



WISP-3 Manual

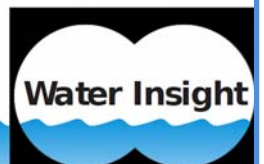
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WISP-3

The WISP-3 is an optical water quality instrument for surface waters. It measures in situ and in real time. This manual leads you step-by-step through its functions and the performance of measurements and provides the instruments background information.

Manual contents

1. Introduction
2. Applications
3. Overview of the WISP-3
4. Specifications
5. Theoretical background
6. Accuracy
7. Calibration
8. Preparations before measuring
9. Taking measurements
10. WISP-web: analysis of the results
11. Company information
12. References



1 Introduction

The WISP-3 is an easy to operate hand-held water quality instrument for surface waters. A fixed mounted system is available for continuous monitoring. WISP-3 measures in situ and in real time, without the need for laboratory analysis and is therefore up to 50% more cost-effective in comparison with traditional analysis.

The WISP-3 is an optical instrument: it retrieves the water quality parameters from the colour of the water. It is called Water Insight SPectrometer with three channels (WISP-3) as it measures the three needed optical properties simultaneously: the total sky-light, the light entering the water under 42 degrees and the light leaving the water at 42 degrees.

WISP-3 uses this spectral information to derive the upwelling light from the water body. Based on 20 years of sound university research at the Institute of Environmental Studies (VU University Amsterdam) and others, know-how and techniques have been developed to determine the concentrations of water quality parameters from this spectral information with accuracies comparable to laboratory analyses.



2 Applications

The WISP-3 is designed for monitoring and research on water quality in water supply reservoirs, swimming water locations, lakes, ditches, rivers and sea. The WISP can also be used for ground-truthing in optical satellite validation.

Due to its speed, flexibility and instantaneous data availability, usage of the WISP-3 and its web portal enables day to day decision support systems of water management organizations where algal blooms affect drinking water safety, swimming water safety, ecological status or environmental protection.

Compared to laboratory measurements the WISP-3 is fast and flexible. Preliminary data (concentrations and reflectance) is immediately presented in the display, the complete data is ready directly after uploading the measurements via the WISP-web.

3 Overview of the WISP-3

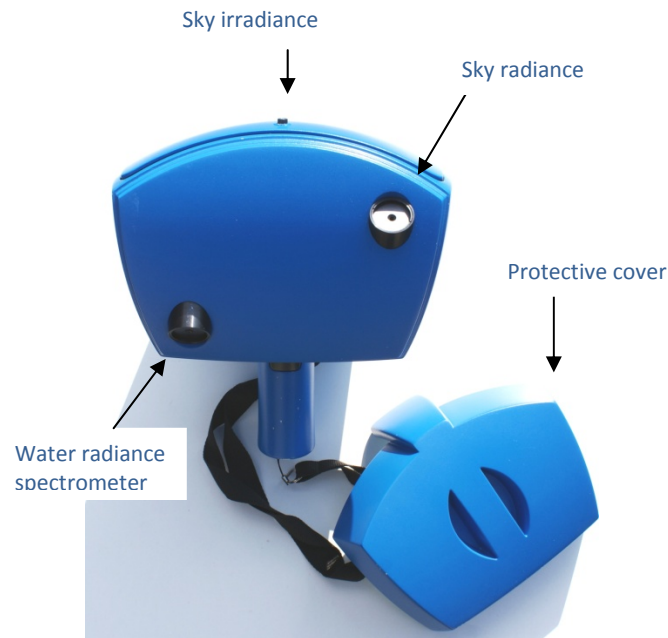


Figure 3.1. Front side of the WISP.

The WISP measures with three spectrometers. Remove the protective cover (Figure 1). Now you will see one spectrometer pointing straight up, measuring the sky irradiance with an Ocean Optics CC3 collector. Two other spectrometers point at angles of 42°, to measure radiance from respectively the sky and the water. These spectrometers have Ocean Optics Gershun tubes with 3°FOV collectors.



