



An evaluation of simple sensors for water quality monitoring

in the context of constructed wetlands

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An evaluation of simple sensors for water quality monitoring. In the context of constructed wetlands

En utvärdering av enklare analysmetoders precision och användarvänlighet. En studie på anlagda våtmarker

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Keywords: Simple analysis methods, Nitrogen, phosphorus, constructed wetlands, GHG, Citizen science

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Abstract

Nature based solutions (NBS) can have a role in mitigating two of today's most pressing environmental issues: eutrophication and climate change. However, there is a need for improvement in the understanding of their effectiveness and potential trade-offs. This requires comprehensive, affordable, and reliable measurement methods.

This study investigates the potential for using aquarium sensors and test strips in water management and citizen science as a simple, inexpensive, and robust method for measuring water quality in constructed wetlands. The study focus is on macro nutrients and proxies for greenhouse gases, and the method is benchmarked against parallel samples analysed by an accredited laboratory. The study also assesses the user-friendliness and cost of the method.

Preliminary results show good potential for nitrate test strips which are evaluated using a smartphone app, as well as filtered colour of water as an indication of total organic carbon. Sensor measurements of alkalinity combined with pH and temperature can be used to estimate dissolved CO₂ concentrations. Phosphate sensor measurements were often problematic but could be interpreted qualitatively. While these methods have some potential for citizen science and low-cost monitoring, results should always be interpreted with caution due to their relatively high uncertainty and low precision.

Keywords: Simple analysis methods, Nitrogen, phosphorus, constructed wetlands, GHG, Citizen science

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Abbreviations

Abbreviation	Description
CW	Constructed wetland
DIC	Dissolved inorganic carbon
DOC	Dissolved organic carbon
GHG	Greenhous gases
NBS	Natural based solutions
SAM	Simple analysis methods
TOC	Total organic carbon

1. Introduction

Small waterbodies including agricultural ponds and wetlands are found throughout the world. Despite their small size, they can have disproportionate impacts on the environment (Downing 2010). These waterbodies can be important for eutrophication control but may also have significant climate impacts. Obtaining the measurements needed to assess the functionality of these waterbodies requires new, affordable approaches to measuring water quality and greenhouse gas (GHG) levels. This is a method development study that includes a parallel comparison of the simpler analysis methods (SAMs) accuracy with an accredited lab as well as, evaluating the SAMs user-friendliness.

1.1 Background

Nature-based solutions (NBS) have the potential to contribute to the mitigation of two of today's most pressing environmental issues: climate change and eutrophication. NBS such as wetlands can e.g. mitigate eutrophication by retaining nutrients and climate change through sediment carbon accumulation (Hambäck et al. 2023).

Although the reintroduction and construction of wetlands can help mitigate several environmental issues, it is crucial to acknowledge the complexity of NBS. The optimal conditions for one desired function may not be optimal for others; both synergies and trade-off effects between the desired functions can occur (Hambäck et al. 2023). For example, there may be a negative correlation whereby GHGs are released by wetlands with high nutrient concentration and retention, and both functions can usually not be achieved in a single wetland (Hambäck et al. 2023)

While constructed wetlands (CWs), a type of NBS, are widely used in Sweden (Djodjic et al. 2022), Denmark (Graversgaard et al. 2018) and elsewhere to mitigate nitrogen (N) and phosphorus (P) losses from land to surface waters, studies have shown that these small, constructed water bodies can be relatively large emitters of GHGs (Peacock et al. 2019; 2021). Emissions of GHGs such as methane (CH₄) and carbon dioxide (CO₂) from small, CWs could in the same studies, be positively related to nutrient status (Peacock et al. 2019; 2021). Being able to better understand and quantify these kinds of trade-offs is essential for informed decision making and improvement while new wetlands are constructed.

Knowledge and monitoring gap

At the same time, there is a lack of evaluation and follow up of the efficiency of existing CWs (Djodjic et al. 2022). A possible reason for this lack is the expense of

making the necessary measurements. This project explores the possibility that cheaper measurements with simpler analysis methods (SAM) can enable more follow up of the CW functionality.

Even though the importance of CWs for nutrient retention and GHG emissions is well known, current environmental monitoring and assessment of water chemistry fails to prioritise small waterbodies such as ponds and wetlands. For example, the Water Framework Directive 2000/60/EC (WFD; European commission, 2000) monitoring only cover waterbodies with a greater area than 10 km² and lakes larger than 50 ha. The spatial and temporal gap in monitoring smaller waterbodies has previously been acknowledged, and small waterbodies were identified as the least monitored freshwater resource by Kelly-Quinn et al. (2023).

This knowledge gap together with the earlier mentioned lack of evaluation of CWs is important to cover. Without an increased understanding of the smaller waterbodies, we cannot fully understand processes at landscape scale. To better comprehend the effectiveness and potential trade-offs between functions of CWs and other small waterbodies more data is needed. Such data should ideally cover a larger spatial area over a longer time as well as several types of small waterbodies (e.g., agricultural, forest and urban ponds).

Deeper knowledge of water chemistry in small water bodies is important not only for understanding the broader context of nutrient and GHG fluxes, but also for democratic local and regional water management. Accessible, reliable, and understandable local environmental data and knowledge can potentially enable landowners and other citizens to participate actively and informatively in water management discussions and decisions. This opportunity for engagement is essential in a democratic process.

While using cheaper and simpler analysis methods, there may also be potential for implementing citizen science in freshwater monitoring. This could help to address the current knowledge and monitoring gap for small water bodies and CWs (Kelly-Quinn et al. 2023). This approach could e.g. involve interested local members of the public, schools, landowners, and land managers.

Citizen science

Citizen science is promoted as a means of collecting large quantities of data while increasing scientific literacy, making science more democratic and increasing social engagement in decision making (e.g. Bonney et al. 2009; Silvertown 2009; Storey et al. 2016; Scott & Frost 2017; Perez-Belmont et al. 2019). Due to the many ways in which citizen science has been implemented, and the wide variety of

participation levels, it is difficult to find a single definition. However, a citizen scientist can be broadly defined as a volunteer who collects and/or processes data as part of scientific research (Silvertown 2009).

Citizen science has been in many different research fields a successful way of gathering data, covering a longer time period and/or a larger spatial area than other collection methods could do, e.g., ice phenology (Futter 2003), or bird counts (Butcher & Niven 2007). While citizen science has been increasingly implemented in several disciplines, such as ecology, biology and environmental science, over the past decades (Silvertown 2009; Bonney et al. 2014; Yevenes et al. 2022), it has not grown as much in disciplines like hydrology, geology, or environmental chemistry, probably due to the technical nature of the sampling methods and the need for participant training (Yevenes et al. 2022).

Despite this, there are examples of successful initiatives and organisations which organise volunteers focusing on freshwater monitoring globally (*Fresh Water Watch* n.d.) as well as local studies (e.g. stormwater ponds in Toronto (Scott & Frost 2017), nutrients in a French river (Abbott et al. 2018), a wetland in Mexico City (Perez-Belmont et al. 2019), nutrients in Lake Utah's river network (Jones et al. 2021) as well as a catchment in central Chile (Yevenes et al. 2022)). Furthermore, the great potential of citizen science, and its ability to cover large spatial areas to address the previously mentioned monitoring gap for small water bodies, along with lessons learned from previous projects have been highlighted by e.g. Kelly-Quinn et al. (2023).

There are many reports of citizen science being criticised for low quality and limited reliability of data (Bonney et al. 2014). While data quality is an important concern in the planning of citizen science projects as in all scientific projects, Bonney et al. (2014) argues that it can be handled with appropriate training, protocols and oversight of volunteers. Further, "quality" and "reliability" are both subjective terms which need to be evaluated in an appropriate context. Kelly-Quinn et al. (2023) highlight that data quality can be ensured by using clearly defined, simple validated methods together with data control and supporting of citizen scientists.

Judging citizen science programs by the same standards used for, e.g., regulatory monitoring may not be reasonable. Instead, data collection, should be assessed considering the question to be answered. This can include, the level of quality needed, the benefit of large spatial and temporal data as well as the cost and potential aligning goals connected to outreach.

Limitations of current monitoring methods

Current methods to monitor and measure water quality are limited in space and time. They typically rely on professional staff to collect samples and commercial or government labs. The data generated by these programmes have high reliability and accuracy but need paid staff and can, therefore, be prohibitively expensive.

The existing citizen science projects including water chemistry use simple test kits with visual analysis (e.g. PACK-test used by Fresh Water Watch). These methods are cheap, easy and safe to use but typically have a relatively low accuracy and high detection limits, measuring between $<0.02 - 1>$ ppm in six steps (*Fresh Water Watch* n.d.). Results from these tests are usually used on a landscape level to identify nutrient pollution hotspots. Oligotrophic environments can however be affected by eutrophication on levels below the visual test's detection limit.

A previous study has successfully modified and validated a simple low-cost sensor (Gawankar & Masten 2023). The study used the Hanna Instruments marine nitrate sensor for freshwater use. This was however done in an educational setting with access to a teaching laboratory and the user-friendliness of the method was not a priority.

Potential for improvements

The present study will explore the possibilities for robust and user-friendly water chemistry analyses using simpler analysis methods based on handheld photosensors. Namely, water quality checkers for aquariums produced by Hanna Instruments (here called sensors); and test strips from Hach which are scanned simultaneously with a reference card using a mobile phone application from Deltares (Deltares n.d.b). Such methods could potentially bridge the gap between simple, low-cost, low-resolution tests, and the expensive, advanced analysis performed in accredited and other professional laboratories.

Provided that the SAMs are sufficiently easy to use, as well as adequately accurate and robust, they could be used as a water quality tool kit for citizen scientists or water managers to access water chemistry in small waterbodies. As a method development contribution, this study will pairwise compare analysis results of SAMs and an accredited lab using simultaneously taken CW water samples.

The pairwise comparison is a strength in this study in contrast to other evaluations of citizen science tools. A common practice in evaluating citizen science methodologies is to compare data collected using both professional and citizen science methods within a given area. However, these samples are not necessarily

collected simultaneously or even at the same locations, as noted by Storey et al. (2016).

Equally important to validation of the SAMs, is to minimize the sources of error in the sampling and analysis procedure. This requires the tools and protocols to be appropriately user-friendly. This together with appropriate training and oversight of data collection as highlighted by Bonney (2014) to ensure high quality data from citizen science. Therefore, this study will evaluate the user-friendliness of simpler analysis methods.

1.2 Aim

Inexpensive and reliable measurements are needed as a complement to professional laboratory analysis to cover the knowledge and monitoring gap regarding small waterbodies. The aim of this study is therefore to investigate whether inexpensive photosensors and test strips in combination with an application for smartphones can be used to assess water quality with a focus on nutrients and GHGs in CWs. This will be done by comparing how SAMs for water chemistry perform compared to corresponding analysis done by an accredited laboratory. Additionally, how user-friendly the methods are in a management and citizen science context will be evaluated and discussed. Therefore, this study aims to answer the following research questions:

1. How accurate are the results of SAMs for water chemistry in the context of CWs compared to analysis done by an accredited laboratory?
2. How suitable are these water quality SAM tests for citizen science and water management?
3. How could accuracy and suitability of the SAMs be improved?

2. Method and material

2.1 Analytical methods

This study focuses on water quality parameters related to nutrients and climate impacts. The nutrient parameters that were measured and analysed were phosphate and nitrate. Climate impact parameters related to GHGs that were measured and analysed were pH, temperature, and alkalinity, which were later used to estimate CO₂ saturation (Jarvie et al. 2017). Colour of water was used as a proxy for dissolved organic carbon content. All parameters are summarized in Table 1.

Table 1 Summary of parameters of interest, parameters measured with simpler analysis methods (SAM), and the laboratory parameters they were compared to. Total number of data points and number of detected samples where the SAM measured above zero.

Parameter of interest	Parameter measured with SAM	Lab	No. of data points
Nitrate	NO ₃ -N (mg/L)	NO ₂ +NO ₃ -N (µg/L)	59 (10 detected)
Phosphate	PO ₄ -P (ppm)	PO ₄ -P filtr. 0.45 (µg/L)	59 (13 detected)
DOC ^{a)}	Colour of water unfiltered (PCU ^{b)})	Turbidity	60
DOC ^{a)}	Colour of water filtered (PCU)	TOC (mg/L)	60
pH, DIC	pH & temp. (°C)	pH & temp. (°C)	79
Alkalinity, DIC	as ppm CaCO ₃	Kond. (mS/m25)	60

^{a)} Dissolved organic carbon, ^{b)} PCU platinum cobalt unit, ^{c)} Dissolved inorganic carbon

General procedures used to collect and thereafter analyse samples in the laboratory were as follows: to avoid contamination all bottles, cuvettes and syringes were rinsed three times with the sampling water, then filled up with the sample if nothing else was pointed out. Before each measurement with the sensors, cuvettes were wiped with an ethanol soaked paper towel to ensure that they were free from water, fingerprints and other dirt that could interfere with the measurement. Furthermore, before reusing bottles, cuvettes, syringes and beakers they were thoroughly rinsed with deionised water.

