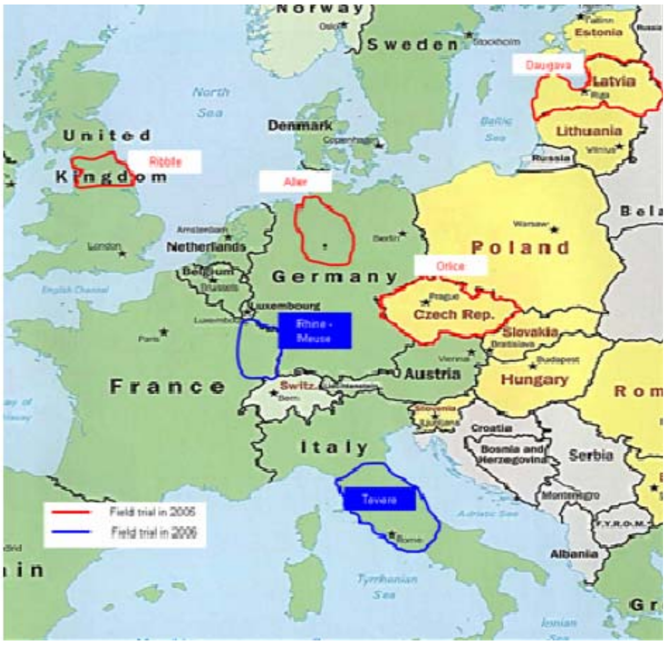
This SWIFT-WFD Best Practice Guide is structured in two main parts:

- Part 1 is an introduction to the SMETs. What are they and what is their function. Particular focus is given to the type of information these SMETs can provide for monitoring the water status under the WFD. References are made to the SWIFT studies and best practices are highlighted.

- Part 2 addresses the issues facing a water manager when selecting and integrating suitable SMETs in new or existing water monitoring programmes for meeting WFD monitoring requirements.

Best Practice Guide Input

The best practices presented in this document are based on the outcomes of the six national field case studies carried out by the SWIFT-WFD project in different river basins: River Ribble (UK), River Aller (Germany), Upper Rhine (France), River Orlice (Czech Republic), River Daugava (Latvia) and River Tevere (Italy). Their purpose was to demonstrate their efficacy in local environments. Moreover, a large scale study was conducted performed in Ejsden (NL) performing river and tank studies for comparison purposes.



Tests in real conditions focused on:

- Basin Pressures: pollutants and anthropogenic pressures;
- Methods' performance, adaptability, robustness, relevance of information, their equivalence to lab methods;
- Their role, function and integration in water monitoring systems.

For more information on these studies please refer to the www.swift-wfd.com site. The adjacent map illustrates the locations of the field case studies.

The SWIFT-WFD website offers also:

- Inventory of existing and currently used or under development SMETs for water quality monitoring;
- Quality control tools for validating methods for water quality monitoring;
- Reports Studies on comparison of biological and chemical methods through inter-laboratory studies;
- Comparison of in-laboratory and in-field biological and chemical methods with classical sampling combined with laboratory-based analyses.

3. Monitoring under the Water Framework Directive – Legal Background

An increasing demand by citizens for cleaner rivers and lakes, groundwater and coastal beaches is one of the main reasons why the European Commission has made water protection one of the priorities of its work in the last 10 years. Therefore, the European Parliament and the Council adopted the WFD Directive, which entered into force in December 2000.

As opposed to earlier water protection, which focused on single types of water, the area covered by this Directive extends to all aquatic systems. Land eco-systems depending on water are also included as well as the protection of the quantity of groundwater.

The basic thinking behind the main objectives of the WFD is that humans can use water as long as the ecological function of the water body is not significantly impaired. Its overall objective is to achieve an effective coordination of water environmental policy and regulation across Europe for:

- Achieving “good status” of all surface, ground and coastal water in the Community by 2015;
- Preventing deterioration and enhance status of aquatic ecosystems, including groundwater;
- Promoting sustainable water use and reduce water pollution.

Monitoring Programmes have a key role in the implementation process of the European Water Framework Directive. They form the basis for developing and controlling effective programmes of measure (Art. 11) for reaching the WFD quality aims. Programmes of measures are activities implemented at catchment level in order to achieve the “good status” of all surface, ground and costal waters by 2015.

The monitoring data compiled in this process should provide information on initial water quality, assess long-term changes from both natural and human pressures, reveal short-term changes where waters are found to be at risk, and lead to measures to rectify the situation where problems hinder compliance with WFD environmental objectives.

3.1. Types of Water Monitoring

It is essential and it is also a requirement that comparable monitoring information is provided by the Member States to develop a river basin management plan based on the Article 13 of WFD.
The three modes of water monitoring specified in the directive’s Annex V are:

1. **Surveillance monitoring** for the assessment of long-term water quality changes and the availability of baseline data on river basins allowing the design and implementation of other types of monitoring. Surveillance monitoring shall be carried out of surface water bodies for providing possibility of sound assessment of the overall water status of the river basin.

2. **Operational monitoring** to provide additional and essential data on water bodies at risk or failing environmental objectives of the WFD and to assess any changes in the status resulting from the programmes of measures.

3. **Investigative monitoring** to assess causes of water quality failures when they are unknown; to evaluate the magnitude and impacts of accidental pollution and where surveillance monitoring indicates that good status is not likely to be achieved and operational monitoring has not yet been established.

3.2. What should be monitored?

Such monitoring programmes have to be implemented by the end of 2006 and shall cover:

- **Surface waters**: the volume and level or rate of flow to the extent relevant the ecological and chemical status and the ecological potential. Annex V, Table 1.1 of the Directive, explicitly defines the quality elements that must be used for the assessment of the ecological status. Quality elements include biological elements and elements supporting the biological elements. These supporting elements can again be grouped into two categories: “hydro-morphological” and “chemical and physicochemical” factors.

- **Groundwater**: the chemical and quantitative water status. The WFD Ground Water Directive (GWD) will ensure that ground water quality is monitored and evaluated across Europe in a harmonised way. The proposed approach to establishing quality criteria is both flexible and iterative, taking account of local characteristics and allowing for further improvements. It represents a proportionate and scientifically sound response to the requirements of the Water Framework Directive.

In 2012, a comprehensive programme of measures to prevent or limit pollution of water, including groundwater, will become operational under the Water Framework Directive. Monitoring results obtained through the application of the proposed Directive on groundwater will be used to design the measures to prevent or limit pollution of groundwater.

3.3. Required Information for Water Monitoring

For effective and efficient water monitoring the WFD requires new holistic information for each water body. For each surveillance and operational monitoring programme and for each surface water category (rivers, lakes, coastal and transitional), the following should be reported on the RBD level based on the WFD[3]:

- Total number of monitoring sites and frequency to be (or expected to be) monitored for each quality element;
- List of Priority Substances and other substances discharged in significant quantities to be monitored;
- Methodology/criteria used to select sites;
- Sampling and analysis methodology to be used for each QE;
- Methodology/criteria used to select monitoring frequencies for each QE;
- Information concerning any monitoring deviation and the number or percentage of sites that is affected (in particular for surveillance monitoring and where possible/applicable also for operational monitoring);
- Information on levels of confidence and precision expected to be achieved from the results of monitoring;
- Information on monitoring requirements for waters used for the abstraction of drinking water in relation to Article 7;
- Information in the case of identification of sub-sites.

Many SMETs may provide information for meeting the above reporting requirements especially in the areas where water variation is high. Besides the necessary “classical” laboratory analyses, SMETs may offer a complementary approach for improving the completeness of monitoring information.

[3] Reporting Sheets for Reporting Monitoring Requirements, Version no.: 5.0

4. Main Facts on the Screening Methods and Emerging Tools

This part of the Best Practice Guide provides a high level overview of the Screening Methods and Emerging Tools:

- what they are,
- modes of use,
- what functions they perform,
- how do they support the WFD monitoring information requirements.

All of the above are supported through empirical information gathered during the national case studies performed by SWIFT-WFD.

4.1. Definition of Screening Methods and Emerging Tools

Screening Methods and Emerging Tools (SMETs) for water quality monitoring may be quantitative, semi-quantitative and qualitative methods.

SMETs main characteristics are, that they:

- offer field measurements, which are on-site, in-situ, or continuous;
- provide fast measurement response;
- are relatively easy to use.