Figure 3.2. Back side of the WISP.

Holding the handle (Figure 2) makes sure the WISP is employed in the correct, upright position, the bulb and mirror assist in keeping this position. The display allows the user to change meta-data such



WISP-3 Manual

as data, time, location and measurement number and presents preliminary results directly after measuring

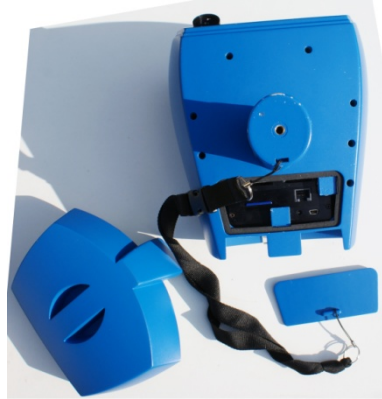


Figure 3.3. Bottom side of the WISP.

The bottom case contains the power inlet for recharging and SD cards for data storage.



4 Specifications

4.1 Deployment specifications

The WISP-3 measures the downwelling irradiance, upwelling radiance and downwelling radiance. From the optical measurements the WISP-3 determines the concentrations of the following parameters:

- chlorophyll, as proxy for algal biomass, 0 - 120 $\mu\text{g l}^{-1}$;
- phycocyanin, as proxy for cyanobacterial biomass, 0 - 1200 mg m^{-3} ;
- suspended sediments (TSM), 0 - 100 mg l^{-1} ;
- Coloured Dissolved Organic Matter* at 440 nm (CDOM), 0 - 4.5 m^{-1}

and information on:

- water transparency: PAR and for separate spectral bands*;
- Secchi Disk depth*
- occurrence of floating layers of cyanobacteria

* The parameters with an asterisk are available via WISP-web.

The WISP-3 measurement is an above surface measurement, which prevents bio-fouling from accumulation of dirt around the spectrometer. However, it is not possible to measure depth profiles as the WISP-3 will only receive information about the first meter (s) from the surface, depending on the transparency. The WISP-3 can be applied under sunny and overcast conditions.

5.2 Physical specifications

- Height (including handle): 22 cm, width 19 cm, length 25 cm;
- Weight 2,2 kg;
- Wavelength range 380-780 nm;
- Spectral resolution 4 nm;
- Aperture 3° FOV;
- Measurement time 30 – 90 s;
- Storage on SD memory card;
- LAN network connection (fixed mount).

The WISP-3 is available as a hand-held instrument and as a fixed mounted system (e.g. on a pole). A fixed mounting is suitable for prolonged continuous monitoring. The hand-held scanner can be used very flexible at different locations.



5 Theoretical background

Pure deep water looks blue because of the specific shape of the water molecules that absorb almost all light, but reflect much blue. Also the substances in the water, such as phytoplankton (algae), suspended sediment (TSM) and Coloured Dissolved Organic Matter (CDOM, molecules of degrading substances) have specific colours. Most algae are green, but cyanobacteria ("blue-green algae") have different pigments and therefore another colour. Sediment reflects much brown/red-ish light and colours the water therefore bright brown/red, but depending on sediment type TSM can have other typical colours. CDOM absorbs much light, especially blue. Water with much CDOM is therefore dark yellow/brown. As the reflection and absorption spectra of different substances in the water vary over the visible light, it is possible to derive the concentrations of these substances from the water colour.