2.2 Study sites and sampling strategy

This study involves 20 CWs located in Uppland and Mälardalen in south-east Sweden. All CWs are included and sampled within the FORMAS funded research project *Promoting Upstream-Downstream Directed Linkages in the Environment: "Joined-Up" Management Perspectives* (PuddleJump); no new CWs were selected in this project. See the map in Figure 1 for locations. Within the project, water

samples from each CW were taken and *in situ* water chemistry parameters were measured using a Hanna HI9829 field multiparameter sensor every second week from April to October 2025. Water samples were then handed over to SLU SWEDAC accredited laboratory and stored coolly until further processing and analyses. This study was conducted from June to August 2025 with a total of four sampling rounds: one pilot round including triplicate measurements in a subset of CWs, all parameters except nitrate, followed by three main rounds containing single measurements for all CWs and each parameter. An overview of the sampling is presented in Table 2. Due to late delivery, the nitrogen measurement started in the second round and continued until a fourth round.

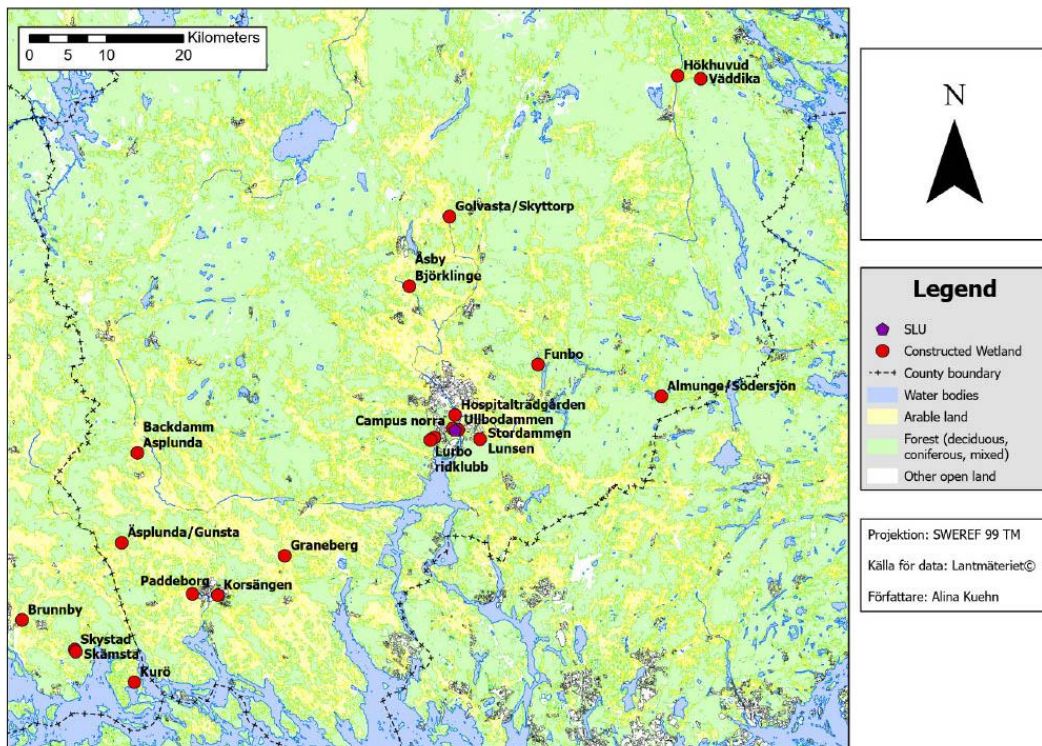


Figure 1 Overview map of the 20 sampling sites (Kuehn, n.p.).

Table 2 Sampling overview, including parameters and date of sampling, all sampling was done in 2025.

Date	Round	Measurements and analysis performed
10-12 Jun	Pilot	Phosphate, pH, temp, alkalinity, colour of water
24-26 Jun	1	Phosphate, pH, temp, alkalinity, colour of water
7-10 Jul	2	Phosphate, nitrate, pH, temp, alkalinity, colour of water
4-6 Aug	3	Phosphate, nitrate, pH, temp, alkalinity, colour of water
19-20 Aug	4	Nitrate, pH

All samples to be analysed with the SAM were taken at the same time and location as samples for environmental analysis at the SLU SWEDAC accredited laboratory. All water samples were taken as grab samples from the shoreline with plastic bottles on a sampling stick (Fyris-hämtare). When possible, the samples were taken 0.5 m below the surface and without stirring the bottom. If the water body was too shallow, samples were taken at approximately half of the water depth, while avoiding stirring the bottom and sampling the water surface. Each bottle was rinsed three times with the sample water before the actual sample was taken. Measurements on site were done from the shoreline using a multiparameter sensor (Hanna HI9829) measuring pH among other parameters.

After sampling, all samples were stored in a cooling room at approximately 4 °C until further analysis. The analyses were done within 48 hours after sampling. This is particularly important for correct results of nitrogen and phosphate which may begin to degrade if samples are stored for a longer time before analysis.

Pilot round

The first part of the pilot included a water sample from a single CW (Ullbo) and single measurements with each type of SAM sensor. While the procedure was carried out, any ambiguities in the instructions and hence, any necessary adjustment, as well as the time it took were noted. The user-friendliness evaluation took into account the following factors: time to execute the analysis of one sample, number of steps in the analysis, whether safety equipment is needed and at last how the reacted sample is safely disposed. The evaluation was then summarised for each SAM and graded on a scale of high, moderate or low user-friendliness.

Additionally, the amount of sampling water needed and any potential to efficiently measure multiple samples were recorded. The purpose was to understand and evaluate the analysis procedure as well as to decide whether the chosen sensors would be suitable for this study with respect to time and user-friendliness.

The second part of the pilot consisted of triplicate measurements with all sensors except from the nitrate sensor. Based on the results from the first part of the pilot round, the nitrate sensor was too difficult and time-consuming in its application and was hence replaced with easy-to-use nitrate test strips. In the next step, samples from ten CWs were analysed in parallel with samples sent to the accredited laboratory. The purpose of this round was to establish methodological accuracy. By taking triplicate measurements, it was possible to assess replicability of sensor results and to determine whether single measurements could deliver equally credible results. Variability associated with triplicate measurements was assessed

by performing an ANOVA which was executed to determine if the variance within the triplicates was smaller than the variance between the CWs.

2.2.1 Nitrate (sensor and test strips)

Nitrate sensor properties

The nitrate sensor (HI781) uses a colorimetric method where a reaction between the reactants and nitrate results in a pink/violet colour of the sample, the intensity and hence the concentration measured by the photosensor (Appendix 1). Detection range is between 0.00-5.00 ppm with a resolution of 0.01 ppm according to the manufacturer and an accuracy of the measurements of ± 0.25 ppm and ± 2 % of reading when measurements are taken at a temperature of 25 °C. (Appendix 1). The full method can be found in the manual in Appendix 1. The analyse with this sensor was executed in a fume hood due, and samples were disposed in a proper manner to potentially hazardous reagents.

It is worth noticing that the sensor is constructed for marine environments and is not recommended for use in freshwaters. However, the method can be adjusted to use in a freshwater context following the protocol of Gawankar & Masten (2023).

As described above, the first part of the pilot study evaluated time consumption and user-friendliness. Therefore, the nitrate checker was used according to the manual without any adjustments. Based on the results of the usability evaluation the nitrate sensor was excluded from the remaining study.

Nitrate strips properties

To measure nitrate, Hachtm strips were applied together with the application “Aquality” by Deltares (Deltares et al. 2023). The strips have according to the manufacturer a measurable range between 0-50 mg/L NO₃-N and 0-3.0 mg/L NO₂-N for nitrate and nitrite, respectively. Deltares estimates measurements with strip and the “Aquality” app to have an accuracy of ± 30 %, when the strip is scanned 60 seconds after dipping in sample water (Deltares n.d.a). Factors potentially interfering with the measurements’ accuracy can be turbid water due to impact of the colour of the test strip, low temperatures leading to underestimation of nitrate concentrations, as well as partial shading of the reference card resulting in improper readings of the application (Deltares et al. 2023).

Procedure

A test strip is dipped in to the water sample for one second, then a 60 second timer is started, and any excess water is gently tapped off with the back of the strip on a

clean paper towel. The strip is then placed on the black area of the reference card. After the 60 seconds, a picture is taken with the mobile camera in the app without shadowing the card. If the card is accidentally shadowed, the picture needs to be manually retaken immediately. Finally, the result is read and saved in the application. Detailed instruction can be found on the app and in Deltares et al. (2023). The procedure was not adjusted but was always carried out indoors in a well-lit laboratory.

Comparison

Results from the nitrate strips were compared with NO₂-N and NO₃-N measurements performed by the accredited laboratory with a flow analysis, photometry method according to SS-EN ISO 13395:199, with a measurable range between 0.1 – 100 mg/L and an uncertainty of 10% when analysing samples with concentrations ≥ 20 µg/L (SLU 2025). Levels of NO₂ were assumed to be negligible.

2.2.2 Phosphate (PO₄³⁻)

Phosphate sensor properties

Phosphate was analysed in a research lab at SLU with a Phosphate Low Range (HI713) produced by Hanna Instruments. If a sample contains phosphate above 0.01 ppm PO₄, the reaction with the reagent will give the sample a blue colour, the intensity and hence the concentration of which is measured by the photosensor (Appendix 2). The phosphate sensor has a detection range between 0.00 - 2.50 PO₄ ppm with the resolution of 0.01 ppm according to the manufacturer. Following the manual, the accuracy of the measurements is ± 0.04 ppm and ± 4 % of reading when measurements are taken at a temperature of 25 °C (Appendix 2). Measurements in ppm were assumed to be equivalent to mg/L. The analyse with this sensor was executed in a fume hood due, and samples were disposed in a proper manner to potentially hazardous reagents.

The manufacturer warns that the following factors may interfere with the method: iron concentrations above 50 mg/L, silica concentrations above 50 mg/L, silicate concentrations above 10 mg/L, copper concentrations above 10 mg/L, presence of hydrogen sulphide, arsenate, as well as high turbidity and highly buffered samples (HannaNorden AB n.d.).

Procedure

First, the sensor is turned on, and a 10 mL cuvette is filled up with sampling water. Secondly the cuvette is inserted into the sensor, which is then zeroed by pressing

the button. After this the cuvette is taken out, a reagent (H1713-0) added, and the cuvette gently shaken for 2 minutes. At last, the sample with the reagent is again placed in the sensor and a 3-minute countdown is started in which the measurement is performed. The full procedure for the sensor method can be found in Appendix 2.

Adjustments in the procedure were only made when errors occurred. In some cases, samples were cloudy, contained particles or plankton, leading to error warnings. If any of this was observed a note was taken and if needed analysis was repeated with a sample filtered through a 0.45 µm filter. The filtration is described in 2.2.3 colour of water. If the measurements will be compared to measurements in PO₄ as P they have to be converted with the factor 0.3261, as the sensor measure phosphate as PO₄,

Comparison

Results from the phosphate sensor were compared with measurements of PO₄-P performed by the accredited laboratory which uses a flow analysis, photometry method with a range of 1-12 µg/L an uncertainty of 1 µg/L and a discrete analysis, photometry method with a range of 4-1000 µg/L and an uncertainty of 2 µg/L, 9% according to SS-EN ISO 15681-2:2018 and SS-EN ISO 15923-1:2024, respectively (SLU 2025).

2.2.3 Colour of water

Colour of water sensor properties

The sensor uses an adapted version of the colorimetric platinum cobalt method according to the Standard Methods for the Examination of Water and Wastewater 21st edition (Appendix 3).

To measure colour of water, the water samples were analysed in a research lab with the colour of water sensor (HI727) produced by Hanna Instruments. The measurable range of this colour of water sensor is according to the manufacturer 0-500 PCU (Platinum cobalt unit) with a resolution of 5 PCU. The accuracy of the sensor is defined as ± 10 PCU and $\pm 5\%$ of reading at 25 °C (Appendix 3).

Procedure

Three cuvettes are prepared; a blank one with 10 mL deionised water, a second one with the 10 mL sample, as well as a third one with 10 mL sample filtered through a 0.45 µm filter to measure the true colour.

After the preparation, the measurement is performed by starting and zeroing the sensor by inserting the blank cuvette and pressing the button to start the analyse. To measure unfiltered colour the blank is removed and the cuvette with unfiltered sample water inserted and measured by pressing the button. To measure the true colour the sensor is then restarted, zeroed as described above, the cuvette with filtered sample inserted and measured by pressing the button. The full instruction manual for the sensor can be found in Appendix 3.

Some minor adjustments were made to the preparation part of the method compared to the manual. Firstly, the unfiltered and the true colour were measured in two identical but separate cuvettes instead of using the same cuvette and rinsing in between the measurements. Secondly, due to practical reasons the sample was first poured up in a beaker. A syringe is filled with 50 mL of the sample which was then used to press it through the filter into another beaker. Lastly, the filters and syringes used had the same properties recommended by the sensors manufacturer but were sourced from a different manufacturer that offered lower prices.

Comparison

The filtered colour of water is expected to correlate with dissolved organic carbon (DOC), and thereby to be a useful proxy for this. The accredited laboratory measured total organic carbon (TOC) which is an unfiltered proxy for DOC. Further the unfiltered colour of the water was compared with accredited lab measurements of turbidity. A comparison between turbidity and the difference between unfiltered and filtered colour of water, (i.e. unfiltered colour subtracted by filtered colour of water). This comparison was meant to eliminate the effect of the filtered colour of water, which was not expected to correlate with turbidity itself.

