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**Work Package 2**  
**Crowdsourcing technologies for the monitoring of the  
colour, transparency & fluorescence of the sea**

**D2.2: Review of state of the art in affordable  
Fluorescence sensors**

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<b>Abstract</b>	This document provides a review of the state of the art in affordable fluorescence sensors.
<b>Keywords</b>	Excitation, emission, CDOM, phytoplankton

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## 1 Introduction

Basic biological and physical water quality parameters, namely chlorophyll *a* (Chl *a*), which is an algal biomass indicator, total suspended particles and coloured dissolved organic matter (CDOM) can be determined and quantified via their optical properties. Water colour, transparency and fluorescence are main characteristics for a determination of these water constituents, and it is one of the goals in WP2 to define a methodology for robust estimation of these three optical water quality parameters by citizens.

The development of novel technologies, methods and sensors for fluorescence measurements is one sub-objective to address this goal in WP2. Target constituents for fluorescence measurements are CDOM and phytoplankton, as well as hazardous substances that belong to the group of polycyclic aromatic hydrocarbons (PAH).

## 2 Objectives

A variety of in situ fluorescence sensors exist for the measurement of water quality parameters and hazardous substances in the marine environment (Moore et al., 2009, Zielinski et al. 2009). The main objective of this document is to review the state-of-the-art in low cost fluorescence sensors that can be used in the prototype design of the smart sensor to be used by citizens, as well as for use of high end sensors via a Bluetooth connection between mobile phones and fluorescence sensors. The description of sensors includes state of the art in light excitation and detection devices as well as interfaces and housing extensions for sample containers. This overview on affordable fluorescence sensors is linked to Task 2.7: *Development and adaptation of fluorescence sensors for smart phone environments* and D2.7: *Prototype of fluorescence sensory system for mobile applications*. Included are exclusively commercially available, easily portable and robust devices, which are manufactured for in situ fluorescence measurements. As compared to specified fluorescence equipment for use in laboratories, the affordable sensors are listed in three ranges.

## 3 State of the art of low cost fluorescence sensors

### 3.1 Specifications of fluorometric measurements of CDOM and phytoplankton

Fluorescence characteristics of water constituents are retrieved by means of the excitation of molecules with light. Excitation can be through a natural source such as sun-light (e.g. sun induced fluorescence in the case of algal Chl *a*), or with an external light source. The use of an external light source allows the selection of specific wavelengths for excitation and the operation during darkness. The strength of a fluorescence signal for a certain target constituent is dependent on the wavelengths, at which the excitation is conducted and at which the emission is captured.

- CDOM and PAH fluorescence is induced via excitation in the in the ultra-violet (UV) spectral region, whereas emission is in the blue. Distinct excitation/emission wavelengths for CDOM are: 260/400-460 nm and 320-360/420-460 (humic like) and 290-310 /370-410 (marine humic-like) (Coble et al., 2007).
- For phytoplankton biomass, in vivo (intact cell) Chl *a* fluorescence is derived from emissions around 685 nm (deep red) (see Govindjee, 1995). From natural excitation (sun induced), Chl *a* fluorescence is visible at this wavelength, a feature that is commonly captured in remote sensing applications (Hu et al., 2005). Furthermore, different excitation spectra with external light sources can be used for the differentiation of Chl *a*, or more specific: algal 'spectral groups' based on typical pigment signatures, e.g. phycobilins for cyanobacteria. These groups are clustered in a green (Chlorophyta), blue (cyanobacteria), brown (Heterokontophyta, Haptophyta, Dinophyta); and mixed group (Cryptophyta) that are derived with excitation at 450, 525, 570, 590 and 610 nm, and measured at an emission at 680 nm (Beutler et al, 2002). Especially dinoflagellates and cyanobacteria (also known as blue-green algae) include species that are able to produce potent phycotoxins and form harmful algal blooms.

