Validation of
Secchi3000 field analyser
for water turbidity measurements

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Background

A vast number of important decisions – many of them environment-related – are based on measurement results. Currently aquatic monitoring relies mainly on manual sampling and laboratory measurements. There are needs to replace labour-consuming monitoring methods by applying new technologies such as on-line measurement systems, remote sensing and modelling.

Secchi3000 was developed to be a low cost and simple operation tool for water quality measurements. The objective was to offer it also for non-experts and citizens interested in water quality issues. Performing measurements with Secchi3000 is simple: The user fills the Secchi3000 container with water from a lake, river or sea, places the measurement structure in the container and takes a photograph with a mobile phone through a hole in the lid of the device (Fig. 1). The photograph is taken with an application called EnviObserver (developed by VTT, Finland). The application sends the photograph to a server together with metadata such as the location of the measurement. At the server the photograph is analysed with an algorithm, which finds the target areas from the picture and computes water quality parameters based on the brightness values of the target areas. Finally, the results are sent back to the users mobile phone and stored in data bases.

The current configuration of the device has so far been calibrated with Secchi disk depth and turbidity measurements. Earlier versions have also been successfully tested with CDOM and TSM [1].

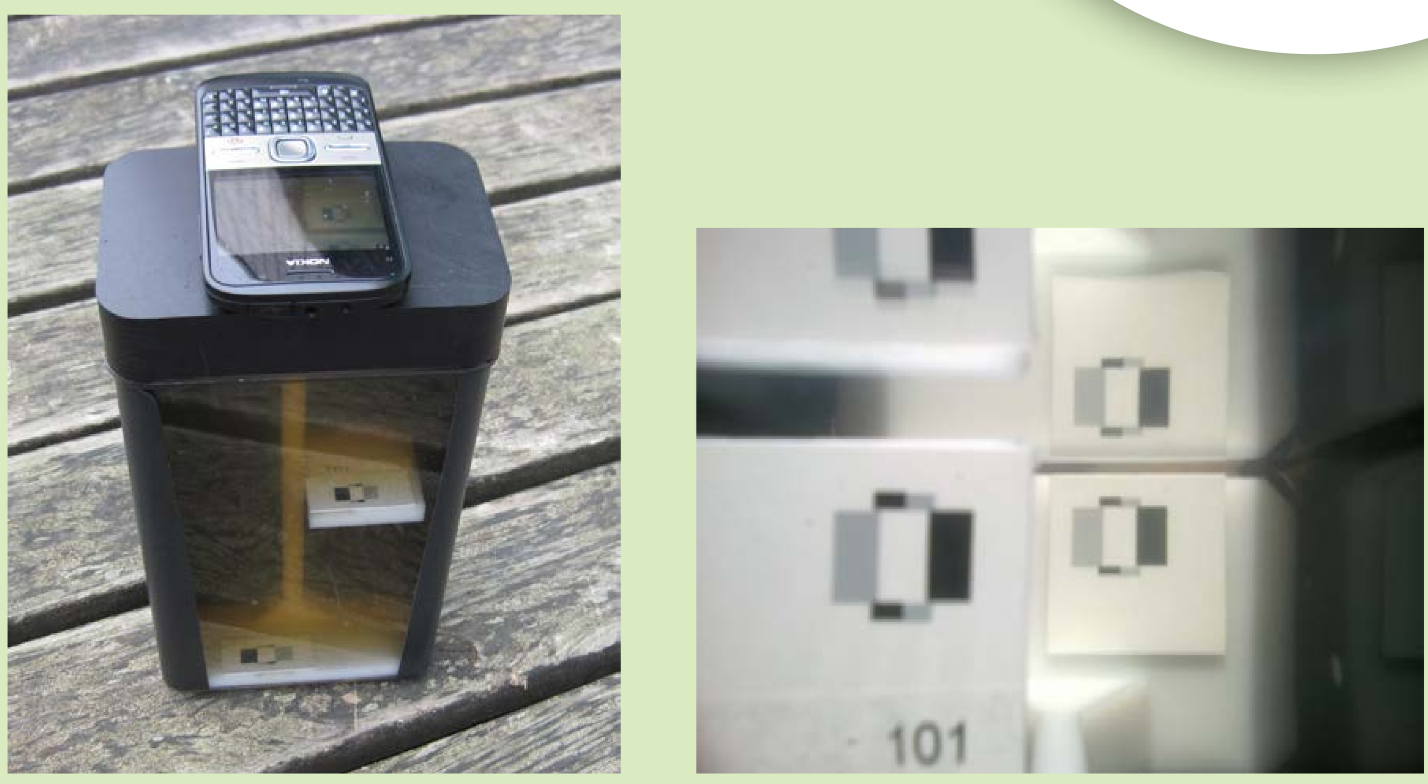

Fig. 1. Secchi3000 and a mobile phone on the top of the device. Inside the container there is the measurement structure with plates consisting of white, grey and black target areas.