To derive substances from water colour dedicated algorithms are needed. One possibility is to use the difference between two wavelengths to determine if there is more absorption at one wavelength than at the other. This type of algorithm is called band-difference algorithm. When there is one dominant substance in the water band-difference algorithms work very well. However, when different mixtures of sediment, algae and CDOM occur, all affecting the absorption and scattering at a certain wavelength, band-difference algorithms sometimes fail. In these cases an inverse bio-optical model can help. Such a model contains spectral information of the type of substances in the water and integrally solves the problem, determining the concentrations of the present substances in such a way that the total absorption and scattering agree with the total reflected light. Such a model is HYDROPT (Van der Woerd and Pasterkamp, 2008). The advantage of such an inverse bio-optical model is that the spectral information can easily be changed to local specific properties, such as red sediment, certain algae types etcetera. The disadvantage of such a model is that it more complex and can therefore not run on a small computer. The preliminary data that appears in the WISP display is therefore calculated with band-difference algorithms. The WISP-web uses a bio-optical model for chlorophyll, SPM, CDOM, Kd and Secchi disk depth. Phycocyanin is only calculated with band differences, as is the determination of floating layers.

Algorithms are:

<u>Parameter</u>	<u>WISP-embedded</u>	<u>WISP-web</u>
Chlorophyll-a	Gons et al, 2005	HYDROPT
TSM	Rijkeboer et al., 2000	HYDROPT
CDOM	n.a.	HYDROPT
Transparency (Kd)	Gons et al, 1997	HYDROPT
Phycocyanin	Simis, 2006	Simis, 2006
Secchi disk depth	n.a.	HYDROPT
Occurrence of floating layers	Water Insight algorithm	Water Insight algorithm

6 Accuracy of the WISP-3

The accuracy of concentration results of the WISP-3 is dependent on five types of variables, with a very different character:

- A. The accuracy of the spectrometers
- B. The calibration of the spectrometers
- C. Correct deployment
- D. Environmental variables
- E. The algorithms used for derivation of the concentrations

Schematically:

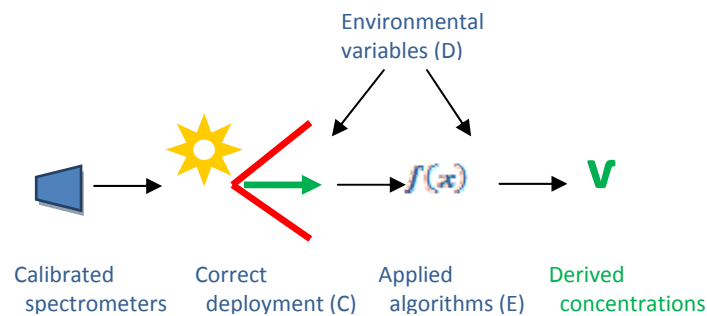


Figure 6.1: a schematic overview of the chain leading to accurate concentration measurements.

The accuracy of each of these steps will be discussed in the remainder of this document, as well as comparisons between the WISP and other optical water quality instruments the derivation of concentrations from optical measurements.

6.1 Spectrometer accuracy (A + B)

The spectrometers, and also the fibres (that collect the light), the Gershun tubes (on top of the radiance collectors) and the Irradiance collector are produced by the Ocean Optics company. Ocean Optics estimates the signal to noise ration of their single spectrometers as 250:1.

The WISPs are assembled and calibrated by Water Insight with a matching Ocean Optics calibration lamp. Separate calibration files for each spectrometer come with each WISP-3 and are used in the software to correct the measurements. Once a year the WISP needs to be re-calibrated by Water Insight.