### 3.2 Description of commercially available fluorescence sensors

In the following, commercially available fluorescence sensors for the retrieval of target water constituents are listed in price ranges from 1000-5000 €, 5,000-10,000 €, and >10,000 €. There are no portable and robust in situ fluorosensors available below 1000 € (Table 1), whereas several manufacturers produce instruments in the range up to 5000 €. Details of listed sensors, including state of the art in light excitation and detection devices as well as interfaces and housing extensions for sample containers, are provided in the following tables (comprised in table 2).

In all listed devices, wavelength ranges for excitation and emission of the different water parameters are determined by the use of highly specific dichromatic filters. In summary, characteristics of state of the art in light excitation, detection, and housing (e.g. the possibility to include a flow-through cuvette) are given (Table 3). For light excitation, the majority of the listed devices (10) use LEDs, whereas only (2) have an inbuilt xenon flash and none operates with a laser. Detection is in most cases with a photodiode (10), only in two cases with a photomultiplier. There are several (10) external housings available for flow through systems but not types of cuvette holders for these fluorescence sensors.

There is, however, one option to combine the Fluoro-Probe of bbe-moldaenke, which is in the highest price range of > 10,000 € with a cuvette in a workstation. Yet, such a device, comparable to e.g. the ProPS (TriOS) (Figure 1) for instruments in the lower price ranges would be a large surplus within Citclops linking between both fluorescence sensor approaches.

**Table 1: Price ranges for commercially available portable and robust fluorescence sensors for the in situ retrieval of relevant water constituents.**

Price Range	TriOS	Wetlabs	ChelSea	SeaPoint	YSI	BBE-moldaenke	Turner
< 1,000 EUR	No sensors available						
1,000 – 5,000 €	micro Flu	ECO FL, WETStar*	UniLux, TriLux	Chlorophyll Fluorometer			C7 Chl a C7 CDOM
5,000 – 10,000 €	enviroFlu- HC		UviLux		EXO1-Water-Quality-Sonde 600OMS V2		
> 10.000 €		ECO FL, WETStar**				FluoroProbe-1000m	

\*simplest configuration; \*\* detailed configuration (battery, high depth, etc.)

No price available for ChelSea: TurbiLux, Aqua Tracka III Fluorometer, Fast Ocean Fluorometer and Cyclops Integrator subm. Flu

**Table 2: Commercially available fluorescence sensors for the in situ retrieval of relevant water constituents.**

manufacturer	product name	electric		measurements		abilities
Wetlabs <a href="http://www.wetlabs.com">http://www.wetlabs.com</a>	ECO FL  <a href="http://www.wetlabs.com/eco-fl">http://www.wetlabs.com/eco-fl</a>	Digital output resolution	14 bit	CDOM,	EX/EM: 370/460 nm	<ul style="list-style-type: none"> <li>Ships with ECOView Host software, Analogue and digital output</li> <li>Analogue scaling to maximize analogue resolution</li> <li>Optional integrated Bio-wiper™ and/or copper faceplate for antifouling</li> <li>Optional internal batteries and memory; over 100,000 samples</li> <li>Full ocean depth model available</li> </ul>
		Analogue output signal	0-5 V	Chl a	EX/EM: 470/695 nm	
		Input Voltage	7-15 VDC	Uranine	EX/EM: 470/530 nm	
		Current, typical	50 mA	(Fluorescein) & Rhodamine	EX/EM: 540/570 nm	
		Current, sleep	140 µA			
		Data memory	108,000 samples			
		Sample rate	8 Hz	Phycoerythrin	EX/EM: 540/570 nm	

		Depth	600 - 6000m	Phycocyanin	EX/EM: 630/680 nm	
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manufacturer	product name	electric		measurements		abilities	
Wetlabs <a href="http://www.wetlabs.com">http://www.wetlabs.com</a>	WETStar	Digital output	0–4095 counts	CDOM,	EX/EM: 370/460 nm	<ul style="list-style-type: none"> <li>• Miniature, low cost, low power optical instruments provide comparable performance to other fluorometers at a fraction of their cost, power requirements, and size.</li> <li>• Novel optical flow tube design,</li> <li>• Pump through and flow-through operation.</li> <li>• Easily mated with existing CTD packages and available with digital output.</li> </ul>	
	<a href="http://www.wetlabs.com/content/wetstar">http://www.wetlabs.com/content/wetstar</a>			Chl a	EX/EM: 460/695 nm		
		Analogue output signal	0-5 V		Uranine		EX/EM: 485/530 nm
		Input Voltage	7-15 VDC		(Fluorescein) & Rhodamine		EX/EM: 470/590 nm
		Current draw, digital	80 mA				
		Current draw, Analogue	40 mA		Phycoerythrin		EX/EM: 525/575 nm
		Response digital	0.125s				
		Response Analogue	0.17s				
		Depth	600m				