Validation tests

Several natural water samples (river, lake, pond, brackish waters) were collected and turbidities were measured with Secchi3000 field analyser and nephelometrically by a Hach 2100AN IS laboratory instrument, which was regarded to be a reference method in these experiments. Laboratory method is based on standard method EN ISO 7027. Effect of lighting conditions and water colour number were investigated. The colour number was determined based on the hexachloroplatinate scale according to standard method EN ISO 7887. Additionally turbidity reference samples were prepared and analysed. Formazin turbidity standard 4000 FNU (HACH) was used for preparation of reference solutions. Measurement uncertainty was estimated according to the Nordtest approach [2].

Analyses were performed in the laboratory of the Finnish Environment Institute, which is an accredited testing and calibration laboratory according to the requirements for the standard SFS-EN ISO/IEC 17025.

Validation results

Comparison of results of Secchi3000 and laboratory instrument

The results show that the measurement errors start to increase when turbidity is more than 8-10 FNU (Fig. 2). In these cases the attenuation of light in the measured water is strong and small differences in the measured light result in large differences of estimated attenuation and turbidity. Large turbidity values are still estimated as large turbidity values by Secchi3000, but the absolute error increases. The response also starts to be non-linear. The measurement with the reference instrument is based on scattering and this could be one explanation for the difference.

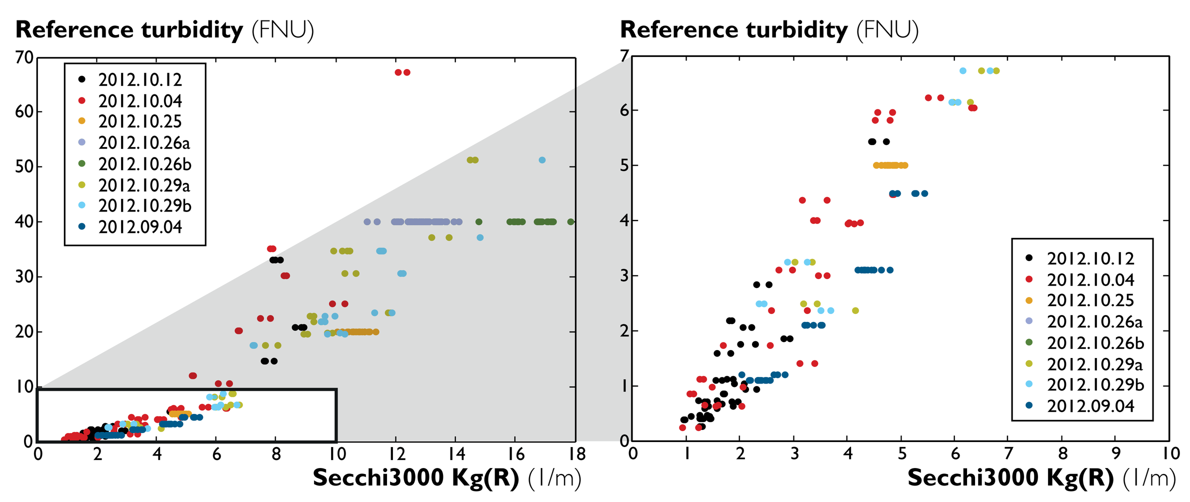

Fig. 2. Comparison of Secchi3000 turbidity results with laboratory reference method.