TOC was measured with a combustion method with the reference SS-EN ISO 20236:2021 with a measurable range between 0.5-100 mg/L and an uncertainty of 0.4 mg/L and 10 % (SLU 2025). Turbidity was measured with a photometry method conforming to SS-EN ISO 7027-1:2016. The method is used for a range between 0.2-250 FNU with an uncertainty of 0.26 FNU and 13 % (SLU 2025).

2.2.4 pH and temperature

pH and temperature sensor properties

Measurements of pH and water temperature were made on site with a waterproof pH tester (HI98128) produced by Hanna Instruments, here and after called a small pH sensor. According to the manufacturer this pH tester can measure pH within a range of -2.00-16.0 pH with a resolution of 0.01 pH, and temperature within a range

of 5.0 – 60.0 °C with a resolution of 0.1 °C. The measurement's accuracy depends on temperature and correct calibration; the manufacturer has defined the accuracy to be ± 0.05 regarding pH at 25 °C and 0.5 °C regarding temperature. The pH meter automatically compensates the pH measurements for temperature. To ensure accurate measurements the manufacturer recommends calibration at least once a month (Appendix 4).

Procedure

The measurement is simply performed by turning on the tester and placing the top of it in the water, covering both the thermometer and pH electrode. The results can then be read when the numbers on the screen have stabilised.

For practical reasons, water was sampled with a plastic beaker from the shoreline of each CW, in which the pH measurement was then performed on site just after sampling. The pH electrode was stored in a buffered storage solution between the sampling rounds and calibrated ones every 1-2 months.

Comparison

Results from the small pH sensor were compared with measurements performed on site with a multiparameter meter (Hanna HI9829), a handheld field computer with a probe containing a thermometer and pH sensor among others, later referred to as the multiparameter pH sensor. This method contrasts with the other comparison methods used on site and is not accredited, yet accurate and used in the PuddleJump sampling. The sensor is suitable to measure pH within the range 0.00-14.00 pH units with a resolution of 0.01 pH units and an accuracy of ± 0.02 pH units. It is suitable in the temperatures between -5.00-55.00 °C and has a resolution of 0.01 °C and an accuracy of ± 0.15 °C (Hanna Instruments n.d.). It is however worth noticing that calibration issues were reported from the field staff before and during the sampling period of this project.

2.2.5 Alkalinity

Alkalinity sensor properties

Alkalinity was analysed in a research lab with an alkalinity sensor (HI775) produced by Hanna Instruments. The alkalinity sensor uses a colorimetric method developed for freshwater samples. The added reagent causes a reaction resulting in samples developing distinct colours from yellow, green to blue depending on the present amount of CaCO₃. (Appendix 5). According to the manufacturer the alkalinity sensor can measure within the range 0-500 ppm (as CaCO₃) with a resolution of 1 ppm. The accuracy of the alkalinity measurements is according to

the manufacturer ± 5 ppm and $\pm 5\%$ of reading at a temperature of 25 °C. Caution is recommended when applying the reagent, as any spill could inhibit the full colour development and thereby affect the uncertainty (Appendix 5). As with the phosphate sensor, ppm measurements were assumed to be equivalent to mg/L.

Procedure

Firstly, the sensor is turned on, and a 10 mL cuvette is filled with sample water. Secondly, the cuvette is inserted into the sensor, where it is zeroed by pressing the button. After this the cuvette is removed, one drop of chlorine remover (H193755-53) is added to avoid potential interference, as well as 1 mL of the reagent (HI775S). The cuvette is then closed, gently inverted 5 times and wiped off to ensure it being dry before inserting it into the sensor. Lastly, the measurement is carried out by closing the sensor and by pushing the button and recording the results. The full procedure for the sensor can be found in Appendix 5. No adjustments to the method were made.

Comparison

Results from the alkalinity sensor were compared with measurements of electrical conductivity performed by the accredited laboratory using the Determination-of-electrical-conductivity-method according to SS-EN 27888, Ed.1. With the measurable range between 0.1-150 mS/m and an uncertainty of 0.4 mS/m and 5% (SLU 2025).

2.3 Data analysis

All statistical analyses were conducted using Microsoft Excel 2016. Analysis of the pilot round contained calculation of mean relative standard deviation of the triplicates for each SAM with triplicates. For the parameters with more than three samples above the detection limit an ANOVA was performed to quantify whether the variation between the triplicates was less than the variation between CWs.

Analyses of round one to four were performed for each parameter by plotting sensor or test strip values against the corresponding values from the accredited laboratory in a scatter plot. In some cases, a logarithmic transformation of the data was applied to better fulfil the criteria of a linear regression.

For each parameter, data from three to four sampling rounds of all 20 CWs were included. Missing data occurs in some cases either due to events when safety during sample collection could not be guaranteed due to cows, or zooplankton and cloudy water in the samples causing measurement errors.

DIC and EPCO₂ were modelled with the Thermodynamic modelling of inorganic carbon in freshwaters (THINCARB) model (Jarvie et al. 2017) using the software R version 4.5.1. The results were then transferred to and analysed in Excel.

2.4 Quality control of data

For each parameter, the full data sets were plotted and visually examined for outliers or other unexpected values. This was followed by an overview of field and laboratory observations per sample and CW, to identify whether any data needed to be excluded. Further quality control of data was executed before and during data analysis for each parameter separately.

Nitrate

The quality control of phosphate included an analysis of laboratory observations to identify any common factors that could explain unexpected underestimations. Furthermore, to identify potentially erroneous data sets, a series of linear regressions were conducted, with each iteration excluding a single sampling round.

Phosphate

The quality control of phosphate included an analysis of laboratory observations to identify common factors contributing to false negative results and overestimation of samples. Furthermore, upon observing the potential interference effect of cloudy samples, additional measurements were executed with five filtered samples in the later sampling rounds.

A visual inspection of results from the lineal regression of the full dataset led to the conclusion that the only three samples measuring concentrations above 0.05 mg/L were from the same CW. These three measurements highly affected the results. Therefore, a new linear regression was executed excluding the samples in question.

Colour of water

The measurements for unfiltered and filtered colour of water were compared to ensure that within one sample, the filtered colour of water was equal to or less than the unfiltered colour of water. This procedure was implemented to ensure that incorrect cuvettes had not been utilised.

pH

Potential outliers were compared with the CW mean measured by the multiparameter. One outlier was excluded from the analysis due to an unexpectedly high difference from the mean pH of the CW.

Alkalinity

In view of the unexpected differences in variance in the correlation between alkalinity and conductivity, the results of the present study were compared with accredited lab measurements of alkalinity and conductivity obtained from CWs in another study.

2.5 Landowner survey

With the aim to understand potential users' interest in cheaper water quality tests and sensors with immediate results, a short pilot survey was performed. The survey was conducted as a part of PuddleJump's landowner day on 26 November 2025, where all landowners in the project were invited to participate. In total 12 participated in the survey, some representing the same CWs. The participants were a mix of private landowners and water professionals acting on behalf of landowners. The presentation and survey were conducted in Swedish to reduce obstacles and increase engagement as the landowners all speak Swedish as a first language. The answers were analysed in Swedish and only summaries and conclusions were translated to English.

Firstly, there was a short presentation about the project's aims, method and preliminary results, including time for the landowners to ask questions. Secondly, the landowners were given a digital questionnaire (see Table 3) to answer individually. An analogue option was available, and two participants replied on paper. At last, a summary of the answer to each question was displayed and the landowners were given the chance to, comment or explain their answers. The concluding conversation was documented by notes on paper during and right after the conversation.

The volunteering respondents are landowners and water managers who both are a part of a research project and took the time to participate on the landowner's day. Due to the small number of participants and the mentioned bias in respondent selection, the responses cannot be considered representative of landowners more broadly. Their perspectives and answers can however give valuable insights for further understanding to investigate potential users interest. The results from this survey were therefore analysed in a qualitative manner.

Table 3 Landowner survey question and response options translated to English.

Question	Response options
Would you be interested taking your own water samples and get less certain but immediate results?"	Yes/No
Do you think you would find these water quality tests useful for:	Multiple selection possible a) Communication with municipality and government agencies, b) Support management decisions, c) To better understand wetlands and water bodies, d) Something else... (free text answer)
What factors do you think could stop you from using this type of simpler sampling?	Multiple selection possible a) The time required to learn how to use the tests, b) The purchase cost, c) Little need for the results, d) Uncertainty in the results, e) Something else... (free text answer)

3. Result

3.1 How suitable are the simpler analysis methods for citizen science and water management?

3.1.1 User-friendliness

The first part of the pilot study aimed to evaluate the user-friendliness, this evaluation took into account the following factors: time to execute the analysis of one sample, number of steps in the analysis, whether safety equipment is needed and how the reacted sample and reagents can be safely disposed. The financial implications of these SAMs, including their initial purchase cost and the cost of each analysis, were also compiled.

The results for each factor and SAM are summarised in the following paragraphs and in Table 4 below. The nitrate sensor required the greatest time, followed by the phosphate sensor, due to the number of steps and waiting times included in these analyses. Except for the pH analysis, which involved a single step, and the nitrate sensor, which necessitated a total of 10 steps, the number of steps in the analyse was similar (i.e. 5). However, nitrate strip has 3 steps (Table 4).

It is also worth noting that two of the sensors, nitrate and phosphate, require safety equipment and precaution. Users need to be aware of handling the reagent appropriately to protect their respiratory organs from the reagent. The same analysis methods produce reacted samples classified as hazardous waste (Safety data sheet available at <https://sds.hannainst.com/vi>). In contrast, the remaining methods require no safety equipment, and all residues after analysis can be safely disposed of either in the sink or as burnable waste.

3.1.2 Cost

All sensors are in a similar price range with smaller differences in purchase price, price per sample and calibration costs. A rounded summary of all cost is presented in Table 4. In terms of purchase price, the nitrate strips stood out because this method does not require a sensor and therefore only costs per test strip. The pH sensor was the most expensive to buy but costs nothing per test. However, the need for calibration once a month means that the price per sample varies, depending on how many samples are taken. Furthermore, the alkalinity analysis costs more per sample due to more costly reagents, while colour of water was the cheapest as no reagents are needed and low-cost filters are used. However, the number of filters

that are needed for satisfying results varies and depends on the cloudiness of the sample.

Nonetheless, this is a rounded summary based on costs of purchase for the tested SAM made through a university laboratory in year 2025, therefore, costs may vary. It is also worth noting that, when purchasing the different sensors, reagents for various numbers of samples were included in the starter pack.

Table 4 Evaluation of user-friendliness and costs for each SAM. (Time and number of steps do not include collecting the water sample. Costs are approximate and rounded based on prices in 2025.)

	Phosphate	Nitrate sensor	Nitrate strip	pH	Alkalinity	Colour of water
User-friendliness						
Time (min)	~10	~15-20	~2	~2	~5	~5
Nr of steps	5	10	3	1	5	5
Safety equipment	Yes	Yes	No	No	No	No
Disposal	Hazardous waste	Hazardous waste	Burnable	n/a	Sink	Burnable
Costs (SEK)^{a)}						
Sensor	1100 ^{b)}	1100 ^{c)}	0	2000	1100 ^{b)}	1500
Per sample	10	10	10	0	25	0.5-1.5
Per calibration				45 ^{d)}		
Summary	Moderate	Low	High	High	High	High

a) Note that the materials for this project were purchased via a university laboratory, costs may vary. b) Cost of sensor includes reagent for 6 analyses, c) Cost of sensor includes reagent to 25 analyses, d) Calibration ones per month with calibration buffer solution.

3.2 How accurate are the simpler analysis methods?

This study comprises two parts to evaluate the accuracy of the SAMs. First, a pilot study tested replicability by conducting three replications of each SAM sensor for a subset of CWs. This was followed by the main study, in which all parameters were analysed by the SAMs in all 20 CWs across three sampling rounds. Results from the pilot round and main study will be separately presented.

3.2.1 Triplicates and replicability

Triplicate analyses were successfully taken for the colour of the water (both filtered and unfiltered), alkalinity, and phosphate. Table 5 shows a summary of the number of samples analysed, the number of samples above the detection limit, and the mean relative standard deviation. Phosphate was only detected in one of the seven CWs where triplicate measurements were taken. The dataset was therefore not suitable for further statistical analysis. Alkalinity and colour were detected in all triplicate samples tested. Results from an ANOVA, summarised in Table 6, showed that almost all the variation was between the CWs.

Table 5 A summary of the results of the pilot study. Including number of samples, samples above the detection limit, and the mean relative standard deviation per parameter.

Parameter	Nr of CWs analysed	Nr of samples above detection level	Mean Relative Standard Deviation %
Colour of water (Unfiltered)	10	10	9.2
Colour of water (Filtered)	10	10	14.7
Alkalinity	5	5	0.8
Phosphate	7	1	5.1

Table 6 A summary of the triplicate samples ANOVA.

Parameter	F	df between	df within	p	% between CW variation
Alkalinity	7013.40	4	10	3.45E-17	100.0%
Colour of water (Filtered)	185.88	9	20	2.79E-17	98.8%
Colour of water (Unfiltered)	365.95	9	20	3.44E-20	99.4%

3.2.2 Accuracy compared to professional methods

The main study involved sampling and parallel analysis using SAMs and professional, mainly accredited, methods. The obtained dataset from both methods for each parameter will here be presented in a pairwise comparison using scatter plots. Analyses results from linear regression, ANOVA, visual inspection of scatter plots and data quality control will also be presented.