manufacturer	product name	electric		measurements		abilities
TriOS www.trios.de	microFlu	Digital output	n/A	CDOM,	460nm peak 100nm FWHM	<ul style="list-style-type: none"> <li>• High sensitivity</li> <li>• Wide operation range</li> <li>• Fast acquisition</li> <li>• Electronic daylight compensation</li> <li>• Miniaturized design</li> <li>• Low power consumption</li> <li>• Low cost easy to handle RS232 interface</li> <li>• Additional analogue output</li> <li>• Automatic sampling after power on</li> <li>• Fully RS232 controllable</li> <li>• Easy to use Windows software</li> <li>• RS232 auto power down if not connected / used controllable with TriBox2, <u>Pocket-MSDA handheld software</u>, PC (MSDA_XE)</li> </ul>
	microFlu-blue microFlu-chl-A microFlu-CDOM expansion: microFlu-DS  <a href="http://www.trios.de/index.php?option=com_content&amp;view=section&amp;layout=trios&amp;id=4&amp;Itemid=29&amp;lang=en">http://www.trios.de/index.php?option=com_content&amp;view=section&amp;layout=trios&amp;id=4&amp;Itemid=29&amp;lang=en</a>	Analogue output signal	0-5 V	Chl a	685nm peak 20nm FWHM	
			Input Voltage	5-15 VDC	Phycocyanin fluorescence	
		Current draw, digital		n/A		
		Current draw, Analogue	n/A			
		Response digital	n/A			
		Response Analogue	n/A			
		Depth	500-6000m			



manufacturer	product name	electric		measurements		abilities
TriOS www.trios.de	enviroFlu-HC	Digital output	n/A	UV photodiode	360 nm peak 50nm FWHM	<b>Features:</b> <ul style="list-style-type: none"> <li>• max. depth rating 6,000m</li> <li>• RS232 interface</li> <li>• 0..5VDC interface</li> <li>• 4..20mA interface</li> <li>• high sensitivity</li> <li>• low power consumption</li> <li>• high quality materials</li> <li>• fast acquisition</li> <li>• RS232 auto power down, if not connected / used</li> <li>• newest anti fouling technology with nanocoating</li> </ul> <b>Applications:</b> <ul style="list-style-type: none"> <li>• pipeline leakage detection</li> <li>• PAH tracing</li> <li>• ROVs and AUVs</li> <li>• petro industry</li> <li>• deep-sea drilling</li> </ul>
	<a href="http://www.trios.de/index.php?option=com_content&amp;view=article&amp;id=230&amp;catid=81&amp;Itemid=107&amp;lang=en">http://www.trios.de/index.php?option=com_content&amp;view=article&amp;id=230&amp;catid=81&amp;Itemid=107&amp;lang=en</a>	Analogue output signal	0-5 V	PAH (polycyclic aromatic hydrocarbons) EPA-PAH Diesel Crude oil Naphthalene Acenaphten Fluoren Phenanthren Fluoranthene Pyrene Benzo(a)anthracen Chrysene Phenol Fuel oil Marine Diesel Oil (MDO) Marine Gas Oil (MGO)		
		Input Voltage	12-26 VDC			
		Current draw	4..20mA			
		Response digital	n/A			
		Response Analogue	n/A			
		depth	6000m			