Their main advantages are that they:

- can improve knowledge of water quality (composition variation);
- capture low concentrations of certain pollutants;
- may provide time average measures;
- have fast response times for result assessment;
- provide supplementary information and they may be used as a complement of classical methods;
- may be cost-effective in certain situations than classical chemical methods.

Their main disadvantages are that they:

- are in general not validated as classical screening methods;
- are lacking adaptation on large scale operations;
- are not widely accepted by monitoring experts;
- may not always be cost-effective depending on the monitoring situation.

The Emerging Tools and Methods may be already on the market or in a prototype form. Many of them are already available for industrial use and they have been already in use for quite some time. For example, biosensors are emerging tools, whereas immunoassays have been on the market for many years.

4.2. Mode of Use of Emerging Tools and Methods

The current water quality monitoring practice is primarily based on laboratory analysis of spot samples collected at prescribed periods of time. But water quality monitoring faces temporal and spatial variability. So, in order to achieve a truly representative status of water quality, the emerging methods and tools may support this quest. SMETs are in general easy to use and they allow field measurements at the source, they assess spatial and time water quality evolution and they provide additional information about the biological and chemical quality of the water.

SMETs can be classified in the following categories based on their mode of use, sampling protocol and analysis parameters. Among these methods some can be used in the field and in the laboratory as for example all biological assays. Currently, their main application is in the laboratory but they can be also be used in the field.

There are three major categories of SMETs:

1. **In situ**: where the measurement is made directly in the water body (e.g. dipping a sensor), sampling therefore is not necessary.

2. **On-site**: the measurement is made in the field close to where a sample was taken (e.g. using a test kit or sensor to analyse a bottle sample on the river bank).

3. **Laboratory**: for some methods field sampling is followed by transport to a laboratory for analysis (the laboratory can be any distance from the sampling site).

On-site and Laboratory SMETs require a sampling protocol. The different types of sampling protocols include:

1. **No sampling**: a technique which does not require any sampling.

2. **Spot sampling**: the sample is taken in a very short time.

3. **Passive sampling**: a technique where the sampling device (e.g. passive sampler) is deployed for an extended period of time to obtain time-weighted average pollutant concentrations.

4. **Continuous sampling**: sampling is made, without interruptions (or with very high frequency), throughout an operation or for a predetermined time. For example, water can be pumped from the river to a laboratory close to the intake site where it can be monitored in a flow-through system (e.g. SAMOS).

The table below summarises the above.

Emerging Tool/ Method	Sampling				Analysis/ Mesaurement			Parameters		
	Spot Sampling	Contin uous	Passive Sampling	No Sampling	On Site	Lab	In Situ	Physico/ Chemical	Specific Pollutants	Toxicity
Laboratory based methods (on-line or portable)	✓				✓	✓		✓	✓	✓
		✓			✓	✓		✓	✓	✓
Chemical Test Kits	✓				✓			✓	✓	
		✓			✓			✓	✓	
Elisa/ Immunoassays	✓				✓				✓	
		✓			✓				✓	
Sensors (Probes)	✓				✓			✓	✓	
		✓			✓			✓	✓	
			✓			✓		✓	✓	
				✓			✓	✓	✓	
Biosensors	✓				✓			✓	✓	✓
		✓			✓			✓	✓	✓
			✓			✓		✓	✓	✓
				✓			✓	✓	✓	✓
Bioassays	✓				✓	✓			✓	✓
			✓			✓			✓	✓
Biological Early Warning Systems		✓		✓	✓				✓	·
				✓			✓		✓	✓
Biomarkers	✓					✓			✓	✓
Passive Samplers			✓			✓			✓	✓

Table 1: SMETs Categories and their use as to sampling mode, type of analysis and parameter groups[4]

4.3. Main Categories of Screening Methods and Emerging Tools

This section provides a short overview of the main categories of SMETs. They have been categorised based on their mode of function. Most of the tools mentioned below have been used during the SWIFT-WFD field trials in relation to the national case studies[5]. Each category is first described, followed by a summary table, which provides some SWIFT-WFD study results. Moreover, where possible SWIFT-WFD study observations are described accompanied by lessons learned.

🕮 For further information, please refer to the "SWIFT Toolbox for Chemical and Biological Monitoring". This is a toolbox SMETs for chemical and ecological water status monitoring under the WFD. The toolbox lists commercially available and prototype SMETs with detailed information such as the technology used including the parameters measured, method used for the measurement, type of water it may be used for, sampling time, cost, fraction measured (total/dissolved), model name, institution/company responsible for production/ commercialisation, precision of the measurement, calibration range and maintenance frequency.

[4] Adapted from the SWIFT Policy Brief No 5

[5] D43 Intermediate report of performance evaluation and validation of chemical methods, www.swift-wfd.com

SWIFT Field Trial in Eijsden, Netherlands describes the categories of technologies tested included passive samplers, biological early warning systems, sensors, direct toxicity assays, toxicity profiling, neutron pulse beam spectrometry, immunoassays, in-field test kits. Please refer to the http://www.swift-wfd.com/ for more details on the study, under Work package 3.4; the link to the document describing this study in detail is: http://www.swift-wfd.com/Local/swift/dir/doc/swift_deliverabledoc_47_D25.pdf and D43 (WP5 report on field trials realized in 6 European sites).

4.3.1. Passive Samplers

Function:	Quantification and identification of organic and inorganic pollutants. They are able to measure time-weighted average concentrations of priority pollutants and they are suitable for long-term monitoring.
Principle and Design:	In various design and based various principles. See examples below
Sampling method	In situ (SWIFT used 7 and 14 days)
Detection limits	Provide contamination detection where sometimes spot sampling is below limit of detection (SPMD). When deployed in water DGT measures labile species. Above a low threshold value, the measurement is independent of solution flow.
Market	Commercially available or near-to-market Cost of the passive sampler: 15€ (DGT), Chemcatcher not sold yet Cost of extraction + analysis in the lab must be added
Passive Samplers:	**DGT**  **Chemcatcher**  **POCIS**  **LPDE**  **SPMD**  **ECOSCOP** 
SWIFT Testing	See **Erreur ! Source du renvoi introuvable.** Field testing to assess adaptability and efficacy in real conditions. Comparison with continuous monitoring. Tank experiments were the pollutant concentration is higher than in natural conditions for comparison of a wide number of passive samplers. Spot sampling for analytical comparison. DGT has been deployed in situ in rivers, lakes, estuaries and the deep sea. While classical methods are very precise in quantitative measures lack in providing a holistic status of the water because of the sampling methods used. Even if the spatial distribution of sampling points is dense, monitoring may take place at a certain point in time as in many cases, monthly, and thus it may not provide adequate and representative data. With the application of time integrative sampling can be proven very adequate, especially in water environments where the water varies

	considerably as for example rivers joining the sea. During the Ribble field study, time integrative sampling was performed with Passive Sampling devices, which were exposed at various sites along the estuary selected according to identified pressure points helped in providing a picture of general relative levels of metals, with detection of concentration hotspots or zone where levels or relative levels of metals differ widely. ☑ Time-integrative nature of sampling provides a more complete picture of the water pollution and the confirmation pollutant concentration differences. It's a more thorough method than with spot sampling. ☑ The measurements of metallic compounds (Cu, Zn, Al) by test kits were not satisfying because of the low level of these pollutants in the considered waters. However, in several cases, qualitative information could be considered. Indeed, for Cu and Zn for example, in many samples, qualitative agreements were obtained. Passive samplers, allowing the accumulation of the pollutant, seem a good alternative when level is very low.