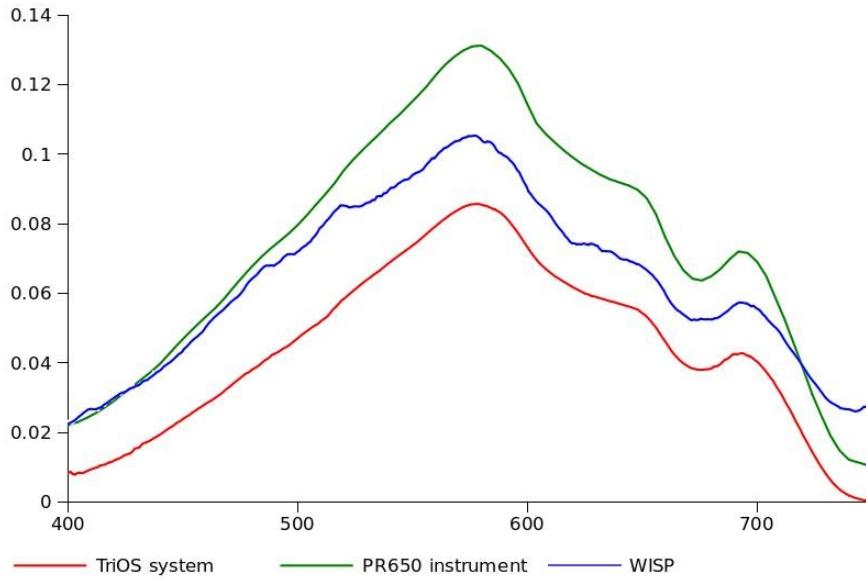


Figure 6.2: inter comparison between WISP-3 and two well-known optical instruments. The y-axis presents the reflectance just below the water surface, the x-axis the wavelength (visible light)

Inter calibrations between the –in the scientific community- well known TriOS system, PR650 portable spectrometer and the WISP were preformed. Figure 2 shows that the reflectance of the water measured with the WISP-3 correlates well with the reflectances measured with these well-known and long-term tested optical instruments. Note that the spectral shape and the height of the reflectance-spectrum are the most important properties. As can be seen in Figure 6.2, the spectral shapes of the three instruments is very similar. The height of the WISP-3 spectrum falls –in this case- in-between that of the other two spectrometers.

6.2 Deployment accuracy (C)

It is very important to deploy the WISP-3 in the correct position to the sun: ~135° away from the sun. In this way direct reflectance effects (e.g. sun glint) that occur at the surface are avoided as much as possible (Mobley, 1999).

Angles < 90° (towards the sun) and ~180° (opposite to the sun) should absolutely be avoided. This position (Figure 3) should be kept until the concentrations of chlorophyll (Chl) and suspended matter (SPM) are shown in the display.



Figure 6.3. Keep the WISP-3 in the correct position relative to the sun

The WISP-3 should be deployed close enough to the water so that the spectrometer looking down will actually measure water. Floating plants, leaves, garbage, bottom visibility and self-shading of a boat or jetty can lead to inaccurate measurements. Also the two spectrometers looking upwards should actually measure sky: measuring below trees, buildings etc. should be avoided.

The WISP-3 can be deployed under sunny and overcast skies, but not during precipitation or at night. The sun should be $> 30^\circ$ above the horizon, which can limit deployment in winter, depending on your latitude. The WISP-3 automatically detects when it is too dark.

6.3 Influence of environmental variability on accuracy (D)

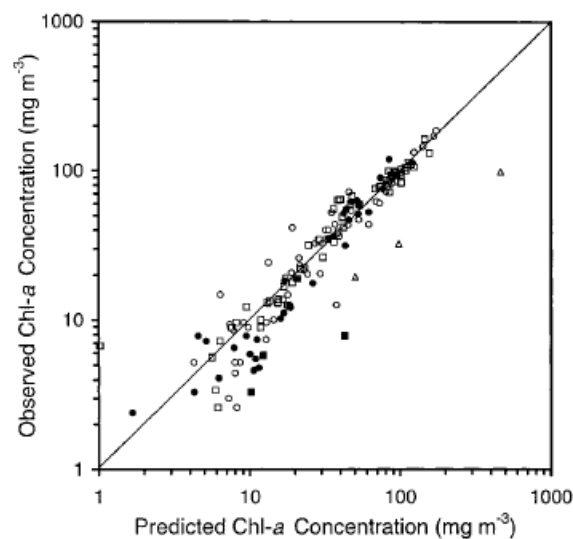
Clear and completely overcast skies are best for optical measurements: scattered clouds may hamper the accuracy, as for example the spectrometer measuring sky measures a sunny location while the water looking spectrometer measures water in shadow. Waves can hamper the accuracy too, although this effect can be sufficiently reduced by measuring in the correct direction relative to the sun. The WISP-3 automatically averages 5 samples, reducing the effect of the darker and lighter sides of waves.