manufacturer	product name	electric		measurements		abilities	
Chelsea <a href="http://www.chelsea.co.uk/">http://www.chelsea.co.uk/</a>	Unilux	Digital output	n/A			<b>Applications</b> <ul style="list-style-type: none"> <li>In-situ chlorophyll &amp; algae class studies Environment monitoring</li> <li>Dye tracing</li> <li>Particulate studies</li> <li>Process control</li> <li>Moored, profiled, towed or ROV / AUV platforms</li> </ul> <b>Features</b> <ul style="list-style-type: none"> <li>Miniature, low cost single wavelength fluorometer</li> <li>Range of wavelength available</li> <li>Digital output in engineering units</li> <li>Additional analogue output as standard</li> <li>User selectable sampling rate, 0.1Hz - 3Hz</li> <li>Low power consumption</li> <li>Internal referencing of excitation intensity</li> <li>Rejection of ambient daylight</li> <li>Low noise, high sensitivity</li> <li>Low turbidity breakthrough</li> <li>User adjustable dynamic range</li> <li>RS232 &amp; analogue output (or RS422 option)</li> </ul>	
	<a href="http://www.chelsea.co.uk/allproduct/marine/fluorometers/unilux-fluorometer">http://www.chelsea.co.uk/allproduct/marine/fluorometers/unilux-fluorometer</a>				Chl a		n/A
		Output signal	0-5 V		Fluoroscein		n/A
		Input Voltage	11-25 VDC		Rhodamine WT		n/A
		Current draw, digital	n/A		Phycoerythrin		n/A
		Current draw, Analogue	n/A		Phycocyanin		n/A
		Response digital	n/A		Turbidity		n/A
		Response Analogue	n/A				
		Depth	600m				

manufacturer	product name	electric		measurements		abilities	
Chelsea <a href="http://www.chelsea.co.uk/">http://www.chelsea.co.uk/</a>	TriLux	Digital output	n/A	Combines 3 measurements of:		<b>Applications</b> <ul style="list-style-type: none"> <li>Algal class studies</li> <li>Chl a monitoring</li> <li>Environmental monitoring</li> <li>Cell culture monitoring</li> <li>Particulate studies</li> <li>Moored, profiled, towed or ROV / AUV platforms</li> </ul> <b>Features</b> <ul style="list-style-type: none"> <li>Digital output in engineering units</li> <li>Additional Analogue output as standard</li> <li>User selectable sampling rate, 0.1Hz-3Hz</li> <li>Low power consumption</li> <li>Internal referencing of excitation intensity</li> <li>Rejection of ambient daylight</li> <li>Low Noise, high sensitivity</li> <li>Low turbidity breakthrough</li> <li>RS232 &amp; analogue output (or RS422 option)</li> <li>User adjustable dynamic range</li> </ul>	
	<a href="http://www.chelsea.co.uk/allproduct/marine/fluorometers/trilux-fluorometer">http://www.chelsea.co.uk/allproduct/marine/fluorometers/trilux-fluorometer</a>				Chl a		470nm
		Analogue output signal	0-5 V		Phycocerythrin		530nm
		Input Voltage	11-25 VDC		Phycocyanin		610nm
		Current draw, digital	n/A				
		Current draw, Analogue	n/A		Turbidity		685nm
		Response digital	n/A				
		Response Analogue	n/A				
		Depth	600 m				

manufacturer	product name	electric		measurements		abilities
Chelsea <a href="http://www.chelsea.co.uk/">http://www.chelsea.co.uk/</a>	UviLux	Digital output	n/A	CDOM	EX/EM: 255/450 nm	<b>Applications</b> <ul style="list-style-type: none"> <li>• In-situ polyaromatic hydrocarbon detection</li> <li>• Crude and refined oil spill monitoring</li> <li>• Hydrocarbon detection</li> <li>• Sub-sea pipeline leak detection</li> <li>• Airport apron pollution runoff</li> <li>• Coastal pollution monitoring</li> <li>• Biogeochemical oceanography</li> <li>• Environmental impact assessment</li> <li>• Biomass indicator studies (CDOM/Tryptophan)</li> <li>• Waste/recycled water quality monitoring</li> <li>• Effluent detection</li> <li>• Towed, moored or ROV deployments</li> </ul> <b>Features:</b> <ul style="list-style-type: none"> <li>• Additional analogue output as standard User selectable sampling rate, 0.1Hz - 3Hz</li> <li>• Low turbidity breakthrough</li> <li>• RS232 &amp; analogue output (or RS422 option)</li> </ul>
	<a href="http://www.chelsea.co.uk/allproduct/environmentalfresh-water/fluorometers/uvilux-fluorometer">http://www.chelsea.co.uk/allproduct/environmentalfresh-water/fluorometers/uvilux-fluorometer</a>	Analogue output signal	0-5 V	Polyaromatic Hydrocarbon	EX/EM: 255/365 NM	
	Input Voltage	9-36 VDC	Tryptophan	EX/EM: 280/365 nm		
	Current draw, digital	n/A				
	Current draw, Analogue	n/A				
	Response digital	n/A				
	Response Analogue	n/A				
	Depth	600 m				