SWIFT Study Site	DGT	Chem catchers	Escopes	LDPE	SPDM	POCIS	Monitoring Objectives
River Ribble, UK	Metals		Metal	Non polar compounds	Non polar compounds	Polar compounds	Screening of organic Pollutants Mapping
River Daugava,LV	Metals and phosphorus compounds	Metals					Surveillance monitoring
River Orlice, CZ		Metals					Metal long term monitoring
River Aller,Oker, DL	√	Metals		√	√	√	Long term monitoring

Table 2: Summary of SWIFT study tests with Passive Samplers

4.3.2. Portable instruments based on laboratory techniques

Function	Usually used for the evaluation of a point source pollution plume, for the selection of representative sites and investigative monitoring.
Principle and Design	Optical Sensor. The measurement is direct (no sample treatment) and recordable, the measurement time is rapid (1 min) and gives an estimation of the global parameters.
Sampling method	On site
Detection limits	
Market	On the market - Pastel UV device has been developed by Secomam (€ 6.700 instrumental cost and no reagent costs).
Pastel UV	
SWIFT Testing	See **Erreur ! Source du renvoi introuvable.**

4.3.3. Multiparameter Probe YSI

Function	Continuous Flow Analysers can be used to measure multiple parameters (e.g. physicochemical and nutrients).
Principle and Design	electrochemical or optical sensors
Sampling method	in situ, on site, spatial variability (depth profiles), temporal variability (continuous measurements), surveillance and operational monitoring Direct, simultaneous and continuous measurement (no sample treatment) Measurment time: 10 minutes Calibration time for all parameters: 45 min -1 hour
Detection limits	0.5 mg/l NO3-N, 0.5 mg/l NH4-N, 2 mg/l Cl
Market	Cost of the instrument: 6000 € Cost of the electrodes: 200 – 1300 €
Multiparameter Probe YSI	
SWIFT Testing	See **Erreur ! Source du renvoi introuvable.**

4.3.4. Colometric Kits

Function	The colorimetric-based test are commonly used to monitor Nitrate, ammonium, phosphate. This method is used for the evaluation of point source pollution plume, for the selection of representative sites and for the investigative monitoring. Their response time is 10-20 min.
Principle and Design	Colorimetric and they are usually based on optical (IR, UV absorption) or electrochemical (Ion Selective Electrode). Results are not recordable.
Sampling method	The toxic compounds (acids) contained in the reagent must be treated.
Detection limits	0.2 mg/l NO3-N, 0.004 mg/l NH4-N, 0.02 mg/l PO4-P, 0,2 mg/l Zn, 0,02 mg/l Al
Market	On the market (Merck: instrumental cost €3000-4500 and 85-180 reagent cost).
Merck Colometric Based Kit	
SWIFT Testing	See **Erreur ! Source du renvoi introuvable.** When compared with classical methods, the results obtained for nitrate are in a good agreement for the Merck spectroquant kits over the whole scale of nitrate concentration measured in Latvia (0.5 – 9 mg/l NO3-N) as well as for the Pastel UV but only in the low range of nitrate concentration (the values for the REZ 3 samples was exceptionally high using the PASTEL UV). However, for the Ion Selective Electrode (YSI multiparameter probe) even if the correlation is good enough, there is an overestimation of the concentration of nitrate (10%) as well as a blank value of 1 mg/l NO3-N. This is due to the higher detection limit of the probe for the determination of nitrate in river when compared to the other two methods tested (PASTEL UV and Merck kits). If the data from the Daugava and the lake Stropu in Daugavpils are looked more in details, it appears that the Merck spectroquant kits are not appropriate to detect concentration lower than 0.2 mg/ l of NO3-N. ☑ Indication of global pollutant load (COD, TOC) can be estimated by using a very rapid procedure (Pastel UV). ☑The measurement of nitrates was well performed by using Pastel UV and Merck Kits but Hach kit seems less adapted. The results are comparable between Pastel, Merck and the reference analysis whereas, the comparison with Hach kit shows a wide dispersion of the data. In fact the quantification limit being 0.5 mg/ l of NO3-N, this test kits can only be used as screening (low / detectable concentration) and not as a quantification tools.

4.3.5. Electrochemical Sensors

Function	Electrochemical measurements have been miniaturised into screen-printed electrodes (SPE) that are incorporated in hand-held equipment for on site monitoring of many heavy metals and certain pesticides. Their measurement time is 5-20 min plus 30 min for pre-treatment prior to analysis.
Principle and Design	Voltametry and screen printed electrode (graphite). It's semi quantitative and quantitative. The results are recordable.
Sampling method	Sensitive method but requires calibration and pre-treatment for the prior analysis.
Detection limits	Heavy metals 0.3 mg/ L^{-1} (Pb), 0.5 µg.L^{-1} (Cd), 1 µg.L^{-1} (Cu).
Market	Near-to-market: Palmsens-SPE (Florence University) Instrument cost is €3200 and noreagent cost. The cost of each disposable electrode is below 1 euro.
Palmsens-SPE Kit	
SWIFT Testing	See **Erreur ! Source du renvoi introuvable.**

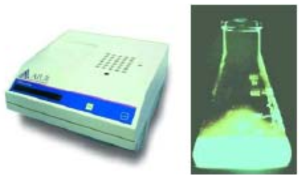
4.3.6. Immunoassays

Function	Commonly used for small molecules such as pesticides. Quantitative, Semi-quantitative and qualitative
Principle and Design	Immunoassay ELISA based test. Immunoassay technology uses antibodies with a highly specific recognition site in their molecular structure allowing specific binding to respective antigens.
Sampling method	Specific, Selectivity, Require materials (vortex, spectrophotometer)
Detection limits	High sensitivity (LoD = 0.05 mg/ L)
Market	On the market. Very low cost €10 reagent.
Atrazine Immunoassays	
SWIFT Testing	See **Erreur ! Source du renvoi introuvable.**

SWIFT Study Site	Pastel UV	Multiparameter probe YSI 6900	Colorimetric test kits	Palmsens	Immuno-assays	Monitoring/ objectives
River Ribble, UK				Zn, Cu, Cd, Pb		Spatial variability (Depth profiles)
River Rezekne, LV	Suspended Mater,TOC, COD, NO3, DBS, BOD	pH, T, conductivity, turbidity, dissolved oxygen) (Cl-, NH4+, NO3-)				Investigative monitoring
River Daugava, LV	√	√	NH4+, NO3-, PO4 3-			Surveillance monitoring
Lake Stropu in Daugavlpis, LV	√	√	√			Acquisition of data and spatial variability (Depth profiles)
River Elbe, Orlice, CZ	√		NH4+, NO3-, PO4 3- Cu, Al, Zn,		Alachlor	Temporal variability Incident detection
River Aller, Oker, DL	√	√	NH4+, NO3,PO43	Zn, Cu, Cd, Pb		Mapping of water bodies. Spatial variability
River Tevere, IT	√		PO4 3-		Atrazine, alachlor, TPH	Field performances evaluation and validation of methods

Table **3** SWIFT Study Summary of the Physico-Chemical Monitoring Devices (Commercialised)

4.3.7. Bioassays

Function	Bio assays are techniques that measure a biological response. This test is used to assess pollution due to general toxicity. Cost differs depending on the tool. Quite short response times: 30 min – 4 hrs.
Principle and Design	Combination of a biological element with a physicochemical detector element in 3 main parts: Sensitive biological element (tissue, microorganisms, organelles, cell receptors, enzymes, antibodies, nucleic acids); Transducer; Detector element (optical piezoelectric, electrochemical, thermometric, magnetic)
Sampling method	
Detection limits	
Market	Vitotox: bioluminescence based test kit (Salmonellathyphimurium). On market. GreenScreen: bioluminescence based test kit (Saccharomyces Cerevisiae) Emerging tool. ToxScreen: microbial based sensor (photobacterium leiognathi) Cost: €900 for instrument and 175 for 100 tests. Other: Microtox® Broad-spectrum acute toxicity – Cytotoxicity (narcosis) Vibrio Fischeri: Response time: 15 - 30 minutes (+ 5 min for cells regeneration), Cost of the instrument: 18 000 €, Cost of reagents: 70 €
Bioassay Examples	**GreenScreen**  **ToxScreen**  **Vibrio Fischeri** 
SWIFT Testing	See Table 4: SWIFT Study Summary of the Bioassay monitoring Devices (commercialized) Correlation between Chemical Analysis and toxicity results of real samples of the Inter-Laboratory Exercises Study based on the bioluminescence inhibition of Vibrio fischeri : The study has shown that the mean values for each real sample using the bioassays using the bioluminescence inhibition of Vibrio fischeri were correlated wit the concentrations of main organic pollutants quantified by classical methods (SPE GC-MS and SPE-LC-MS). Moreover, the absence of false negatives was observed (for more information refer to footnote 7). ☑The rapid toxicity assessment using bioluminescence inhibition of Vibrio fischeri can be used as a rapid tool for screening toxicity caused by organic pollution in water including situations with complex matrices. The comparison of specific SMETs was performed during two major studies. One on Meuse river (Netherlands) and inter-laboratory exercises at European level. Comparison of Specific SMETs during Inter-Laboratory Exercises Study: Toxicity tests based on the bioluminescence inhibition of Vibrio fischeri using five commercially available Bioassays were performed for the first time at a European Scale. The study shows good repeatability and reproducibility of results of samples from a wastewater treatment plant, even when using different SMETs based on the same principle. The different commercial devices tested by different laboratories across Europe showed comparatively good responses. ☑In spite of being a standard test with a high reproducibility level, sources of variability may be introduced when the measurements are carried out in different laboratories. Differences on sample handling may influence strongly

	the final toxicity result when real complex samples are analyzed. In order to minimize the sources of variability handling samples standard protocols specifically designed for different matrix samples must be established. ☑In order to obtain robust and transferable results, it is recommended that a very precise and detailed protocol is provided to laboratories for them to follow exactly the same procedure of handling toxicity samples.