Nitrate

The findings obtained from nitrate strips demonstrate a strong correlation with those derived from the accredited lab except for strip measurements conducted on

cooled samples. The obtained results, however, demonstrate a systematic overestimation

A comparison of all results from the nitrate strips and the accredited lab, is presented in Figure 2. It is worth noting that some unexpected false negatives and large underestimations were observed. Furthermore, all underestimations occurred within the same sampling round (round 3) and may be associated with measurements conducted on water samples that were too cold.

An exclusion of data from sample round 3 (Figure 3) enhanced the correlation and resulted in an increased R^2 value. The exclusion of any other sampling round resulted in a decrease in R^2 , (Table 7).

Noticeable in both figures is that the strips generally overestimated the nitrate concentration more than the expected error, with an increasing error with higher concentrations.

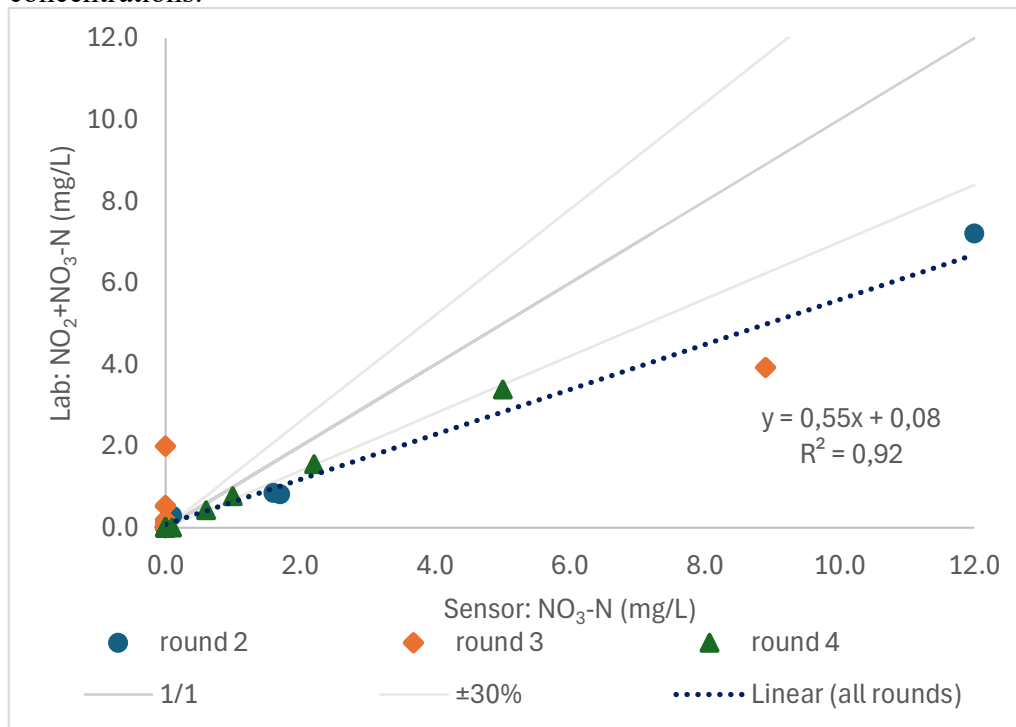


Figure 2 All nitrate samples, accredited lab measurements plotted against strip measurements, including a linear regression line (dotted), data points colour coded based on sampling round, 1:1 line in dark grey and expected error range $\pm 30\%$ in marked with grey lines.

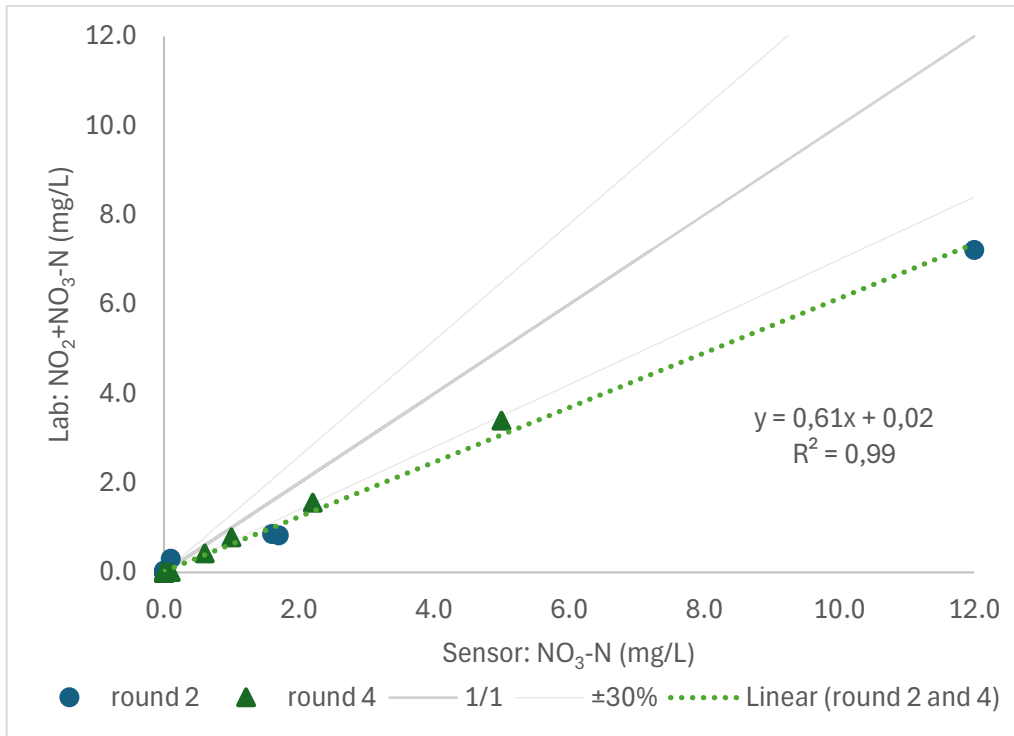


Figure 3 All nitrate samples, excluding round 3, accredited lab measurements plotted against strip measurements, including a linear regression line (dotted), data points colour coded based on sampling round, 1:1 line in dark grey and expected error range $\pm 30\%$ in marked with grey lines.

Table 7 Summary of linear regression results, showing changes in R^2 when one sampling round at a time was excluded, as well as when no round was excluded (-).

Excluded round	R^2	Y
-	0.92	$0.55x + 0.08$
2	0.82	$0.49x + 0.13$
3	0.99	$0.61x + 0.02$
4	0.91	$0.53x + 0.10$

Phosphate

The results of the phosphate analysis conducted using the sensor and the AL, as illustrated in Figure 4, demonstrate that the data is distributed unevenly, with the majority of measurements falling within the lower range and only a few recorded in the higher measurable range. Moreover, the dataset contains both several false negatives and large overestimations.

Out of the 20 CWs, the sensors detected phosphate in 6 CWs while the accredited lab detected phosphate above the sensor's detection limit, $10 \mu\text{g/L}$, in 11 CWs. Out of the 11 CWs only three CWs had measured phosphate levels above 0.04 mg/L . This means that most of the false negatives are within the sensor's expected error

(± 0.04 mg/L and 4%). Also, most of the overestimations are within the margin of expected error (± 0.04 mg/L and 4 %).

While most measurements are within the margin of error it is noticeable that they cannot be described as normally distributed. The correlation can rather be described as three linear groups, false negatives; underestimations; and overestimations (see Figure 5). It needs to be highlighted that the three highest measurements, all from the same CW, have a significant impact on the regression line.

Results from a linear regression of the same dataset excluding data from that specific CW is presented in Figure 5. As a consequence of excluding these values, the false negatives and unevenly spread data become more prominent with a very low correlation ($R^2 = 0.2$).

Plankton and cloudy samples were identified as potential interference factors during the analysis. These factors are likely to interfere in several ways, e.g. plankton moving within the sample, or cloudiness in the sample that often precipitated and sedimented because of adding the reagent to the sample. Even though all interference factors were noted together with the measurements, no clear pattern of their effect on the results could be identified during the data quality check. Out of the five samples that were remeasured with filtered samples due to plankton or cloudiness, four became closer to the lab value and one resulted in a larger error.

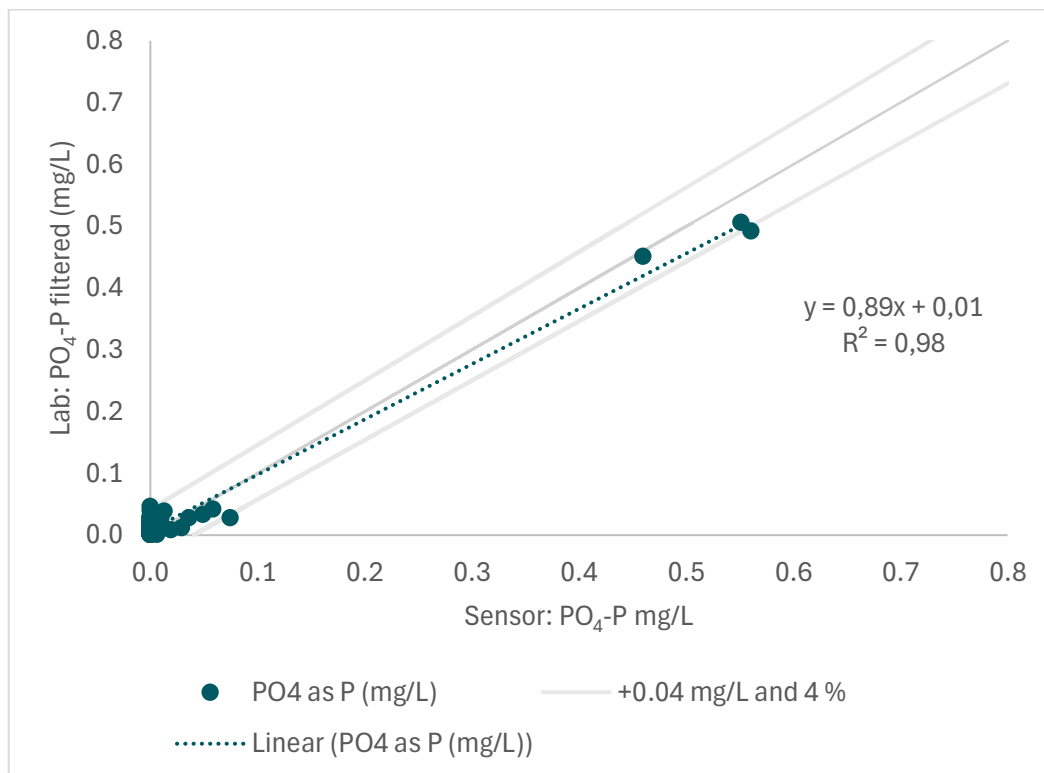


Figure 4 All phosphate samples, accredited lab measurement plotted against sensor measurements, including a linear regression line (dotted), 1:1 line in dark grey and expected error range (± 0.04 mg/L and 4 %) in marked with grey lines.

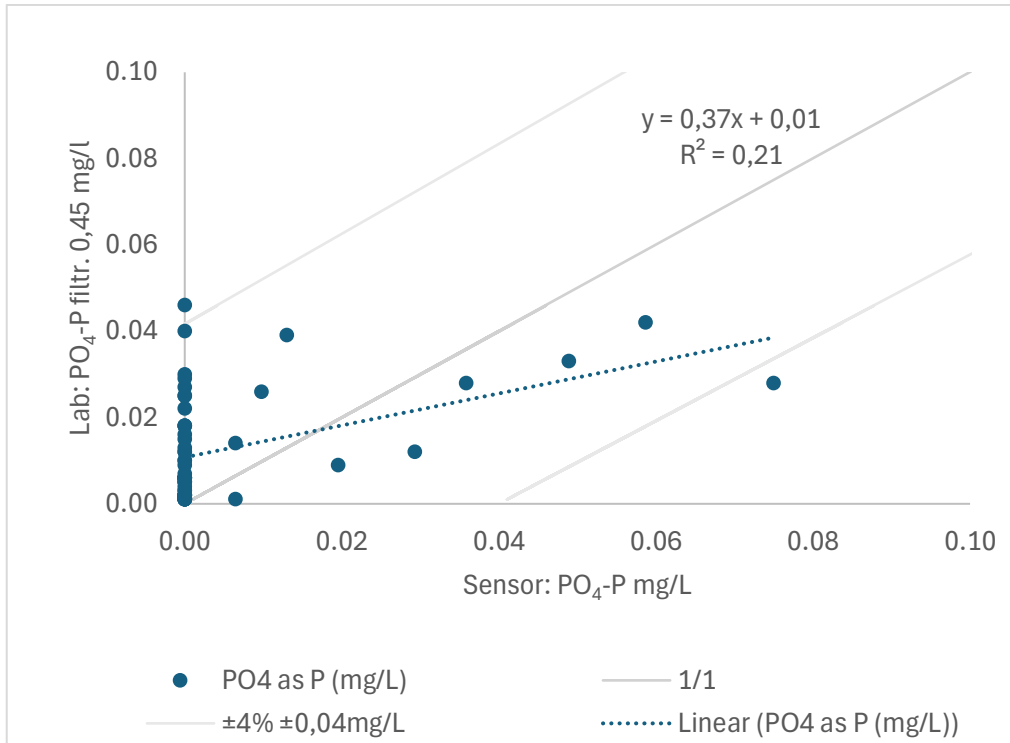


Figure 5 All phosphate samples excluding values for one CW due to their impact on results, accredited lab measurement plotted against sensor measurements, including a linear regression line (dotted), 1:1 line in dark grey and expected error range (± 0.04 mg/L and 4 %) in marked with grey lines, excluding values for one CW due to their impact on results.