manufacturer	product name	electric		measurements	abilities
Chelsea <a href="http://www.chelsea.co.uk/">http://www.chelsea.co.uk/</a>	Turbilux	Digital output	n/A	Turbidity, particle studies/gravimetric analysis Industrial feed meter indicators Environmental impact assessment Waste/recycled water quality monitoring Effluent detection EX/EM: 860/860 nm	Applications <ul style="list-style-type: none"> <li>• Turbidity, particle studies/gravimetric analysis</li> <li>• Process control</li> <li>• Reservoir monitoring</li> <li>• Profiling on CTDs</li> <li>• Coastal pollution monitoring</li> <li>• Biogeochemical oceanography</li> <li>• Environmental impact assessment</li> <li>• Waste/recycled water quality monitoring</li> <li>• Effluent detection</li> <li>• Towed, moored or ROV deployments</li> </ul> Features: <ul style="list-style-type: none"> <li>• Digital output in engineering units</li> <li>• Additional analogue output as standard</li> <li>• User selectable sampling rate, 0.1Hz - 3Hz</li> <li>• RS232 &amp; analogue output (or RS422=)</li> <li>• Acetal C housing</li> <li>• SD1-12 output option</li> </ul>
	<a href="http://www.chelsea.co.uk/allproduct/marine/fluorometers/turbilux-fluorometer">http://www.chelsea.co.uk/allproduct/marine/fluorometers/turbilux-fluorometer</a>	Analogue output signal	0-5 V		
	Input Voltage	9-36 VDC			
	Current draw, digital	n/A			
	Current draw, Analogue	n/A			
	Response digital	n/A			
	Response Analogue	n/A			
	Depth	600 m			

manufacturer	product name	electric		measurements		abilities
Chelsea <a href="http://www.chelsea.co.uk/">http://www.chelsea.co.uk/</a>	AquaTracka III <a href="http://www.chelsea.co.uk/allproduct/marine/fluorometers/aquatracka-iii-fluorometer">http://www.chelsea.co.uk/allproduct/marine/fluorometers/aquatracka-iii-fluorometer</a>	Digital output	n/A	Chl a	EX/EM: 430/685 nm	Applications: <ul style="list-style-type: none"> <li>• Chl a and other fluorophor detection</li> <li>• Rhodamine and fluorescein dye tracing</li> <li>• Particle concentration by light scattering</li> <li>• Profiling, towed, moored or ROV deployment</li> <li>• Pollution monitoring</li> <li>• Bio-geo chemical oceanography</li> <li>• Hydrothermal vent studies</li> </ul> Features: <ul style="list-style-type: none"> <li>• High sensitivity</li> <li>• Wide spectral waveband available 400nm to 800nm</li> <li>• Long term calibration stability</li> <li>• High ambient light rejection</li> <li>• High signal to noise ratio</li> <li>• Single 4 decade logarithmic range</li> <li>• Dual-beam radiometric system</li> <li>• Interface to CTDs and data loggers</li> <li>• Titanium pressure housing</li> </ul>
		Analogue output signal	0-4 V	Rhodamine	EX/EM: 500/590 nm	
		Input Voltage	9-18 VDC	Fluoroscein	EX/EM: 485/530 nm	
		Current draw, digital	n/A	Turbidity	EX/EM 440/440 nm	
		Current draw, Analogue	n/A			
		Response digital	n/A			
		Response Analogue	n/A			
		Depth	6000 m			