4.3.8. Biological Early Warning System

Function	Biological Early Warning Systems (BEWS) use organisms to provide a rapid toxicological response to the presence of pollutants. The response time depends on the parameters monitored. Biomarker measured at the individual level is ecological relevant if it can describe, explain and predict the effects of pollutants on population and community evolving in their natural environment. Fish has been the most biological marker studied in natural water, mainly for the EROD test, so there are several baseline values and methodology normalised.
Principle and Design	Fish and other organisms like daphnids, bivalves, molluscs are used to provide a rapid warning in response to a deterioration in water quality. Contrary to the population/community biological hierarchies, tests using the individual biological marker are usually easy to standardize and reproducible.
Sampling method	
Detection limits	
Market	LimCo's Multi-species Freshwater Biomonitor (MFB) *is a* semi-continuous biotest based on the test species behaviour, e.g. avoidance, stress respiration or morbidity. The in situ version of the Musselmonitor (Delta Consult, Kapelle, Netherlands) is using mussel shell movements and allows many settings to further tune the instrument to the demands of the user, notably on sensitivity and alarm criteria.
BEWS Examples	**MFB**  **Musselmonitor** 
SWIFT Testing	See Table 4: SWIFT Study Summary of the Bioassay monitoring Devices (commercialized)

The following table summarises the type of test performed during the SWIFT field studies with the Bioassay monitoring commercialised devices.

SWIFT Study Site	Microtox	ToxScreen	Vitotox	Green Screen	Aboatox	BEWS	Monitoring/ objectives
River Ribble, UK	Toxicity (cytotoxicity)	Toxicity (cytotoxicity)	Genotoxicity	Genotoxicity			Map toxicity hotspots Identify Active/Toxic compound/Mixture
River Aller, Oker, D					Heavy metals	Multispecies freshwater biomonitor	Detection and In situ general toxicity
River Tevere, IT and WWTP dowstream	√	√					Performances evaluation of methods

Table 4: SWIFT Study Summary of the Bioassay monitoring Devices (commercialized)

4.4. SMETs Quality Validation

WFD considers water quality management at a River Basin scale but it does not foresee any specific monitoring requirements or recommendations on Quality Assurance. It indicates that all monitoring shall conform to the relevant standards on the national, European or international scale (e.g. developed by CEN and ISO) to ensure the provision of data of an equivalent scientific quality and comparability (see Annex V 1.3.6.).

Quality Control (QC) and Quality Assurance (QA) are integral parts of sound monitoring. The procedures for sampling and treatment of samples prior to analysis have a direct impact on the accuracy of the monitoring results[6]. The method for producing monitoring information, the production of the data and the way of using the data must be quality controlled and assured. All classical monitoring methods are quality assured and validated.

Quality factors among others that should be considered are:
- Performance parameters,
- Method Validation,
- Traceability of results.

Furthermore, the in the CIS guidance document 7 on Monitoring it is recommended but not legally binding that laboratories are accredited according to the principles of EN ISO/IEC-17025, including participation in proficiency testing and analysis of suitable reference materials.

For the majority of SMETs this exercise has not yet been completed and this is one of the main drawbacks that water experts have been pointing out during the SWIFT-WFD country surveys. It has been recognised that the following areas need attention for the extended use of SMETs in the light of the WFD:
- confidence levels regarding SMETs and
- absence of accreditation or recognised protocols for quality control and quality assurance.

D12 and D44 will explain and gives some examples on performances evaluation and confidence levels

[6] Water Framework Directive Document: ENV-COM010307-7

4.5. How SMETs may support the WFD Monitoring Requirements

This section of the Best Practice Guide aims to provide an overview of how SMETs may support the WFD monitoring and information requirements.

The table below prepared by SWIFT-WFD shows how SMETs categories may support the WFD monitoring and information requirements with the functions of SMETs and how they can better support monitoring programmes. See also in Part 2 Table 7 The Functions based on the Water Framework Directive.

The WFD monitoring requirements...	...can be achieved through the following application of screening methods and alternative devices:	Possible screening methods and alternative devices
All surface water monitoring types		
Classify (chemical/biological) status of water bodies WFD Article 8, Annex V 1.3	Adjusting monitoring networks in terms of frequency	Biological Early Warning Systems, chemical/electro-chemical sensors
	More extensive monitoring to account for the expected lack of data (as baseline data cannot be corrected retrospectively)	Chemical/electro-chemical sensors, bioassays
Design future monitoring programmes efficiently and effectively WFD Article 11, Annex III and Annex V 1.3.1	Testing for short-term trends	Passive samplers, Biological Early Water Systems?
	Accounting for the range of natural variability and variability arising from anthropogenic activities of all quality elements	Biomarkers, passive samplers
	Adjusting monitoring networks in terms of density and location (selection of monitoring points)	Biomarkers, chemical/electro-chemical sensors
	Obtain a more acceptable level of risk, precision and confidence	Passive samplers
	Testing water bodies for grouping water bodies into homogeneous groups	Passive samplers, chemical/electro-chemical sensors
Surveillance monitoring (as laid down in Annex V 1.3.1 in the WFD):		
Supplement and validate the impact assessment procedure detailed in Annex II	Testing for long-term trends	Bioassays, biosensors, passive samplers, Biological Early Warning Systems
	Obtain adequate knowledge of the types and range of variability of conditions in water bodies to be monitored	Biomarkers, Biological Early Warning Systems, passive samplers
Assessment of long-term changes in natural conditions, as well as from widespread anthropogenic activities	monitor a sufficient number of sites to provide an adequate description of spatial effects	Chemical/electro-chemical sensors?
	Monitor significant new/emerging pollutants	Bioassays, biosensors,
Assessment of transboundary effects and effects on the sea	Estimate pollutants loads transferred across international boundaries or discharging into sea	Passive samplers, chemical/electro-chemical sensors?
Operational monitoring (as laid down in Annex V 1.3.2 WFD):		
Assess changes in status of those water bodies identified as being at risk in response to the application of measures for improvement or prevention of deterioration	Monitor a sufficiently number of sites at an appropriate frequency to enable the required precision and confidence that result is representative	Biomarkers, chemical/electro-chemical sensors, immunoassays
	Obtain an adequate knowledge of the types and range of variability of conditions in water bodies	Chemical/electro-chemical sensors, immunoassays
	Testing for trends	Passive samplers
	Screening for high peaks in pollution load	Biological Early Warning Systems, bioassays, biosensors
Investigative monitoring (as laid down in Annex V 1.3.3 WFD):		
Assess causes of water bodies failing to achieve environmental objectives	Provide for detection of the full range of potential impacts	Biological Early Warning Systems, bioassays, biosensors, chemical/electro-chemical sensors, immunoassays

The WFD monitoring requirements...	...can be achieved through the following application of screening methods and alternative devices:	Possible screening methods and alternative devices
where the reason for failure has not been identified	Obtain an adequate knowledge of the types and range of variability of conditions in water bodies for identifying location of pressure/source of pollution	Chemical/electro-chemical sensors, immunoassays, passive samplers

Table 5 EMT Categories, their Function and Supported Types of Monitoring

The comparison of the field methods with classical laboratory analysis is an important step in the validation procedure of SMETs. It is not only question of quantitative responses but also the assessment of the experimental procedures, the time needed and the difficulties of field measurement (e.g. environmental conditions, sampling difficulties and variation of the response). SWIFT-WFD has performed several inter-laboratory studies and field studies comparing SMETs with classical methods[7].