Another type of environmental variability is variability in optical properties of the substances in the water. The WISP-3 as well as the WISP-web use general (inland) water algorithms, which were scientifically tested for lakes with a high variability in specific optical properties. However, to apply a WISP-3 in a totally different environment (e.g. tropics, open ocean, white/red sand beaches etcetera), local specific optical properties need to be determined and incorporated. If required, we can preload the WISP with alternative algorithms. Please contact us to discuss options if required.

6.4 Accurate algorithms (E)

Concentrations can accurately be derived from optical measurements when a suitable algorithm is used (e.g. calibrated for the local optical properties). As the WISP-3 is fairly new, we are still working on a direct comparison dataset between WISP-3 and laboratory chlorophyll concentrations. Therefore, data of Gons, 1999 (Figure 6.4) is used to illustrate the accuracy of optical algorithms here. One can see that the scatter between the chlorophyll concentrations derived with laboratory and optical measurements is within $\sim 20\%$, a scatter comparable to what will be found between different laboratories.

The optical data of in Figure 6.4 was measured with a PR650 instrument. As WISP-3-reflectances agree well with PR650-reflectances (Figure 6.2) the WISP-3 will lead to similar concentration results as shown in Figure 6.4.





WISP-3 Manual

Figure 6.4. The observed (laboratory) concentrations of chlorophyll against the predicted (derived from optical measurements) concentrations of chlorophyll.

(Figure reprinted with permission from Gons, H.J., 1999. Optical Teledetection of Chlorophyll a in Turbid Inland Waters. Environmental Science and Technology 33. Copyright 1999 American Chemical Society.)

In the WISP-3 relatively simple (band difference) algorithms are used, to make sure measurements do not take too long. For more information on algorithms see "Theoretical background" Software updates for the WISP are provided via WISP-web.

After uploading the reflectance measurements to the WISP-web, a more precise but more complex algorithm (HYDROPT) is applied to the data (van Der Woerd and Pasterkamp, 2008). It is possible to calibrate this algorithm with local optical properties, to adapt it to for example a dominant local algae species. In the WISP-web also Secchi disk depth and Coloured Dissolved Organic Matter can be calculated, that require a high calculation capacity.



7 Calibration

When you receive a WISP from Water Insight it is calibrated. Calibration files for the three separate spectrometers come with your WISP and are used in the software to correct the measurements. Once a year the WISP needs to be re-calibrated at Water Insight.

We calibrate the WISP with Ocean Optics calibration lamps. Inside the WISP-3 the fibres which connect the irradiance collector and the Gershun tubes with the optical spectrometers are fixed with lock tite. Opening the WISP-3 may reduce the accuracy and makes the calibration files worthless.

8 Preparations before measuring

8.1 Planning

The solar elevation should be $> 30^\circ$ above the equator during measurements. You can determine the solar height at the planned time and day of measuring on web-based solar height calculators (you can find links at WISP-web) or by checking the day in advance.

8.2 Preparing the WISP

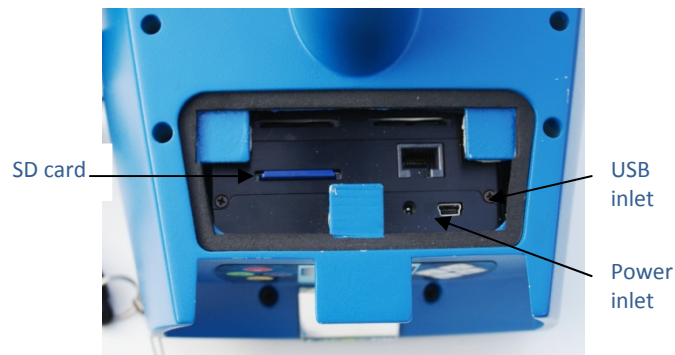


Figure 8.1. The bottom case of the WISP.