manufacturer	product name	electric		measurements	abilities
Chelsea <a href="http://www.chelsea.co.uk/">http://www.chelsea.co.uk/</a>	Fast Ocean	Digital output	n/A	Phytoplankton photosynthesis and gross primary production. Ex: 450, 530 and 624 nm	<b>Applications</b> <ul style="list-style-type: none"> <li>• In situ estimation of gross primary productivity (GPP): With fully configured FastOcean-based system</li> <li>• In vitro estimation of GPP: By combining FastOcean with the FastAct laboratory system</li> <li>• Sea-truthing of satellite data: GPP and light absorption</li> <li>• Bloom detection: Employing three independently adjustable excitation wavelengths</li> <li>• Toxicant detection</li> <li>• Real time monitoring</li> </ul> <b>Features</b> <ul style="list-style-type: none"> <li>• Third generation FRRf3: Smaller, lighter and more capable than its predecessors, with integrated pressure sensor</li> <li>• Three excitation wavelengths: Independently controlled LED arrays for fluorescence excitation centred at 450, 530 and 624 nm</li> <li>• Internal data storage and full integration with the FastPro8 GUI</li> </ul>
	<a href="http://www.chelsea.co.uk/allproduct/marine/fluorometers/fastocean-system/fastocean-fluorometer">http://www.chelsea.co.uk/allproduct/marine/fluorometers/fastocean-system/fastocean-fluorometer</a>	Analogue output signal	n/A		
		Input Voltage	n/A		
		Current draw, digital	n/A		
		Current draw, Analogue	n/A		
		Response digital	n/A		
		Response Analogue	n/A		
		Depth	n/A		

manufacturer	product name	electric		measurements		abilities
Seapoint <a href="http://www.seapoint.com">http://www.seapoint.com</a>	Seapoint Chlorophyll Fluorometer  <a href="http://www.seapoint.com/scf.htm">http://www.seapoint.com/scf.htm</a>	Digital output	n/A	Chlorophyll -a	470- 685nm CWL, 30nm fwhm	<b>Features:</b> <ul style="list-style-type: none"> <li>• Good ambient light rejection</li> <li>• Linear output with chlorophyll concentration</li> <li>• Four programmable ranges</li> <li>• Low offset voltage does not require adjustment</li> <li>• Pin compatible with Seapoint Turbidity Meter and</li> <li>• Seapoint Rhodamine Fluorometer</li> <li>• Interfaces easily with data acquisition systems</li> <li>• Rugged, corrosion-free materials</li> </ul> <b>Applications:</b> <ul style="list-style-type: none"> <li>• Profiling, Moored, Towed, or In-Line Measurements</li> <li>• Water Quality Monitoring</li> <li>• Biomass and Nutrient Studies</li> <li>• Environmental Stress Tolerances</li> <li>• Lake and Watershed monitoring</li> <li>• Ocean Science and Research</li> </ul>
		Analogue output signal	0-5 V			
		Input Voltage	8-20 VDC			
		Current draw	15-27mA			
		Response	0.1s			
		Depth	6000m			



manufacturer	product name	electric		measurements		abilities
Turner <a href="http://www.turnerdesigns.com/">http://www.turnerdesigns.com/</a>	C3™ Submersible Fluorometer (this is the multi-parameter instrument, the fluorometers for Chl a and CDOM are included as C7 in Table 1) <a href="http://www.turnerdesigns.com/products/submersible-fluorometer/c3-submersible-fluorometer">http://www.turnerdesigns.com/products/submersible-fluorometer/c3-submersible-fluorometer</a>	Power Supply	8-30 V By 5 Watts	CDOM/FDOM		<ul style="list-style-type: none"> <li>• One, Two or Three Optical Sensors</li> <li>• Temperature Sensor Included</li> <li>• Optional Depth Sensor</li> <li>• Optional 3-Brush Mechanical Wiper</li> <li>• All Plastic Housing</li> <li>• Robust Memory – Over 64,000 Data Lines.</li> <li>• Easy to Use Software with Data Management Capabilities</li> <li>• Optional C-ray Deployment Body Enables Horizontal Towing C-FINS Integration with ArcGIS®</li> <li>• Integrate with VideoRay Pro 4 Submersible ROV</li> </ul>
		Max. current draw	12 Volt			
		operational	200 mA	Chl a	EX/EM: 430/685 nm	
		Sleep mode	3 mA	Fluorescein Dye		
				Oil		
				Phycocyanin		
		Depth	600m	Phycoerythrin		
				PTSA Dye		
Rhodamine Dye						
Tryptophan						