During the French field study, a possible use of SMETs as permanent alarm devices was investigated as an adequate choice for upstream control important and vulnerable water resources or installations (such as water drinking withdrawals) that could be threaten by large industrial sites or urban discharges. Biological Early Warning Systems (BEWS), which deliver general toxicity indications or on-line systems monitoring general parameters (pH, T°, conductivity, TOC) would be suitable. Such alarm stations already exists in Huningue (south region of Alsace) for preventing accidental pollution to infiltrate in the Alsatian aquifer. BEWS also exist in drinking water plants (Nancy Water) that withdraw water from river submitted to potential pollution threats. In the wastewater treatment, they are also used at the entry of the station to prevent biology stations' death following toxic discharges. BEWS may be used in similar manner by industries with high water quality requirements[8].

Scenario testing in Latvia (river waters) showed that Pastel UV would be useful for identifying representative monitoring site locations. By using Pastel UV STEMs costs would be lower than with traditional laboratory analysis for obtaining preliminary water quality data[9].

Experimentations in Orlice (river waters) showed that some devices are more adapted than others for the measurement of some parameters (e.g.metals, phosphate, ammonium) and that some devices present limits in their use, especially when the concentration of the analyte is low in the water[10].

☑ Validating SMETs results vs. classical methods should be complemented by precise studies of the analytical performance of these devices in the conditions of field measurement (e.g. variability of the results is possible due to environmental conditions, presence of interferences, problem of conservation of the sample, principle of the SMETs).

☑ Concerning qualitative measurements, it has been shown that field methods provide a rapid monitoring of the water quality. Without taking into account the raw value, the trend of the measurement by a specific device could be a parameter of interest for following water variability.

☑ As a conclusion to this section, a lesson learned during the discussions with stakeholders from the case studies is that SMETs will not replace traditional monitoring methods in the near future. But they can complement existing methods in providing different type of information for making better/cheaper water status decisions and to answer the new WFD requirements.

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[7] D21Correlation between Chemical Analysis and Toxicity Results of the Real Samples of the SWIFT-WFD Inter-Laboratory Exercise on Water Toxicity, www.swift-wfd.com

[8] D64/1/c: Potential uses of Screening Methods and Emerging Tools under the WFD -Perspectives in water quality monitoring– Case study report (France, Alsace)

[9] D64/1: Potential uses of emerging tools under the WFD-Perspectives in water quality monitoring (Riga, Latvia)

[10] D43 Intermediate report of performance evaluation and validation of chemical methods, www.swift-wfd.com

5. Part 2 –Integrating SMETs in Water Monitoring Programmes

Part 2 of the SWIFT-WFD Best Practice Guide addresses the issues facing a water manager when selecting and integrating suitable SMETs in new or existing water monitoring programmes for meeting WFD monitoring requirements. This section is based on the lessons learnt during the SWIFT national field studies.

There are two situations that the implementer may be in:

1. There is already a monitoring programme for the water body;
2. There is no monitoring programme or a very limited one in the specific water body.

In the first situation, the implementer must know the information gaps that the present monitoring programme has in comparison to the WFD requirements. In the second situation, the implementer must consider the nature of the water body and the type of information needed in order to create a sustainable and complying to the WFD monitoring programme.

5.1. Information Needs

Defining the information needs is a key step in identifying fit-for-purpose SMETs. It is also recommended to consider the monitoring programme as a project with resource intensive conditions.

The strengths of the current practice of water monitoring is that it is based on accredited analytical methods, well defined uncertainties on analytical methods, standardised methods for sampling and a lot of historical data. The weaknesses of the current practice though are that the water manager will find only what it is looked for. If the concentrate is on compliance with Environmental Quality Standards (EQSs) measures concentrations only at time of sampling; where there are temporal fluctuations the picture of water quality obtained can be precisely wrong and it is difficult to obtain a map of water quality where there is significant spatial variation.

In conclusion, with the current practice a more representative picture of water quality can be obtained using a number of approaches:

1. Frequent sampling
2. Automatic sequential sampling to provide composite samples over a period of time (usually 24 hours)
3. Continuous, on-line monitoring systems (e.g. the SAMOS system, some sensors, BEWS)
4. Bio-monitoring

SMETs provide complementary information or "better information" to current practice such as:

1. Information in periods between infrequent spot sample;
2. They may increase confidence in spot sampling data;
3. Help identify spot sampling data not true reflection of average conditions;
4. They could save costs associated with wrong decisions (better to be roughly right rather than precisely wrong);
5. Information where levels of contaminants below levels of detection;
6. Indicate where more detailed monitoring needed (true screening);
7. Rapid mapping of an area;
8. Rapid information following accidental spillage.

In order to define the information needs for evaluating the status of the specific water body, the implementer must:

- Have long-term vision for the river basin district. This is mentioned several times in the Water Framework Directive. According to the WFD Annex V, surveillance monitoring programmes must provide information for the assessment of long term changes in natural conditions and the assessment of long term changes resulting from widespread anthropogenic activity[11];

- Taking into account the natural time-lag for the pollution transfers and renewal of resources. Such time-lag should be taken into account in timetables when establishing measures for the achievement of good status of groundwater and reversing any significant and sustained upward trend in the concentration of any pollutant in groundwater.
- Have an understanding of the environmental conditions, economic, political, cultural, and social aspects of water resources planning problems[12].

If a water monitoring programme is already in place, it may be considered what quality elements or parameters the existing monitoring programme covers and does not cover for meeting the WFD requirements. It must be pointed out that the actual definition of status of the water body as a result of the current monitoring programme should be carefully considered with the risk of a wrong classification resulting in a failure *good status*. In order to avoid such wrong assessments the information delivered by the current monitoring programme must be carefully evaluated against the WFD Article 4 requirements.
Use the Rational Table (see Table 6 and Table 7) to pinpoint the information required. The Quality Elements Flowchart (see Figure 1) maybe also used if the current monitoring programme does not focus on certain types of assessments i.e. ecological / biological monitoring.

If a water monitoring programme does not exists, then based on the physical and morphological parameters of the specific water body and after an analysis of its characteristics, it must be considered what information are required to identify the water status based on WFD Article 5. What known and evident water pressures are there? The CIS Guidelines 2 and 3 as well as Appendix 1 can be used for guidance. After identifying the overall information needs, then the Quality Elements Flowchart can be used to identify the SMET categories for consideration and how the identified information gaps may be bridged.

[11] Page 18 of WFD CIS Guidance Document No. 11
[12] Page 22 of WFD CIS Guidance Document No. 11

Quality Elements Flowchart

The flowchart is based on the quality element required to be monitored and it provides the possibilities of assessments and which SMETs can provide "better" information.

The start of the flowchart is in the middle "Quality elements". From there follow the arrows depending on the elements (black boxes) that need to be monitored. After identifying the monitoring method, reference can be made to the "SWIFT Toolbox for Chemical and Biological Monitoring" for a very detailed the SMETs of the specific group.

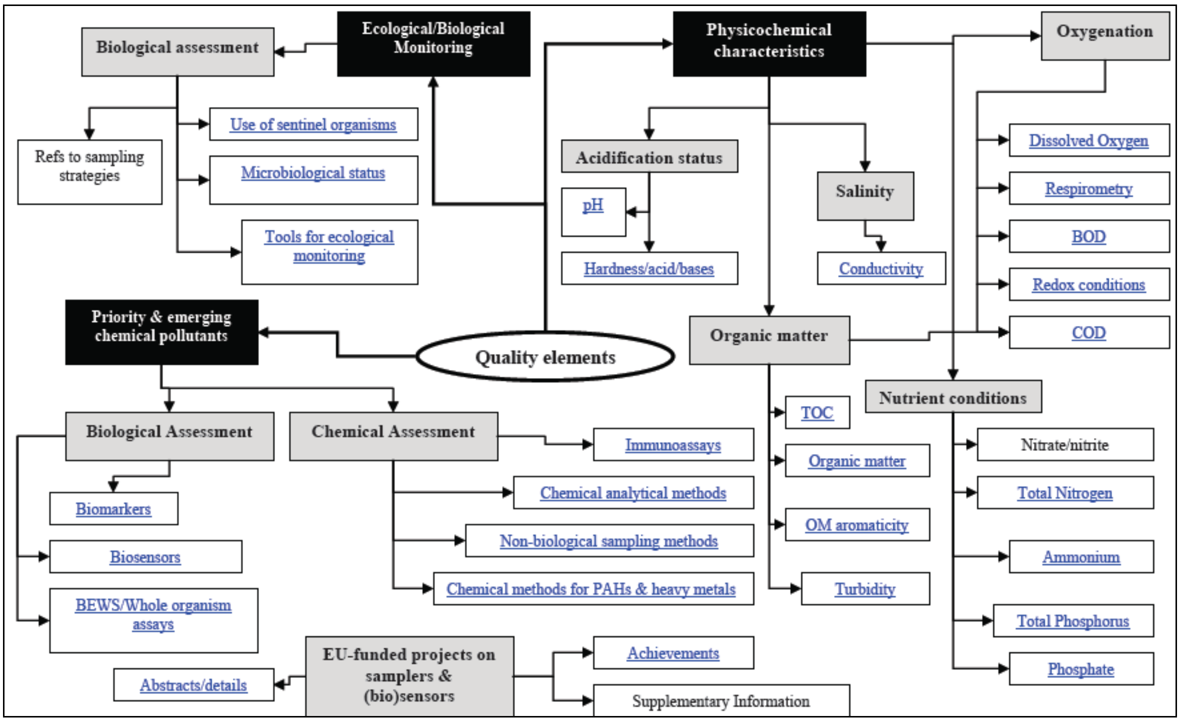

Figure 1: Emerging Methods and Tools can address different monitoring needs depending on the Quality Elements to be monitored[13].