Colour of water

Colour of water, especially filtered measurements, was expected to correlate with TOC while unfiltered colour of water was expected to correlate with turbidity. The results of the correlation analysis of filtered colour of water samples and TOC are presented in Figure 6. It is noteworthy that the residuals above the regression line exhibit a large and uneven variation, while the residuals below the regression line demonstrate lower and more uniform variation. Further the same figure indicates that filtered colour of water could be linearly related to minimum TOC.

Figure 7 presents results from a comparison between unfiltered colour of water and TOC, showing a larger and more uneven variation and a slightly lower correlation than the comparison with filtered water.

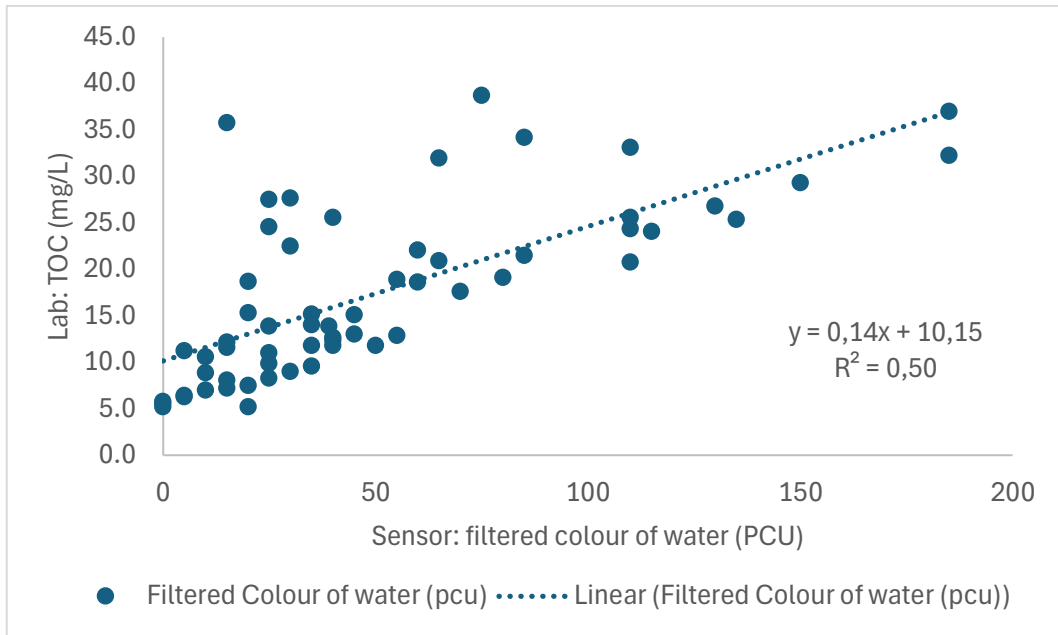


Figure 6 All filtered colour of water sensor measurements plotted against Total organic carbon (TOC) accredited lab measurements, including a linear regression line (dotted). (PCU=platinum cobalt unit)

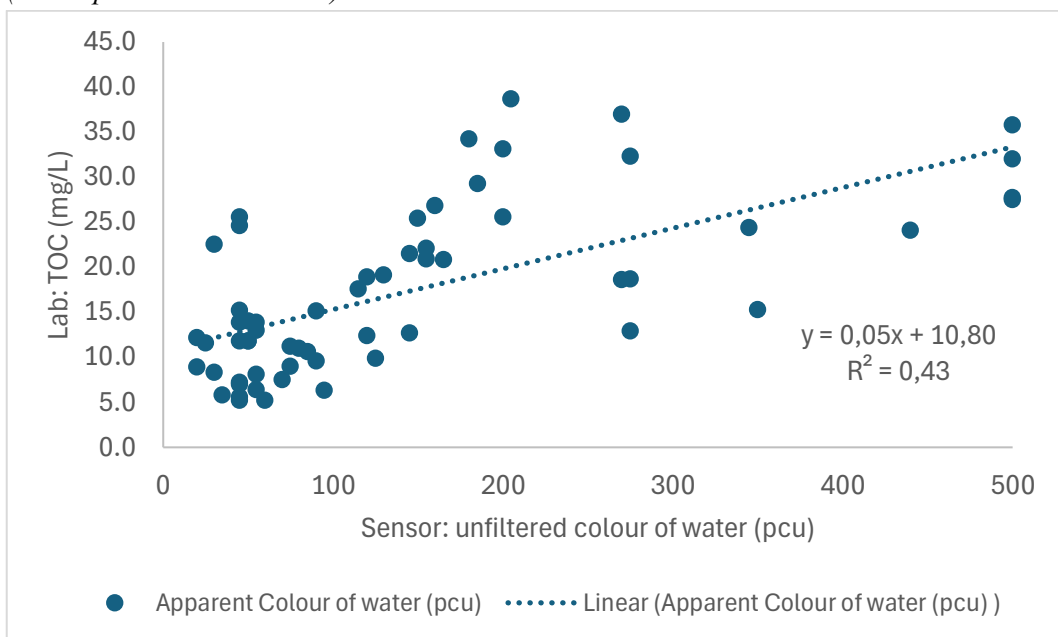


Figure 7 All unfiltered colour of water sensor measurements plotted against total organic carbon (TOC) accredited lab measurements, including a linear regression line (dotted). (PCU=platinum cobalt unit)

Moreover, Figure 8 presents the results of the linear regression of logarithmically transformed data from unfiltered colour of water and turbidity. Figure 9 presents results of the logarithmically transformed linear regression between the turbidity data (on the y axis) and difference of filtered and unfiltered colour of water (on the x axis). The results show a relatively high correlation in both cases ($R^2 = 0.64$)

respectively $R^2 = 0.66$). However, figure 8 shows a more evenly distributed residual variation, indicating unfiltered colour of water could be a proxy for turbidity.

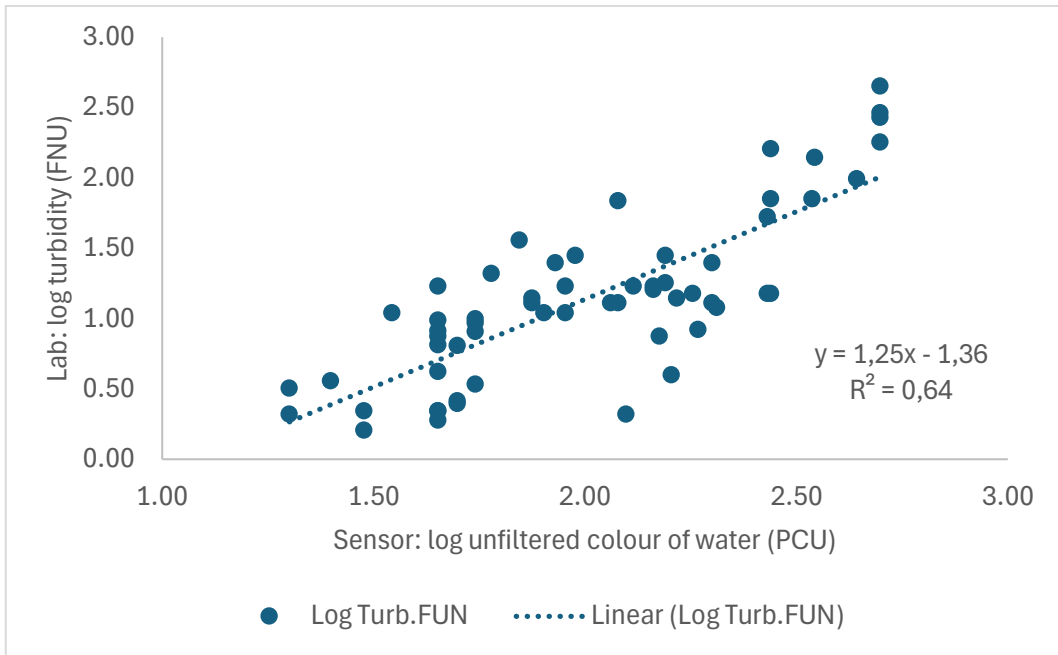


Figure 8 All unfiltered colour of water sensor measurements logarithmic transformed and plotted against logarithmic transformed accredited lab measurements of turbidity, including a linear regression line (dotted). (FUN=Formazin Nephelometric Units, PCU=platinum cobalt unit)

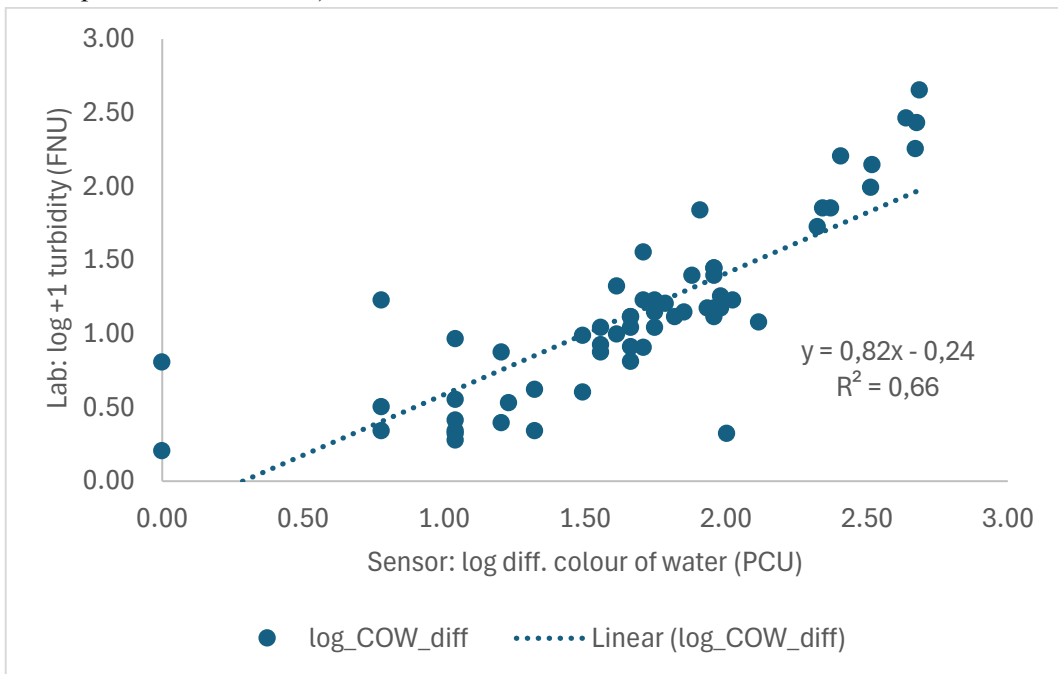


Figure 9 Comparison of the difference between unfiltered and filtered colour of water (COW) sensor measurements to accredited lab measurements of turbidity, logarithmic transformed, including a linear regression line (dotted). (FUN=Formazin Nephelometric Units, PCU=platinum cobalt unit)

pH

Figure 10 visualises the comparison between results from the small and the multiparameter pH sensor. Table 8 shows the summary of the result from the one-sided ANOVA conducted on both datasets. Firstly, it is worth noting that the results show a relatively low correlation ($R^2 = 0.7$) when comparing the measurements taken by two pH sensors. The observed differences seem to be systematic and increases with higher pH.

Results from the ANOVAs shows a higher total variance in the dataset obtained with the small sensor than the multiparameter sensor. Further the analysis of both datasets shows a higher variation between the CWs than within the CWs. This difference is however smaller in the dataset obtained from the small sensor (66%) compared to the multiparameter sensor (78%).

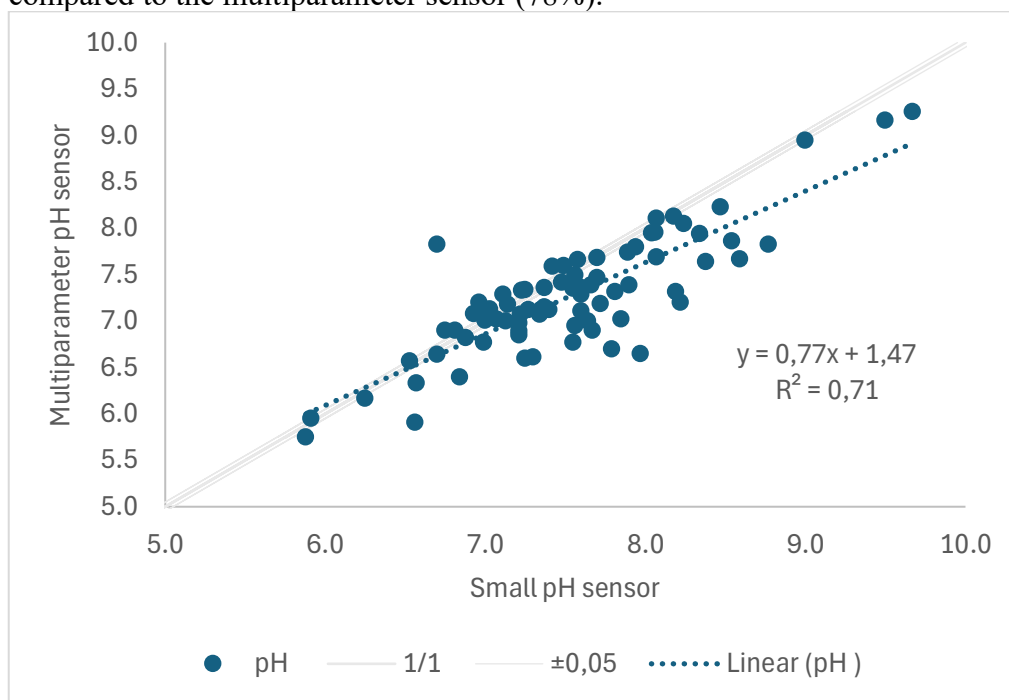


Figure 10 Comparing measurements between the small pH sensor and the multiparameter pH sensor, including a linear regression line, 1:1 line and expected error (± 0.05 pH) in grey.