manufacturer	product name	electric		measurements		abilities
Turner <a href="http://www.turnerdesigns.com/">http://www.turnerdesigns.com/</a>	The Cyclops Integrator™  <a href="http://www.turnerdesigns.com/products/submersible-fluorometer/cyclops-integrator-submersible-fluorometer">http://www.turnerdesigns.com/products/submersible-fluorometer/cyclops-integrator-submersible-fluorometer</a>	Power Supply	8-30 V By 3 Watts	CDOM/FDO M		<ul style="list-style-type: none"> <li>• One, Two or Three Optical Sensors</li> <li>• Customer-Specified Packaging</li> <li>• Low Power Requirements</li> <li>• Quick Power Up - 3 Seconds to 1st Data Output</li> <li>• Simple Data Integration</li> </ul>
		Max. current draw	12 Volt	Chl a	EX/EM: 430/685 nm	
		Operational	100 mA	Fluorescein		
				Dye		
				Oil		
		Sleep mode	n/A	Phycocyanin		
				Phycoerythrin PTSA Dye		
		Rhodamine Dye		Tryptophan		
		Depth	600 – 6000m			

manufacturer	product name	electric		measurements		abilities
bbe-moldaenke <a href="http://www.bbe-moldaenke.de">http://www.bbe-moldaenke.de</a>	Fluoroprobe <a href="http://www.bbe-moldaenke.de/chlorophyll/fluoroprobe/">http://www.bbe-moldaenke.de/chlorophyll/fluoroprobe/</a>	Power Supply	-	DAM	-	<ul style="list-style-type: none"> <li>• Environmental monitoring</li> <li>• Warning system for algae blooms</li> <li>• Algal distribution in the Arctic/Antarctic</li> <li>• Oceanographic research</li> <li>• Mooring, experiments, continuous analysis</li> <li>• Limnological research</li> <li>• Research and teaching</li> <li>• Tracer measurements</li> </ul>
		Max. current draw	12 Volt	Chl a	-	
		Battery capacity	3900 mA h	Cyanobacteria	-	
				Phycocyanin Phycoerythrin	-	
				Aquaculture		
		Sleep mode	n/A			
		Depth	100 – 1000m			

manufacturer	product name	electric		measurements		abilities
YSI <a href="http://www.ysi.com">http://www.ysi.com</a>	EXO1 Water Quality Sonde <a href="http://www.ysi.com/productsdetail.php?EXO1-Water-Quality-Sonde-89">http://www.ysi.com/productsdetail.php?EXO1-Water-Quality-Sonde-89</a>	Power Supply	9-16.5V DC	Conductivity/ Temperature	-	No information given on the website
		Max. current draw	-	FDOM	-	
		Data Memory	512 MB >1.000.000 readings	Dissolved Oxygen	-	
				pH or pH / ORP	-	
				Depth		
		Sleep mode	-	Total Algal Chlorophyll/ Blue-green Algae		
		Depth	250m			

manufacturer	product name	electric		measurements		abilities	
YSI <a href="http://www.ysi.com">http://www.ysi.com</a>	600OMS V2 <a href="http://www.ysi.com/productsdetail.php?600OMS-5">http://www.ysi.com/productsdetail.php?600OMS-5</a>	Power Supply	9-16.5V DC	Conductivity/ Temperature	-	No information given on the website	
		Max. current draw	-	FDOM	-		
		Data Memory	-	Dissolved Oxygen	-		
				Depth	-		
				Rhodamine			
		Sleep mode	-	Total Algal Chlorophyll/ Blue-green Algae	Turbidity		
					Salinity		
				Specific Conductance			