[13] A Toolbox Of Existing And Emerging Methods For Water Monitoring Under The WFD, Deliverable D5, www.swift-wfd.com

5.2. SMETs based on their Function and Information

Depending on the information gaps that should be bridged for meeting WFD requirements, the following reasons may be considered.

In order to select suitable SMETs the implementer should take into account:

- the availability of the marketable or emerging method/ technology;
- that the SMETs include screening methods;
- that these methods may be quantitative, semi-quantitative and qualitative;
- the nature of the field measurement (on-site or in-situ) that must be performed, i.e. temperature variations, water level variations, types of pressures and their location.
- the response time required;
- if the method/ tool should improve frequency of the measurement/monitoring;
- if it is to control water bodies at risk;
- if it is to improve knowledge of water quality (composition variation);
- how they could be used as a complement of classical methods already used at the current situation.

Improved information on water quality can help in:

(i) identifying areas with specific water quality problems and thus the classification of water bodies as at risk or not-at-risk (as relevant to the WFD characterisation);
(ii) better identifying sources of pollution at the origin of a problem; and
(iii) help identifying measures better targeted to problems and sources of pollution.

However, the relevance of enhanced information will depend on whether there is really a need for new information, whether the information obtained effectively (better) describes reality and whether decisions are effectively taken based on information.

If a monitoring programme exists, the implementer must consider how the classical methods are used in the current monitoring programme. If the current water monitoring is performed at specific times and at specific sampling points, then it should be considered if the monitoring may be complimented with a method that can handle variation in the water parameters, i.e. seasonal, accidental pollution in heavy industrial areas.

If no monitoring programme exists, the implementer needs to decide in the type of monitoring that should be performed in order to identify the status of the given water body. Some investigative monitoring is required in order to give an indication of the water status. Once some information has been collected, then types of operational monitoring should be considered.

The Rational Tables

Changes in monitoring systems may be performed following two approaches. The first approach is focusing on certain problematic situations that need resolution. In contrast to the "operational approach" under the field trials performed by the SWIFT-WFD project the functions approach has been developed. SMETs respond to a wide array of water monitoring demands either as a complementary analytical method to existing standard methods or on their own depending on the quality elements required to be identified and analysed. Function in this respect means "the possible role(s) an emerging tool could have in WFD monitoring".

Approach 1: The table below shows the main operational reasons for the use of SMETs for water monitoring in solving certain problematic situations.

Problematic Situation	SMETs Type
1. Standard spot sampling is costly and labour-intensive.	Passive samplers Immunoassays Sensors/biosensors
2. Chemical monitoring based on spot sampling fails to detect and account for temporal variation in pollutant concentrations: It fails to provide a truly representative picture of the extent of contamination.	Passive samplers Continuous Monitoring Equipment (e.g. SAMOS) Certain on-line sensors/ biosensors Biological Early Warning Systems (BEWS)
3. The collection of bottle or spot samples allows the determination of total contaminant concentrations: It fails to account for the bioavailability of pollutants in water (especially for non-polar organics and certain heavy metals).	Biosensors Passive Samplers Immunoassays(in certain circumstances)
4. Certain situations/sites such as drinking water intakes or wastewater effluents require results from monitoring to be obtained rapidly, however, standard spot sample collection, and transport to the laboratory before processing and analysis is a lengthy procedure.	BEWS On-line monitoring systems Sensors or Biosensors
5. Standard chemical monitoring can deliver important information on chemical levels for many pollutants, but it fails to provide any information on the toxicity of water samples.	BEWS Biosensors Biomarkers Whole-organism Bioassays
6. Screening methodologies including sampling and analytical steps need to be implemented by relatively unskilled monitoring personnel.	Immunoassay test kits Passive sampling Bottle sampling Whole-organism bioassays Certain sensors and biosensors
7. At present, water quality monitoring does not rely on ecological and biological monitoring, however, a greater role is needed to assess ecological and biological integrity of water bodies, and use biological information as an early warning for system disturbances.	Biomarkers Ecological monitoring and their combination

Table 6 The Rational Table (From Allan et al., Talanta 2006)

The Functions Tables is grouped by Monitoring Type: All Monitoring Types, Surveillance Monitoring, Operational Monitoring and Investigative Monitoring[14].

The functions, characteristics and principles of the SMETs have been collected in a tabular form in correlation to the water body's monitoring requirements for ease of identification and selection.

No.	Monitoring Requirements	Important Variable	Approach	Type of Water Body	Suitable ETM Function	SMETs Function Support
All Monitoring Types						
A1	Optimal Monitoring (OM): Get the most representative information on water quality by accounting for Temporal Variability of quality elements	Monitoring Network Adjustments for frequency	Temporal Variability of Quality Elements	All Types	Biological Early Warning Systems (BEWS) Chemical / Electrochemical Sensors	Long Term water quality change monitoring and provide early warning for deterioration Allow frequent and rapid determination of chemical concentrations
					Passive Samplers	Concentration Measurements over time
A2	WFD: Validate and supplement risk assessment: Provide representative assessment of overall water status within each catchment and subcatchment areas	Extensive monitoring to supplement for lack of sufficient information	Determine chemical and biological indicators Testing for presence/absence of chemicals	All Types	Chemical / Electrochemical Sensors	Rapid determination of chemical concentrations
					Passive Samplers	Information on presence/absence of chemicals
					Immunoassays	Rapid determination of chemical concentrations
A3	WFD: Assess long-term modifications in natural conditions OM: Provide assurance that water quality trends are representative (avoiding risk of wrong indications due to infrequent spot sampling)	Quality assurance that water status trends are representative	Assure water status through long-term trends. No deterioration takes place	All Types	Passive Samplers	Measurement of time-integrated pollutant level
					Biological Early Warning Systems (BEWS)	Long Term water quality change monitoring and provide early warning for deterioration
A4	WFD: Assess long-term changes resulting from widespread anthropogenic activities. OM: Design monitoring to prove that anthropogenic activities do influence the water status.	Accounting for the range of natural variability and variability due to anthropogenic activities influencing all quality elements.	Identify sites under anthropogenic influences Differentiate between natural and anthropogenic influences.	All Types	Passive Samplers	Information on presence/absence of pollutants
				Surface, coastal and transitional waters	Biomarkers	Identification of contamination sources or hotspots.