Charge the WISP battery. An adapter for 220 V to 5 V is delivered with the WISP (European and US adapter included). Open the bottom case of the WISP (Figure 4) and connect the adapter to the power inlet. After charging, insert the SD card in the WISP and close the bottom case.


8.3 Jaz-menu

When you press cancel (x) in the main menu, you enter the Jaz-menu, in which the WISP software runs. The Jaz-menu provides information on the battery: navigate up or down (\blacktriangle , \blacktriangledown) and press (v) when you found “battery information” to see if it needs to be charged. To return to the WISP software, press (x), navigate back to “WISP” and press (v).

8.4 Adjust settings



Figure 8.2. Display

Turn the WISP on () and press configure, followed by date + time, latitude and longitude to check the meta-data that will be stored together with the measurements. Within a sub-menu the arrow buttons (\blacktriangleleft , \blacktriangleright , \blacktriangle , \blacktriangledown) can be used for adjustments. Press accept (v) to store these settings, or



cancel (x) if no adjustments are needed. Go back to the main menu with cancel (x) or shut down the WISP ().

9 Taking measurements

9.1 Determine position

Take the protective cover off. Turn the WISP on and keep it straight in front of you. You should direct ~135° away from the sun (Figure 9.1) and avoid angles < 90° and 180° (opposite to the sun).



Figure 9.1 Position relative to the sun

Make sure to stand close enough to the water so that the spectrometer looking down will actually measure water. Avoid floating plants, leaves, garbage, bottom visibility and self-shading of the boat or jetty you are on. Make sure you measure sky with the two spectrometers looking upward: avoid measuring below trees, buildings etc.

9.2 Sample station: base filename

Create a filename for your sample station within the settings menu (“configure” – “base filename”). Navigate through the small keyboard (◀, ▶, ▲, ▼) and accept signs with (✓). To accept the name, navigate to “done” and press (✓). Multiple samples will now be stored under this name (name000, name001 etc). Be aware that the base filename is lost when the WISP is turned off.

9.3 Measure



Figure 9.2. Performing a measurement

In the main menu, press Measure (#) to measure. The WISP display will show “adapting to light”, followed by the percentage of the measurement that is preformed. Keep the WISP in the right position (Figure 9.2) until the concentrations of chlorophyll (Chl) and suspended matter (SPM) are shown in the display. When there is not enough light for measurements this will be shown as “not enough light”. Note that the WISP will measure when the solar position is not correct, you should take care of the correct position yourself.



When you are satisfied with the results press go back to the menu with (x) and press save (v). In the menu you can also view the derived reflectance spectrum (press ●).

10 WISP-web: analysis of the results

WISP results are stored at the SD card. Preliminary concentration results and reflectance (R0-) at the first nine bands of the MERIS satellite (M1-M9) are stored in text files with the base file name of the sampling station. Raw (non-calibrated) data of the three optical channels is also stored, ready for uploading to WISP-web.

The WISP-web system offers extensive services for analysis of the results, including:

- real time data access;
- quality control;
- more advanced algorithm (higher accuracy and calculation of Kd, CDOM and Secchi depth);
- tools for creating time series;
- tools for comparisons;
- tools to generate overlays of satellite and WISP data;
- tools to generate other aggregated products.

To upload your measurements, turn off the WISP is turned off take out the SD card by pressing the button beside it and insert it directly to the SD port of your computer. Browse through the spectral results in the folders called 'specxxx' and upload the selected spectral information to <http://geoportal.waterqualitymap.eu>.



11 About us

Water Insight BV is a company that offers innovative products and services in the field of geoinformation and surface water quality monitoring. State-of-art remote sensing technologies are used from different platforms including boats, airplanes and satellites for our products and services.

Water Insight was founded in 2005 by Dr. Steef Peters and Dr. Marnix Laanen. We provide water remote sensing products and services for in situ measurements and satellite data. We participate in leading international research projects.

Customers are national and regional water management authorities and national and international commercial companies.



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