**Table 3: State of the art in light excitation and detection devices as well as interfaces and housing extensions for sample containers of portable fluorescence sensors (listed in Table 2).**

Manufacturer	Sensor	Excitation			Detection			Housing extension Sample container for flow through or cuvettes available?
		LED	Xenon flash	Laser	Photodiode	Photomultiplier	Spectrometer	
TriOS	micro Flu	x			x			flow through chamber
TriOS	enviroFlu- HC		x		x			flow through chamber
Wetlabs	ECO FL, WETStar* ECO FL, WETStar**	x			x			
ChelSea	UniLux	x			x			flow through chamber
ChelSea	TriLux	x			x			flow through chamber
ChelSea	UviLux	x				x		flow through chamber
ChelSea	UV AquaTracka		x			x		flow through chamber
SeaPoint	Chlorophyll Fluorometer	x			x			
YSI	EXO1-Water-Quality-Sonde 600OMS V2***	x			x			flow cell
BBE-moldaenke	FluoroProbe-1000m	x			x			flow through unit & option to do laboratory operation with a workstation: 25ml glass cuvette
Turner	C7 Chl a	x			x			flow cap
Turner	C7 CDOM	x			x			flow cap

\*simplest configuration; \*\* detailed configuration (battery, high depth, etc)

\*\*\* communication: Bluetooth wireless technology

## 4 Concluding remarks

A wide range of robust and portable fluorescence sensors for the retrieval of CDOM and phytoplankton signals at appropriate excitation and emission wavelengths are commercially available (Table 1). Additionally, PAHs can be retrieved by some of these in situ instruments. Sensors that meet state of the art characteristics in excitation and emission wavelengths, such as the MicroFlu series of TriOS for CDOM and algal pigments Chl *a* and phycocyanin, fall in a price range between 1000 and 5000 EUR. As compared to higher priced instruments, these sensors are affordable for a group of users with an interest in precise measurements of water constituents. Furthermore, this sensor series is steerable via a handheld pocket device (Pocket-MSDA handheld software). Such sensors can be adapted to mobile phone environments via a Bluetooth connection and thereby would provide the full range of fluorescing water constituents for mobile phone users within Citclops.

The development of more economic devices that may also be used for crowdsourcing comprises the use of low-cost components. One aspect here would be a price reduction in the use of plastic instead of high end dichromatic filters to narrow the wavelength ranges of excitation and emission spectral ranges, another possibility is a reduced housing with restricted depth ranges. Up to now, there is no cuvette holder available for the listed portable in situ fluorescence sensors. Yet, the construction of a cuvette holder for these lower priced, as well as high end instruments would bring an added value for Citclops measurements, as such an adaptor would enable fluorescence measurements of water in a sampling cuvette in confined environments (e.g. with adjusted temperature) as well as reference measurements to a cuvette adaptor for direct fluorescence measurements with mobile phones. Such devices are available for portable absorption devices (e.g. for the ProPS by TriOS) (Figure) and would be of great advantage within Citclops.



Figure: Cuvette holder for portable absorption device (ProPS, TriOS)<sup>1</sup> and workstation for bbe's FluoroProbe<sup>2</sup>. The FluoroProbe without workstation is in the highest price range of > 10,000 EUR.

<sup>1</sup>[http://www.trios-science.com/index.php?option=com\\_content&view=article&id=212%3Anew-accessories&catid=1%3Alatest-news&Itemid=50&lang=de;](http://www.trios-science.com/index.php?option=com_content&view=article&id=212%3Anew-accessories&catid=1%3Alatest-news&Itemid=50&lang=de;)

<sup>2</sup><http://www.bbe-moldaenke.de/chlorophyll/fluoroprobe/>

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## 6 List of Key Words/Abbreviations

<b>CDOM</b>	Coloured Dissolved Organic Matter
<b>Chl a</b>	Chlorophyll a
<b>fDOM</b>	Dissolved Organic Matter Fluorescence
<b>PAH</b>	Polycyclic Aromatic Hydrocarbon
<b>UV</b>	Ultra Violet