[14] see Maton L.; Graveline N. (2006): Synthesis of the national case study reports on the assessment of the likely changes in WFD monitoring costs resulting from the use of low -cost screening devices Deliverable 64/3

No.	Monitoring Requirements	Important Variable	Approach	Type of Water Body	Suitable ETM Function	SMETs Function Support
A5	OM: Quantifying the spatial variability and parameters of quality elements in heterogeneous river basins.	Adjusting monitoring networks in terms of density and location.	Identify spatial variability of quality elements	All Types	Passive Samplers	Detect impact of anthropogenic activity especially for sources with high fluctuation.
			Identify contamination sources or hotspots. Show dispersion or migration of pollution.	Surface, coastal and transitional waters	Biomarkers	Identification of contamination sources or hotspots.
			Identify monitoring points for specific components (biological or chemical)		Chemical / Electrochemical sensors	On-site mapping of an area.
A6	OM: Minimize risk of non-representative monitoring results for avoiding misclassification and inefficient and inappropriate measures.	Obtain an acceptable level of risk, precision and confidence range.	Make sure that all contamination sources are monitored.	All Types	Passive Samplers	Specification of contaminants
			Adjust monitoring in terms of frequency, density and location. Test whether contaminants in water have acute effects on organisms.		Toxicity assays and biocensors	Test for acute effects on organisms.
			Surveillance Monitoring			
S1	WFD: Assessment of long-term changes in natural conditions and changes resulting from anthropogenic activities. OM: Design of monitoring network that provides representative information on water quality and prevents distortion through unrepresentative spot sampling.	Testing for long-term trends	Identify long-term trends in natural conditions. Show impact of pollution sources on these trends.	All Types	Bioassays / biocensors	Mapping of toxicity hotspots
					Passive Samplers	Assess long-term changes and trends in levels of pollutants
					BEWS	Long Term water quality change monitoring and provide early warning for deterioration
S2	WFD: Efficient and effective monitoring programmes. OM: Monitoring programmes with optimal frequency, location and	Obtain adequate knowledge of the types and range of variability conditions of the water bodies to be	Early identification of sources of contamination that could lead to deterioration in water quality. Adjust	Surface, coastal and transitional waters	Biomarker	Early detection of biological imbalance. General ecosystem / organism health status.
				Most types	BEWS	Early warning of changes in water quality at sensitive sites.

No.	Monitoring Requirements	Important Variable	Approach	Type of Water Body	Suitable ETM Function	SMETs Function Support
	density of samples that take into account temporal and spatial variability.	monitored.	monitoring networks in terms of frequency, density and location (A1 and A5).	All Types	Passive samplers	Screening of pollutant for presence or absence
S3	OM: Provide an assessment of the overall surface water status within catchment areas; monitor more waterbodies in heterogeneous river basin districts.	Monitor a sufficient number of sites to provide an adequate description of spatial effects.	Show dispersion/ migration of pollution.		Chemical / Electrochemical Sensors	On-site mapping of an area.
S4	OM: Surveillance monitoring programme that monitors water bodies with "good" water status do not deteriorate over time.	Monitor for new pollutants	Identify new pollutants	All Types	Biosensors/ Bioassays	Detection of "active" or toxic compounds not detected by standard chemical analysis.
S5	WFD: Monitoring should be carried at sites, where the pollutant load transferred across national boarder can be estimated.	Estimate pollutants loads transferred across national boundaries.		Surface (Ground Water)	Passive samplers	Integrated assessment of pollutant load crossing national boundaries.
			Operational Monitoring			
O1	WFD: The number of selected monitoring stations must be sufficient to assess the impact and magnitude of pressures. For waterbodies subject to more than one point source, stations need to represent magnitude and impact of the multiple sources in order to take appropriate measures. For diffuse sources and hydromorphological pressures, more than one station may be necessary in order to show the impact of diffuse pollution. The most sensitive sites must be monitored.		Identify point and diffuse pollution sources and their dispersion or migration. Select monitoring sites, which give representative information on different impacts.	Surface, coastal and transitional waters	Biomarkers	Identification of contamination hotspots/ sources
				All Types	Chemical / Electrochemical Sensors	Rapid determination of chemical concentrations.
				All Types	Immunoassays	Rapid determination of chemical concentrations.
O2	OM: Design operational monitoring programmes that takes into account the variability of conditions in water bodies.	Obtain an adequate knowledge of the types and range of variability in conditions in water bodies.	Identify variability of pressures that are caused by natural conditions. Identify variability of pressures that are caused by anthropogenic pressures. Screening for high peaks of pollution loads.	All Types	Chemical / Electrochemical Sensors	Rapid determination of chemical concentrations.
					Immunoassays	Rapid determination of chemical concentrations.
					BEWS	Toxicity assessment of effluents (e.g. remediation sites)
					Bioassays / biocensors	Mapping of toxicity hotspots
					Passive Samplers	Measurements of time-integrated concentrations of pollutants

No.	Monitoring Requirements	Important Variable	Approach	Type of Water Body	Suitable ETM Function	SMETs Function Support
O3	OM: Obtain confidence on the true status of the water body. Especially when the status is at the boundary good/ moderate.	Testing for trends		All Types	Passive Samplers	Measurements of time-integrated concentrations of pollutants
					BEWS	Show changes in water quality over a long-term and early warning deterioration.
			Investigative Monitoring			
I1	OM: Investigate the reason non compliance with Environmental Objectives in a rapid and representative manner	Provide for detection of the full range of potential impacts	Identification of new/ unknown point/ diffuse sources.	Most types of water	BEWS	Toxicity assessment of effluents (e.g. remediation sites)
				All Types	Bioassays / biocensors	Mapping of toxicity hotspots after pollution accidents
			Identification of accidental pollution.	All Types	Chemical / Electrochemical Sensors	Rapid determination of chemical concentrations.
				All Types	Immunoassays	Rapid determination of chemical concentrations.
I2	OM: Design investigative monitoring programme taking into account the variability of conditions of water bodies.	Obtain an adequate knowledge of the types and range of variability in conditions in water bodies.	Identify variability of pressures that are caused by natural conditions.	All Types	Chemical / Electrochemical Sensors	On-site mapping of an area.
					Immunoassays	On-site mapping of an area.
			Identify variability of pressures that are caused by anthropogenic pressures.		Passive samplers	Screening of pollutant for presence or absence
I3	OM: Design Investigative monitoring that enables adequate design of measures	Assess the magnitude and impact of accidental solution	Identify the sources of pollution	All Types	Passive samplers	Identify sources of pollution
					Chemical / Electrochemical Sensors	On-site mapping of an area.
					Immunoassays	On-site mapping of an area.

Table 7 The Functions based on the Water Framework Directive

5.3. Budget Considerations and Cost Assessment of Potential Use

One of the most important factors that has been identified during the interviews with water monitoring experts has been the limited budget available for water monitoring. Therefore, the cost of implementing a water monitoring method and its application must be considered in relation to the type of monitoring required.

To get an overview of these costs one needs to get information on:

- the monitoring methods which are used at this monitoring station (spot/bottle sampling, bio-monitoring, field test kits, passive samplers, on-line monitoring devices)
- the number of monitoring points at which water quality is measured if the monitoring device is not stationary (e.g. field test kits, passive samplers, bio-monitoring).
- the parameters which are measured with these existing methods (to find out which parameters have to be measured additionally to meet the requirements of the WFD)
- how often the different parameters are measured / intervals of monitoring taking account of the different parameters
- how long the water quality is measured (e.g. a special parameter is measured repeatedly throughout a special period)
- where the sample is analysed (distance to the laboratory) and which elements of cost arise when analysing the sample
- the storage of samples and data
- which elements are fixed costs and which ones are variable costs.

A common cost framework has been used within all SWIFT-WFD case studies. In this framework, both the different costs components (investment, supplies, and personnel) as well as the different tasks within monitoring activities were considered.

Figure 2 gives an overview of these different aspects of costs.

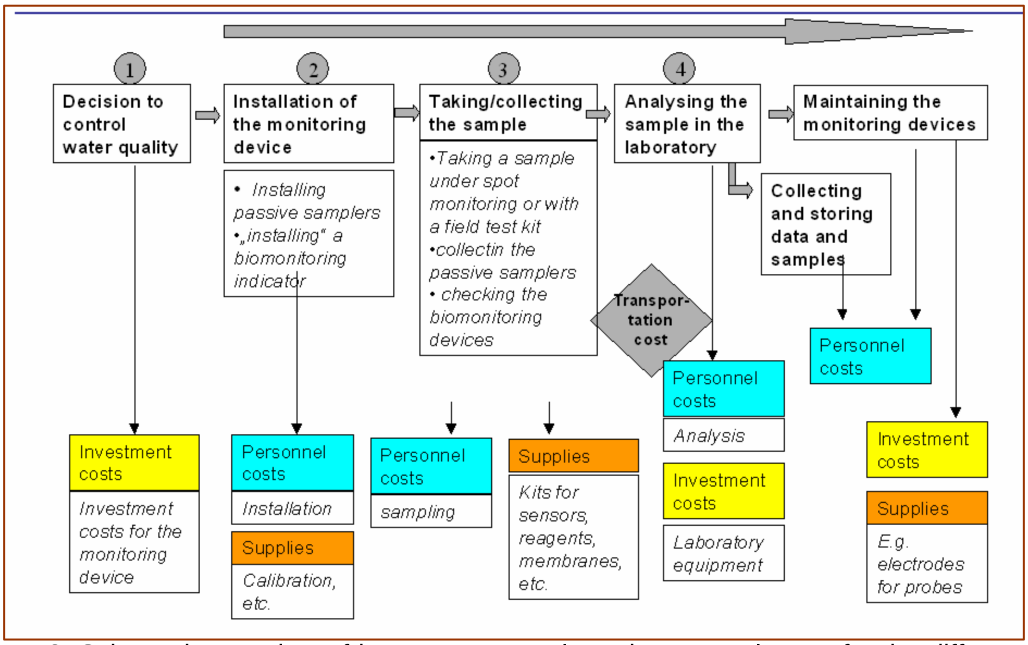

Figure 2: Schematic overview of investment, supply and personnel costs for the different tasks within monitoring networks

The cost components of SMETs have been collected, compiled in the framework of SWIFT testing activities by technical SWIFT experts. For each method, investment costs as well as necessary supplies and time have been analysed and compiled in a comprehensive database.