Table 8 A summary of the ANOVA comparing the two pH methods.

Parameter	F	df between	df within	p	% between CW variation
pH (small)	6.2	19	59	2.91E-08	66.6%
pH (multiparameter)	10.91	19	59	5.76E-13	77.8%

Alkalinity

Results from the comparison between the alkalinity sensor measurements and the accredited laboratory measurements of conductivity are presented in Figure 13 and

with logarithmically transformed data in Figure 14, both including a linear regression line. The logarithmically transformed data shows a higher correlation ($R^2 = 0.88$). It is noteworthy that the variation is noticeably higher at an alkalinity level of 100-200 (mg/L CaCO_3), indicating that the relationship cannot be adequately described as linear. In the logarithmically transformed plot, the change in variation becomes less prominent, but still remains. Further, results from the ANOVA show that most of the variance occurs between the CWs for both data sets, see Table 9.

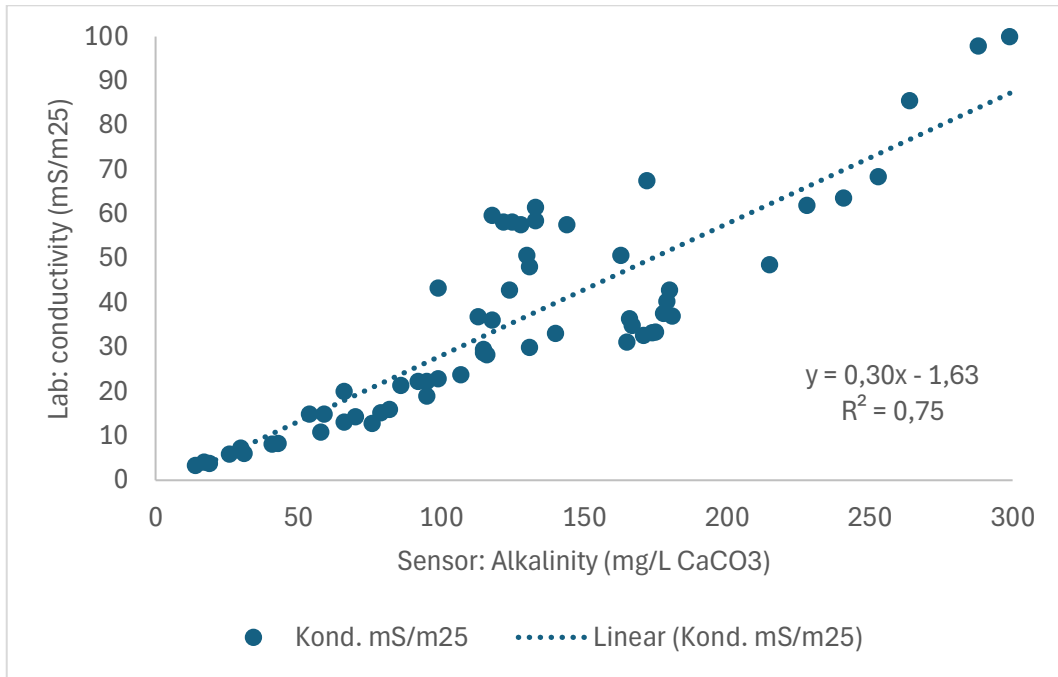


Figure 13 A comparison of sensor measured alkalinity plotted against accredited lab measurement of electric conductivity, including a linear regression line (dotted).

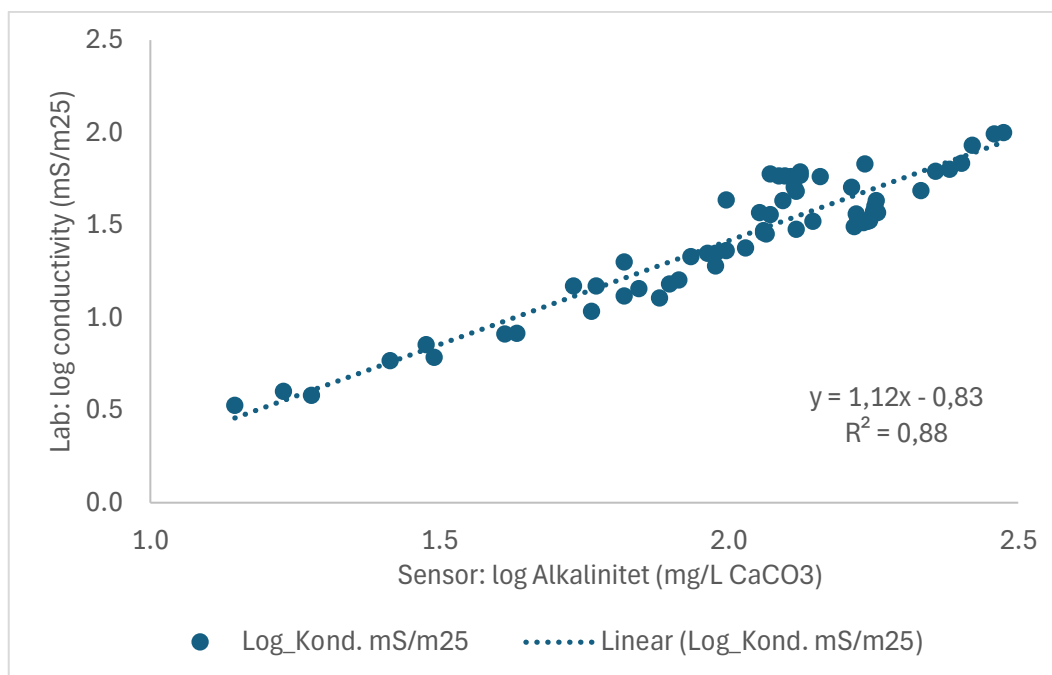


Figure 14 A logarithmically transformed comparison of sensor measured alkalinity plotted against accredited lab measurement of electric conductivity, including a linear regression line (dotted).

Table 9 A summary of the ANOVA comparing alkalinity and conductivity measurements.

Parameter	F	df between	df within	p	% between CW variation
Alk.	56.67	19	40	5.07E-23	96.4%
Kond.	84.81	19	40	2.23E-26	97.6%

3.3 Estimate of dissolved inorganic carbon

The CWs' carbon dioxide saturation ($EpCO_2$) and dissolved inorganic carbon (DIC) were estimated using the THINCARB model (Jarvie et al. 2017), deploying sensor measurements of alkalinity, pH and temperature. Modelling results are presented per CW in Figure 13 ($EpCO_2$) and Figure 14 (DIC), arranged from lowest to highest according to lowest estimated $EpCO_2$.

Low saturation ($EpCO_2$ below one, Figure 13) indicates that the CW is likely to be a net CO_2 sink, while supersaturation (values above one) is likely to indicate that the CW is a net CO_2 source. The results suggest that some of the CWs are a possibly CO_2 sink, while others are likely to be a source; it is harder to determine the rest.

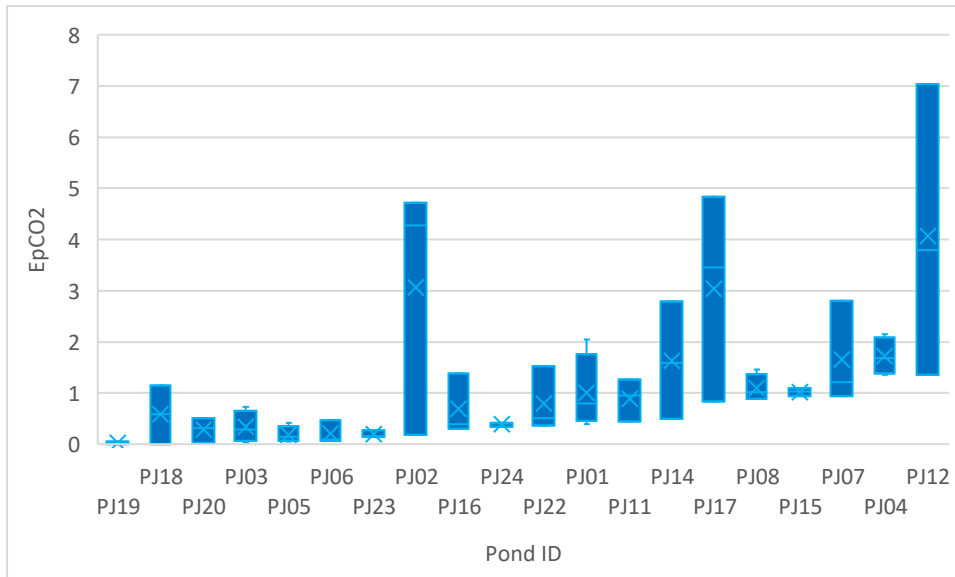


Figure 13 Modelled carbon dioxide saturation ($epCO_2$) presented per constructed wetland (CW), the bars represent the maximum and minimum simulated $epCO_2$ while x represent the CW mean. (The water is saturated when $epCO_2=1$)

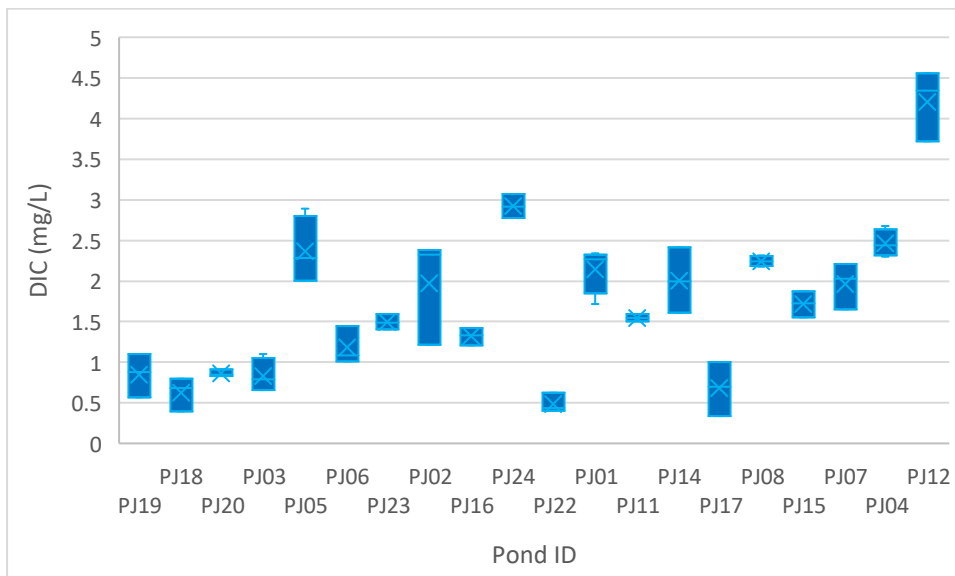


Figure 14 Modelled Dissolved inorganic carbon (DIC). The bars represent the maximum and minimum simulated DIC while x represent the CW mean.

3.4 Landowner interest

The results of the landowner survey will be summarised here for each question. Due to the low number of respondents and the bias introduced by asking landowners who are already involved in a research project, the results will not be presented quantitatively. All survey responses can be found in Appendix 6. Respondents were

not asked whether they were private landowners or water professionals. Hence, the answers cannot be linked or analysed based on this.

The answers to the first question, showed a mixed interest among the respondents in taking and analysing their own water samples which provides immediate but less certain results. The majority was however interested.

The second question focused on areas of application where the respondents would find the sensors and tests useful. Respondents had multiple choice and an option for a free text answer. No one chose the option “to support management options”. The most common answer was “to better understand wetlands and waterbodies” and fewer chose “communication with municipality and government agencies”. One respondent provided the following free text answer: “As a tool in biology and chemistry education to easily conduct experiments on water quality”.

The replies were more varied for the last question, asking about factors that could stop them from using this type of simpler sampling. The most common answer was “uncertainty in the results” The alternatives: “The time required to learn how to use the tests”, “the purchase cost” and “little need for the results” all got responses. One respondent provided the following free text response “lack of time”.