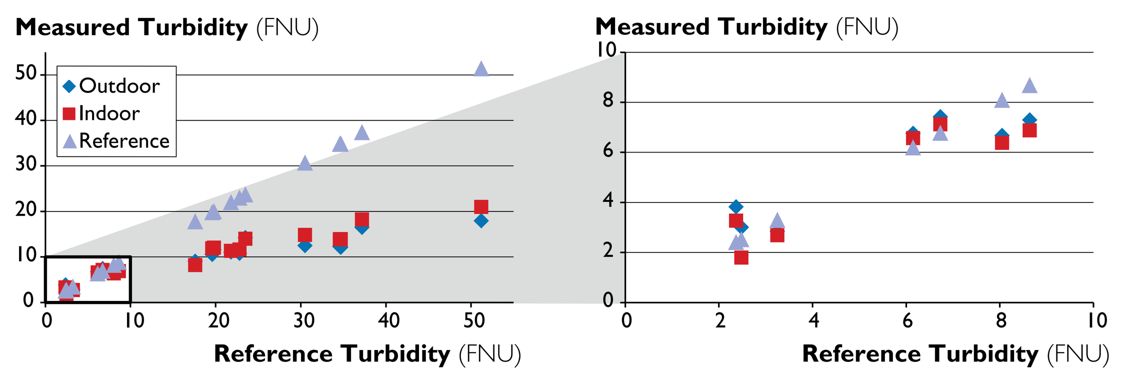

Fig. 3. Effect of lighting conditions on turbidity values obtained by Secchi3000. Laboratory method was applied as a reference method.

Effect of sample colour

Secchi3000 was observed to be robust for potential interferences caused by water colour. The colour of the water did not result any systematic error to the results of Secchi3000 field analyser. The difference from the reference value was divided evenly between ±1,5 FNU.

Effect of lighting conditions

Possible systematic errors due to different lighting conditions were investigated by measuring turbidity of standard reference samples (20 FNU) outdoors in sun light and indoors in room lighting and while sun was shining through window to the sample water. According to t-test, the significant difference was found between the average values obtained from same sample with different lighting conditions. Measured turbidity was higher for the samples analysed indoor and room light than samples analysed outdoors.

Also natural water samples with different turbidities were analysed both in- and outdoors. Results were consistent with turbidity values lower than 10 FNU and they were also in good accordance with the values given by laboratory reference method (Fig. 3).

Measurement Uncertainty

Measurement uncertainty was estimated according to the Nordtest approach, where combined measurement uncertainty is broken down into two main components – the within-laboratory reproducibility u(Rw) and the uncertainty due to possible bias u(bias). MUkit (Measurement Uncertainty Kit) was employed for calculations [3], and summary of the uncertainty budget is presented in Table 1. Limit of quantification was estimated to be 1,7 FNU and measurement uncertainty was calculated for turbidity values between 1,7–10 FNU. Uncertainty range was divided into two sub ranges: Low range from 1,7 to 5,0 FNU and high range from 5,0 to 10 FNU. Higher turbidity values were ignored due to restrictions of the present algorithm to measure these values.

Table 1. Uncertainty budget for turbidity measurement in natural water by Secchi3000

Source of Uncertainty	Low Range (1,7–5,0 FNU)	High Range (5,0–10 FNU)
Within-laboratory Reproducibility		
Standard deviation from control samples	0,19 FNU	3,8 %
Standard deviation from routine sample replicates	0,26 FNU	3,2 %
u(Rw)	**0,32 FNU**	**4,9 %**
Method and Laboratory Bias		
Bias	-0,04 FNU	-0,8 %
s(bias)	0,19 FNU	3,8 %
$u(c_{ref})$	0,12 FNU	2,3 %
u(bias)	**0,13 FNU**	**1,6 %**
u_c	**0,35 FNU**	**5,5 %**
U (k=2)	**0,7 FNU**	**11 %**

Conclusions

Secchi3000 field analyser was validated for turbidity measurements and according to the results Secchi3000 was appropriate for measuring turbidities lower than 10 FNU. Algorithm applied for present turbidity calculations is not fully suitable for higher concentrations. For potential routine use this is not a problem since turbidities in Finnish natural waters is usually low. In May-September 2012 on average 81 % of the measured surface water turbidity values were below 10 FNU in Finnish lake waters (n=2770) and 65 % in rivers (n=4787). Approximately half of the results in lake waters and 20 % in river waters were below the limit of quantification of Secchi3000. Further development of Secchi3000 analyser is needed for achieving lower quantification limit.

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Eesti tuleviku heaks
mmea Measurement, Monitoring and Environmental Assessment
CLEEN Cluster for Energy and Environment
MAA- JA VESITEKNIIKAN TUKI

References

1 S. Koponen, K. Kallio, T. Pyhälahti, S. Anttila I Secchi 3000 & Mobiwater, JVP Report, TEKES, 2011 http://www.jvphanke.fi/JVP_Secchi3000_Mobiwater_WorkReport_V1.0_2011_01_13.pdf

2 B. Magnusson, T. Näykki, H. Hovind, M. Krysell (2012) Nordtest technical report 537- Handbook for the calculation of measurement uncertainty in environmental laboratories, edn 3.1, Nordic Innovation, Oslo, Norway. www.nordtest.info

3 T. Näykki, A. Virtanen, I. Leito Software support for the Nordtest method of measurement uncertainty evaluation, Accred Qual Assur (2012) 17:603–612

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