- **Investment costs of SMETs:** this cost factor includes all necessary equipment with a lifetime of several years. This is the tool itself (e.g. buying a multi-parameter probe) as well as necessary equipment needed for using the tool (e.g. a special heater, stirrer, etc.). In order to derive a cost per analysis, the total investment costs are broken down to an annual cost using an annuity rate with a discount rate of 3%. This allows for the fact, that an equipment is generally used over its whole lifetime until it is fully depreciated;

- **Supply costs:** this includes all supplies that are not reusable. These can be part of the tool itself (e.g. the kits used for test kits, passive sampling bodies) or other supplies that are necessary to use the tool (solutions, filters, membranes). Supply costs are variable costs and arise with each analysis and rise proportionally to the number of analysis.

- **Personnel costs:** Personnel costs arise with all monitoring tasks that require labour input (preparation of sample, sampling, extraction). They are variable costs that arise with each analysis. As personnel costs vary between different countries, they are depicted as necessary time in the general description of cost characteristics.

- and **costs for analysis** (where relevant): the laboratory analysis requires additional investment costs, supplies and personnel. These however vary for different parameters that need to be analysed and between the different case studies. Thus, for simplicity, the cost for analysis has been taken from relevant price lists of laboratories. It has to be noted, that the price list does probably not reflect the "true" cost of analysis as a laboratory has the possibility to lower these costs for larger orders. The cost from the price list might thus lead to a slight over-estimation of costs of analysis;

Examples of cost estimation and comparison of different methods can be found in the respective reports of the SWIFT project's national field studies[15].

5.4. Impact Analysis of SMETs

Impact analysis provides a systematic process for identifying, describing and evaluating the effect of including or not including SMETs in the water-monitoring programme of a particular water body. The main goal of performing an Impact Analysis is to study if the adaptation of an SMETs will provide better and more complete information to guide decisions on water monitoring. Better decisions will have multiple effects, namely on environmental, socio-cultural, economical and political aspects of the stakeholders and the users of the water body.

Performing an impact analysis does not imply that all factors must be analysed. On the contrary, factors must be thought in relation to one another, in order to be able to evaluate at the end their outcome.

It is essential to define the scope of the assessment. As most environmental impacts include a broad number of externalities, it must be decided what should be included (e.g. effect on irrigation, fishing, drinking water, water reserves etc.). Here environmental is used in its broader definition and it includes natural environment, socio-economic and political environments as well.

It is important to decide from the start the time of the assessment. Because water is a resource important to everyone and it is status plays an important environmental role in a very broad aspect with multiple effects, it is very important to define a timeline before defining the alternatives. This timeline will be used to include or exclude of effects if a given monitoring method is used in one way or another (i.e. sampling method, monitoring site(s), include downstream/ upstream locations). In fact, a number of impacts may be immediate (i.e. effect of polluted water on side river channels), whereas there are effects that arise later (i.e. ground water impact). For the long-term impacts, if they are

[15] See Lückge, H. Dworak T. (2006): D52 – Synthesis report on the assessment of the likely changes in WFD monitoring costs resulting from the use of screening methods and emerging tools

included in the timeline, because it is difficult to quantify their value, it is suggested to estimate a value of net-benefit or a type of salvage value. This value can then be included in the cost-benefit analysis.

For assessing the potential benefits of an SMET, it is necessary to identify its impact on the water monitoring. The following flowchart may be used for identifying the major impacts that are required to be included in the impact analysis and as much as possible quantified. Many potential impacts may not be possible to translate into economic values because there are insufficient data. In these cases a qualitative assessment should be used. Following the impact identification process, a list of the impacts that should be considered is prepared.

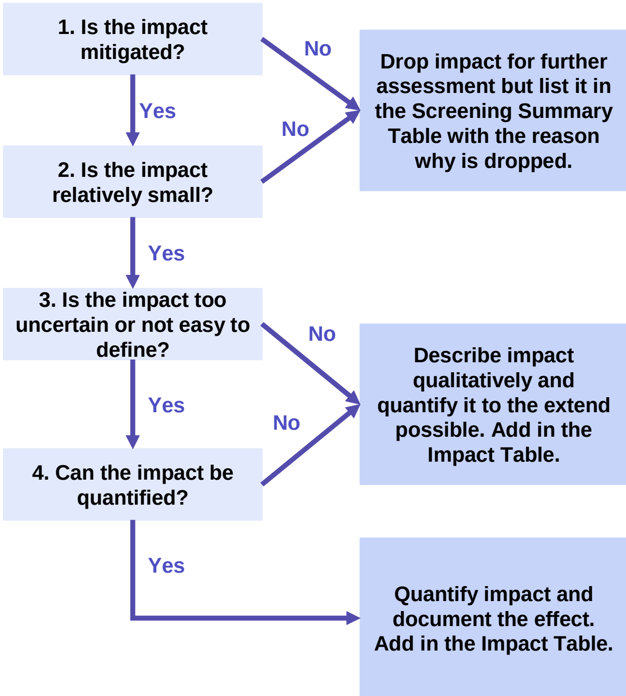

Figure 3 Impact Identification Steps

Applying screening methods and emerging tools can be instrumental in reducing the probability of wrong decision – with benefits potentially balancing the additional costs of applying these methods and tools[16]. The following questions may be considered in the impact identification process.

- Consider what is currently used and the quality of the results provided. Is it sufficient?
- Do better information can be obtained on the state of the water status with SMETS? How and what impact does it have? In what areas?
- Consider the risk if not using SMETs. Is there any? Could they prevent the water status from worsening?
- Evaluate the pros and cons of continuing with the current situation or of considering utilising SMETs.
- Evaluate the potential of SMETs and their cumulative impacts associated with their proposed inclusion in the monitoring programme. Can better information be obtained on the state of the water status?

[16] Which impact of enhanced information on decision making? Food for thought, Nina Graveline, BRGM, SWIFT-WFD Newsletter June 2006.

5.5. Acceptance of SMETs

Introducing and using new monitoring methods and tools must be done through conscious change management. Change is usually opposed due to uncertainty of what results it would bring. Through the SWIFT project's national field studies, surveys have been conducted for analysing the factors of acceptability or non acceptability of SMETs. The acceptability of SMETs was analysed through the utility, the usability and the culture of the organizations. All national surveys[17] showed that there is scepticism in using SMETS. This scepticism is based on the following factors:

- Water managers and laboratories analysing water tend to prefer the classical monitoring methods because they know them and they have been validated.
- The culture of accuracy prevails and thus classical methods are preferred even though they provide accurate measurements but only at a specific point in time.
- If the local market is using classical tools, SMETs distributors tend not to promote them.
- Scepticism concerning the usability of SMETs may be based on climatic conditions as for example extreme cold weather, strong water tides etc.
- Not knowing the possibilities that SMETs offer. Manufacturers and distributors have not explained extensively the possibilities of use of SMETs and how these tools are operating.
- Some SMETs have a high detection limits and for low concentrations of pollutants were not suitable.
- Water experts continue comparing SMETs with the classical methods instead of using them as a complementary tool.
- If the culture of the organization shows low risk and error tolerance, then the classical methods are preferred.
- High starting costs prevent the adaptation of SMETs

The above issues should be addressed as part of the implementation plan of SMETs. The most important factor is educating and training the water experts in the mode of use and utility by showing the possibilities that SMETs may offer as complimentary tool to the classical methods and for getting complete and "better" information on the water status.

[17] SMET Acceptance Report, www.swift-wfd.com