In the closing conversation, it emerged that at least one of the respondents already monitored the water quality using methods that provided greater certainty in the results than the simpler sensors and tests. Another respondent commented that they were using the phosphate sensor in chemistry and biology education and had also noticed a lower accuracy in low concentrations. At last, one respondent asked if there were also test strips for phosphate available.

4. Discussion

This study aims to explore the potential of using simple, low-cost tools to measure water quality and give insight into eutrophication potential and climate impacts of constructed wetlands. The three research questions presented above will be discussed in the following order 1) How suitable are the water quality tests for citizen science and water management? 2) How accurate are the results of simpler analysis methods for water chemistry in the context of constructed wetlands compared to analysis done by an accredited laboratory? 3) How could accuracy and suitability of the simpler methods be improved? The answers to question 1) and 2), will be discussed including suggestions for further studies and improvements, followed by a summary of the main findings and a conclusion.

4.1 How suitable are the simpler analysis methods for citizen science and water management?

The suitability of SAMs for citizen science and water management is dependent on their user-friendliness. User-friendliness was evaluated based on the following factors: analysis time; how many steps were in the analysis as an indicator of complexity; whether safety equipment is needed or not; and how the analysed sample and reagents can be safely disposed (Table 4). Furthermore, the investment cost and cost per sample were considered.

To summarise the evaluated sensors measuring parameters related to GHG (colour of water, alkalinity and pH) as well as the nitrate strips together with the Deltares app were estimated to have a high user-friendliness. The sensors measuring nutrients were less user-friendly. The nitrate sensor had a low user-friendliness, and the phosphate sensor had moderate user-friendliness (Table 4). While phosphate was judged to be user-friendly enough for citizen science or management use, the nitrate sensor was excluded from further evaluation.

Time and simplicity

The nitrate strips and pH sensor stand out in terms of both the short time of analysis of a sample and how easy the method is to execute. Furthermore, the app used for scanning the nitrate strips includes features such as saving data in a standardised format, allowing the measurement value to be supplemented with metadata, enabling data sharing, (Deltares n.d.b) and providing instructions that were considered easy to follow. All these functions of the app for use with nitrate strips are identified (Kelly-Quinn et al 2023) as characteristics that methods used for citizen science projects should have if they are to be successful. In contrast, none

of the other SAMs tested in this study include a solution for saving or storing the results. Instead, results must be manually recorded by the user.

Although there were protocols in the sensor manuals (Appendix 1-5), these were not always clear and used a complicated vocabulary. However, there are video tutorials provided by the producers and freely available online (e.g. by searching for the sensors name on YouTube) which are easy to follow. These weaknesses, however, are more a matter of how and in what context of citizen science or water management the sensors are used than weaknesses in the sensors themselves. These shortcomings could be resolved by means of a clear, complementary protocol and a standardised way, preferably digital, to store and share data, developed by the project managers.

Although the pH sensor was simple to use for making measurements, it stands out with its monthly calibration requirements. Compared to the other sensors which only require cleaning the cuvettes after use.

The THINCARB modelling (Jarvie et al. 2017), was in this study conducted using the software R version 4.5.1. It can also be run in other software but that requires prior knowledge in coding, which cannot be considered suitable for citizen science. The model would need to be made accessible to people without experience in statistical programs or coding. This could, for example, be executed through creating an app or website where measurements can be entered and modelled estimates can be obtained. This could also be used to quality assure the calculations and reduce the risk of individual users using the model incorrectly.

Safety

Personal safety for samplers is always important, and even more so if they are non-professionals and are sampling voluntarily also pointed out by. It is therefore concerning that the reagents used in the sensor methods for measuring nitrate and phosphate can be harmful for humans in different ways. To minimize the health risks related to the use of these reagents, all analyses were conducted under a fume hood based on advice from the lab manager. However, one cannot assume that citizen scientists or water managers will have access to a fume hood or equivalent. If used as a combination of citizens science and education, it might be more likely that a fume hood can be used.

Furthermore, it is easy to argue that environmental monitoring of water quality should not release anything that could harm the aquatic environment. It is therefore concerning that the above discussed reagents must be disposed of as hazardous

waste. Proper disposal requires knowledge and access to appropriate disposal services.

To increase the range of citizen science applications of the phosphate sensor proper health and safety guidance must be developed alongside the analysis protocol. This need related to the Hanna Instrument phosphate sensor has also been identified by CaSTCo (The Catchment Systems Thinking Cooperative) who are hosting a method library for citizen science at their webpage (CastCo n.d.).

Cost

The cost per sample (0.5-10 SEK) using the SAMs is low compared to analysis performed by an accredited or professional lab. Nonetheless the price per sensor (1100-2000 SEK) could, depending on the user, be seen as a high investment cost. For an individual or small landowner, the low price of the sensors may be decisive to measure water quality at all, or to begin doing so regularly. However, to consider them affordable, one must know how to interpret the results and understand their applications. If these methods are used without guidance on how to use them, as well as how to save and interpret the results, additional resources in the form of time are required to learn. Results from the landowner survey indicate that time to learn and use the sensors as well as little need for the results are factors that could stop them from start using this type of SAMs. This required time could reduce the affordability of the sensors compared to paying for a professional laboratory analysis.

However, in the context of an environmental monitoring project led by researchers, a government agency or an NGO, the purchase cost could be seen as more affordable. For those organisations, the question might be where and how many water quality measurements can be afforded rather than whether to measure at all. Further, time to develop guidance and protocols can as pointed out by Kelly-Quinn et al. (2023) not be neglected in citizen science projects neither. However, each user of the method does not have to spend as much time. While considering the cost of time, it can therefore be concluded that the sensor method is more affordable in an environment project context than for a single user.

4.2 How accurate are the simpler analysis methods?

What is accurate “enough” depends on the purpose, but in some cases cheap, approximate data may be better than no data at all. What is enough depends on the question asked and the precision needed, what a suitable method is, therefore, has to be judged on a case-by-case basis.

While the nitrate strips, phosphate and pH sensor were compared to accredited laboratory measurements of the same parameter, the other sensors were compared to laboratory measurements of related parameters. The comparison between lab and SAM were expected to show a linear relationship of one to one and high correlation for the first ones, while the later were expected to show a less prominent correlation and might not show a linear relationship.

Further, each parameter will be discussed in more detail, focusing on what worked and what did not work as well as what needs to be considered when evaluating the use of sensors.

4.2.1 Nitrate

Comparing results from the scanned nitrate strips and the accredited lab, it shows a consistent overestimation slightly larger than the expected $\pm 30\%$. The consistency in the overestimation is promising for the use of this method as an indicator in monitoring, even though the overestimations were larger than the expected. Worth to notice is however the methods sensitivity to shadow and cooled samples, as well as the time between when the strip was dipped and scanned in the app.

The methods sensitivity to cooled water samples previously pointed out both by Deltares (Deltares n.d.a) and Kjærnegaard (2019), became noticeable in the results of this study. In the comparison between strips and accredited lab measurements round 3 stood out with several large underestimation and false zero measurements. This can probably be explained by the fact that the samples were taken from the cooling room a shorter time before analysis than in the other rounds, meaning they were cooler when analysed. Further the comparison of R^2 values while excluding one round at the time from the linear regression, shows a higher correlation when round 3 is excluded and a lower R^2 when the other rounds are excluded, presented in table 7. This finding confirms a previously reported temperature sensitivity of the method (Kjærnegaard et al. 2019).

Previous studies have also shown that except for temperature, time between dipping the strip in sample water and scanning it with the app can have a substantial impact on the accuracy of results (Kjærnegaard et al. 2019; Deltares n.d.a). It is therefore reasonable to assume that the consistency in the results shown in figure 3 partly can be explained by the consistency in temperature and scanning time. Hence, it needs to be underlined that the current study carried out the nitrate measurement in a laboratory at approximately $20\text{ }^\circ\text{C}$ and not in the field. Use of this method in field might give less consistent result than this study. These findings further stress the

need for a robust protocol which is easy to follow consistently and where those factors are considered.

Different recommendations have been developed to improve the use of the app method and thereby the reliability of the results. Deltares (n.d.a) showed that scanning 60 seconds instead of 30 seconds after dipping the strip, as used in the current study, decrease the effect of temperature. Kjærnegaard et al. (2019) showed that the mean of scanning at 30 and 60 seconds together with replicates of the method can increase the accuracy even more. The same authors recommend that samples should have a temperature between 4-10°C.

This method can, despite the relatively high expected uncertainty, be used as an indication of nitrate concentration, for example to identify hotspots and where to prioritise eutrophication measures. Such application of the method already exists in e.g. Denmark (Graversgaard et al. 2018).

4.2.2 Phosphate

Due to the limited range of phosphate in the samples tested in this study, it is hard to make any conclusions about the sensor in general. The results are uncertain but within the expected error at low concentrations of phosphate. It is also noteworthy that, according to the laboratory measurements, only one of the sampled CWs contained phosphate concentrations above 0.05 mg/L in any of the sampling rounds. This in relation to the sensor's measurable range being 0.01–2.5 mg/L, and the expected margin of error being ± 4 mg/L and ± 4 %. Thereby, most samples were within the measurable range and should be detected by the sensor, at the same time false zero measurement is within the margin of error.

Results in figure 4 and 5 showing both over- and underestimations including false zero measurements. While most both over- and underestimations is within the expected margin of error, they seem to be systematic. Cloudy or turbid samples as well as samples containing plankton and other debris were expected and noted to interfere with the measurement. All occurrence of such possible interfering factors were noted during the analysis. Nevertheless, no systematic pattern explaining the large overestimation could be identified.

Further, the extra measurements of filtered water which was done in the later rounds when cloudiness or turbidity was noted only summed up to five samples and could not be used to make any statistical conclusions. However, four out of five filtered samples gave results closer to the lab measurement, indicating that filtering can increase the accuracy. In addition, the accredited laboratory method used to analyse

phosphate, includes a filtering step using the same filter size as used in this study 0.45 µm. It would therefore be useful to conduct further studies comparing the accuracy of the results with and without filtered samples. Finally, it would also be useful to evaluate whether the Ultra Low Range phosphate sensor of the same manufacturer would give more reliable results in the lower range, relevant for oligotrophic environments.

Differences in temperature when the samples were taken, cannot be eliminated as possible explanations. However, no temperature measurements were taken alongside phosphate in the lab, and the manufacturer states that the sensor is calibrated at 25 °C. It is also worth to notice that no gloves were used during the preparation, and contamination of the samples during preparation cannot be excluded neither.

It is also worth to notice that even though no published literature evaluating the accuracy of using Hanna Instruments phosphate sensor was found, several citizen science projects are using or recommending the use of it (eg. Deltares, CastCo). In CastCo:s method library it is recommended to measure turbidity and temperature alongside phosphate measurements.

To summarise, the limited range of phosphate concentrations in the analysed samples is a limitation in this study. The phosphate results obtained show that the sensors measurement is systematically over- or underestimated but within the margin of expected error. The sensor could possibly be used to find phosphate hotspots in the landscape and as an indication of low concentrations. However, to confirm this further validation studies would be needed using samples which cover the whole measurable range.

4.2.3 Colour of water

While colour of water is expected to correlate with dissolved organic carbon, this was not a parameter measured in the accredited lab, hence the comparison with total organic carbon (TOC). Additionally, a comparison with turbidity was done. Of the filtered and un-filtered colour of water, the former showed the highest correlation with TOC, while unfiltered and the difference between un-filtered and filtered water could be related to turbidity.

Since the colour of water was not measured at the accredited lab, the data was validated by performing an ANOVA of the triplicate sample set from the pilot round (see Table 6). The results showed that almost all the variance (99.4%, $p < 0.01$) was between CWs rather than within triplicates. This confirms that the method can be replicated. However, high concentrations of iron in the water can interfere with this

method, since such concentrations give the water a colour on the PCU scale (Appendix 3).

Looking at the correlation between filtered colour of water and TOC, results from the linear regression indicated a moderate correlation ($R^2 = 0.49$). Further, the scatter plot in figure 6 shows a higher variance above than below the trendline, meaning the correlation cannot be considered linear. This high variance above the trendline can possibly be explained by occurrence of non-coloured dissolved organic carbon (e.g., Köhler et al. 2013). Nevertheless, there seems to be a linear relationship between filtered colour of the water and minimum TOC. This suggests that measurements of filtered colour of water could be used as a proxy for the minimum level of total organic carbon in small water bodies.

Looking at the correlation between unfiltered water and alkalinity, the log-transformed relationship was better fitted by linear regression than the non-log-transformed relationship for both the unfiltered colour of water and the difference between the unfiltered and filtered colour of water. Both showed a moderate correlation with turbidity, with comparable R^2 values of 0.64 and 0.66, respectively. This indicates that both could be used as a proxy for turbidity. However, unfiltered colour of water only requires one measurement, no filtering or calculation of the results, and is therefore more suitable for the context of citizen science and water management.

Based on the results and discussed in this study, measurements of filtered colour of water could be used as a proxy for minimum TOC, and unfiltered colour of water could be used as a proxy for turbidity. The application of those proxies is however only recommended to be indicative and should be interpreted with caution.

4.2.4 pH

A comparison of the two pH sensors reveals relatively high correlation ($R^2 = 0.71$) but given that both devices are intended to measure the same parameter in the same CW it can be considered unsatisfactory low. Considering that the evaluated sensor was compared with a field sensor and with higher certainty but not an accredited laboratory, it is hard to tell what the cause of the difference in results. Additionally, discussions with field staff indicated that the multiparameter pH sensor likely had calibration issues during parts of the sampling period.

Another methodologically source of error in the comparison between results of the pH sensors can be potential explained by the difference in where pH was measured. Water samples for the smaller pH sensor were collected in a beaker at the shoreline,

whereas the multiparameter pH sensor consists of a handheld computer and a probe, connected by a long cable, allowing it to be put directly into the water. Hence, the multiparameter sensor was placed at the surface bottom of each CW at a greater distance to the shoreline.

Results from the preformed ANOVA were less definitive. Nevertheless, the results indicated that the variation in pH was greater between groups (CWs) than within them.

The observed discrepancies between the two methods appear to be consistent. Based on this, it is not appropriate to compare measurements from the two different devices in this study. However, differences in pH could be monitored using each method separately. More consistent calibration could potentially increase the accuracy of both methods.

4.2.5 Alkalinity

Unfortunately, alkalinity was not measured in the parent project where this study was conducted. Alkalinity results obtained from the sensors was therefore, compared with conductivity measured in the accredited lab. Results from the alkalinity sensor show relatively high correlation with conductivity, especially after a log transformation of the data (figure 14 nr and $R^2 = 0.88$).

However, a concerning increase in the variance at an alkalinity level between approximately 100-200 (mg/L CaCO₃) were identified, meaning that results could be less certain in this range. A comparison of alkalinity and conductivity data from another project also sampling Swedish constructed wetlands where both parameters were analysed in the accredited laboratory showed a similar correlation and pattern in variance (Futter et al. in prep). It can be deduced that this correlation pattern is indicative of a relationship between alkalinity and conductivity in CWs, as opposed to the possibility of unexpected errors in the sensor measurements.

Alkalinity could, based on the results in this study, be used indicatively and as a proxy for conductivity. However, to fully evaluate the accuracy of the alkalinity sensor, further studies would need to conduct a comparable study where alkalinity is measured in parallel by both sensor and accredited lab.

4.2.6 DIC & EPCO₂

The modelling of DIC and EPCO₂ employed results from alkalinity, pH and temperature measurements. Its accuracy is therefore dependent on the accuracy of

those parameters and how appropriate the model equations are for Swedish conditions.

There is potential to model DIC using input data from these sensors. However, the modelled DIC and EPCO₂ in this study cannot be validated due to the lack of parallel measurements of DIC and CO₂. Further studies with parallel measurements of CO₂ flux and water analysis using the sensors used in this study are therefore needed to evaluate and validate their usefulness in modelling CO₂ flux. Validation could be achieved by taking water samples for analysis of alkalinity, temperature, and pH in parallel with dissolved CO₂ measurements from, for example, a Picarro sensor. This could allow refinement of the parameter values used in the Jarvie et al. (2017) model. Measurements of calcium concentrations should also improve the accuracy of the EPCO₂ predictions (Jarvie et al. 2017).

4.3 How could accuracy and stability be improved

In addition to the previously mentioned possibilities for improving suitability and accuracy and further validating the methods, several common areas for improvement were identified, and will here be discussed.

A general conclusion when analysing the accuracy of the sensors was that the samples obtained did not cover the sensors whole measurable range. Meaning, this evaluation's conclusion is only valid for the part of range covered. It is therefore in further validations important to include a broader range of samples. This can be obtained by measuring samples with known concentration. It is on the other hand valuable to, as in the current study, measure freshwater samples from constructed wetlands to evaluate their accuracy for this application. In order to reap the benefits of both approaches, it is possible to conduct measurements on freshwater samples spiked with a known concentration (Gawankar & Masten 2023).

Apart from validating a method, the accuracy of citizen science can be improved by making the method more suitable, for example by simplifying it and ensuring it is clearly defined (Bird et al. 2014). As the citizen science monitoring of water quality and chemistry by nature are more technical than e.g. ecological monitoring, appropriate training and protocols becomes more important. It is therefore important to learn from previous and ongoing citizen science projects, for example by using frameworks like the one developed by (Kelly-Quinn et al. 2023). Even though the SAM sensors in this study can be considered user-friendly, they require an introducing training to increase safely and accurate use. Furthermore, the sensor measurements have to be manually recorded, therefore storage and sharing of data in a standardised way is necessary complement. An example of how this can be

obtained was found in the nitrate app by Deltares, where the app except for scanning the strips makes it possible to store, and share collected data in a uniform format together with location and other meta-information.

4.4 Conclusions

In this study, the aim was to evaluate the potential for using simple, low-cost methods to measure water quality and give insight into eutrophication potential and climate impacts of constructed wetlands. This was done by assessing the SAMs user-friendliness and accuracy compared to accredited lab methods as well as how it could be improved. In this section the most important findings are summarised and general conclusions are presented. Further, more detailed conclusions for each SAM are separately presented.

The results of this evaluation showed that all SAMs evaluated in this study, except from the nitrate sensor could be suitable for citizen science and water management. However, to improve the suitability and accuracy, they would need to be combined with appropriate training of users, a robust protocol including safety routines, how to minimise known sources of error as well as system to report and store the obtained data. Examples of how much of these can be obtained was found in the evaluated nitrate app from Deltares.

Nitrate

The method using nitrate strips and the Deltares application is user-friendly and has a low cost per sample, but it also has a relatively high expected margin of error ($\pm 30\%$). Results from the current study showed a slightly higher but consistent overestimation, as well as false zeros due to cold samples. Previous studies have developed protocol recommendations to increase the reliability of the results. This was based on an assessment of the method's sensitivity to temperature and the time between dipping the strip in the sample water and scanning it in the app, indicating that training of users can increase accuracy. The conclusion is therefore that this method, together with training, can be accurate and suitable enough for use in water management and citizen science in an indicative manner, for example, to identify nitrate hotspots and to prioritise eutrophication measures.

Phosphate

In summary, the limited range of phosphate in the analysed samples is the main limitation of this study. The phosphate results show that the sensor's measurements are systematically over- or underestimated but remain within the expected margin of error. The sensor could potentially be used to identify phosphate hotspots in the landscape and to indicate high or low concentrations. However, to confirm this, further validation studies would need to use samples covering the entire measurable range. Furthermore, the phosphate sensor can become more suitable for water management and citizen science if used in combination with user training and a clear protocol, including safety and disposal recommendations. However, those protocols and training would need to be developed in further studies.

Colour of water

Results from the current study showed a relatively high correlation between filtered colour of water and minimum TOC, as well as between unfiltered colour of water and turbidity. It was also shown that a majority of the variation were between the CWs, confirming the methods replicability. The conclusion is therefore that measurements of filtered colour of water could be used as a proxy for minimum TOC, and unfiltered colour of water could be used as a proxy for turbidity. The application of those proxies is however only recommended to be indicative and should be interpreted with caution. The method is user-friendly and have a relatively low cost per sensor, and a very low cost per sample. The conclusion is therefore that the colour of water sensor method is suitable to apply in water management and citizen science.

pH

Results from the comparison between the two pH sensors showed a consistent discrepancy with concerning low correlation given that both devices are intended to measure the same parameter. Due to the comparison with a non-accredited method and calibration issues it was not possible to quantify the accuracy. However, it was shown that both methods had a slightly higher variance between CWs than among measurements taken in the same CWs. The conclusion is therefore that it is not appropriate to compare measurements from the two different devices. However, differences in pH could be indicatively monitored using each method separately. More consistent calibration could potentially increase the accuracy of both methods. Further, results shows that the pH sensor are user-friendly, have a relatively low cost per sensor and per calibration and no cost per sample. The conclusion is therefore that the sensor is suitable for application in water management and citizen science.

Alkalinity

Results from the alkalinity sensor show relatively high correlation with conductivity, especially after a log transformation of the data. Furthermore, it was shown that a majority of the variance was between the CWs, compared to within triplicates, confirming the methods replicability. Alkalinity measured by the sensor could, based on this be used indicatively as a proxy for conductivity. However, to fully evaluate the accuracy of the alkalinity sensor, further studies would need to conduct a comparable study where alkalinity is measured in parallel by both sensor and accredited lab. Further, results shows that the alkalinity sensor are user-friendly, have a relatively low cost per sensor and per sample. The conclusion is therefore that the sensor is suitable for application in water management and citizen science.

DIC and epCO₂

The modelling of DIC and EPCO₂ was using results from alkalinity, pH and temperature measurements. Its accuracy is therefore dependent on the accuracy of those parameters and how appropriate the model equations are for Swedish conditions. No parallel measurements of CO₂ fluxes were taken, and no conclusion of the methods accuracy can therefore be made. Further, with parallel measurements of CO₂ flux and water analysis with the sensors would therefore be needed to validate the accuracy of the method. In terms of suitability for use in water management and citizen science, the THINCARB model would need to be made accessible and user-friendly, for example, through an app or website where measurements can be entered and modelled estimates can be obtained.

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Populärvetenskaplig sammanfattning

Anlagda våtmarker kan hjälpa till att fånga upp näringsämnen i vattendrag som har läckt från exempelvis lantbruksmark eller tätorter. Att fånga upp näringsämnen i våtmarker kan minska risken för algblomning och andra problem som är kopplade till övergödning. Tidigare forskning har dock visat att det finns en risk att våtmarker som är bra på att fånga upp näring istället släpper ut växthusgaser. Utsläppen av växthusgaser, såsom koldioxid och metan, leder i sin tur till ökade klimatförändringar. Exakt hur dessa faktorer påverkar varandra vet forskarna ännu inte. För att bättre förstå sambanden mellan näring och växthusgaser i anlagda våtmarker behövs fler mätningar av både näring och växthusgaser i olika typer av våtmarker, gärna över lång tid. Uppföljning av hur anlagda våtmarker fungerar dock sällan bland annat på grund av att det kan vara dyrt att mäta näring och växthusgaser i vatten.

För att öka förståelsen och möjligheten till mer uppföljning finns därför ett behov av enklare och billigare mätmetoder. Ett sätt att få många datapunkter för en relativt låg kostnad som har fungerat inom andra forskningsfält är medborgarforskning. Ett format där frivilliga kan bidra till forskningen genom att ta och analysera prover i av något som intresserar eller påverkar dem.

Syftet var därför att utvärdera om enklare metoder för att mäta vattenkvalitet var tillräckligt enkla men ändå exakta nog för att användas inom medborgarforskning och vattenförvaltning. Därför utvärderades metodernas användarvänlighet och det undersöktes hur pålitliga metodernas mätningar var jämfört med ett professionellt laboratorium. Metoderna som testades var teststickor som skannas med en mobilapp samt sensorer avsedda för att mäta vattenkvalitet i akvarium. De mätte näringsämnena fosfat och nitrat, vilka är viktiga när det kommer till övergödning; färg på vattnet som indikation på mängden löst organiskt kol; samt pH, temperatur och alkalinitet, som kan användas för att beräkna mängden oorganiskt kol i vattnet och risken för att koldioxid tas upp eller släpps ut.

Resultatet från utvärderingen av användarvänligheten visar att sensorerna som mäter näringsämnen var mer komplicerade än de övriga och krävde viss säkerhetsutrustning. Av dessa bedömdes fosfatsensorn vara tillräckligt användarvänlig, medan nitratsensorn var alltför komplicerad. Övriga sensorer och teststickor bedöms vara användarvänliga, men för att kunna använda dem inom medborgarforskning skulle samtliga sensorer behöva kompletteras med tydliga rutiner för hur mätningar skall utföras, hur resultaten ska tolkas och rapporteras, samt utbildning av användarna. Dessutom skulle beräkningen av risken för koldioxidutsläpp kunna göras mer tillgänglig genom till exempel en hemsida där

sensorernas mätvärde kan matas in. Dessa åtgärder skulle kunna öka både användarvänligheten och resultatens exakthet.

Jämförelsen med labbmätningarna visade att sensorernas mätresultat inte är exakta, men ligger inom den förväntade felmarginalen och är tillräckligt konsekventa för att användas som indikatorer. Detta innebär att resultaten behöver tolkas med försiktighet. Vad som är tillräckligt exakt kan dock skilja sig beroende på vilken fråga man försöker besvara. Till exempel kan fosfatsensorn användas för att identifiera var i landskapet koncentrationerna av näringsämnet är högst, vilket är kunskap som kan användas för att prioritera åtgärder för att minska utsläppen. Däremot bör sensorerna inte användas för att mäta små förändringar i en våtmark över tid.

Acknowledgments

This study was funded as a part of the Promoting Upstream-Downstream Directed Linkages in the Environment: “Joined-Up” Management Perspectives (PuddleJump) project.

There are many people I would like to thank for making this study possible. I would like to begin with my field colleagues, Alina and Maria. Thank you for your educational and fun way of teaching me how the sampling works, despite the angry cows. I would also like to thank Marcus for all your help in the lab and for generously contributing with your chemical expertise.

I would also like to thank my colleagues and friends who during this journey have shared their knowledge, acted as sounding boards or helped proofread my text. No one mentioned, no one forgotten, thank you for everything.

Finally, I would like to express my huge gratitude to my two fantastic supervisors: Martyn Futter, thank you for your patience and ability to help me moving forward when I was stuck; Alina Kuehn, thank you for your clarity and all your constructive feedback. The way both of you have guided and supported me through this project, with its ups and downs, have made me feel secure while also challenging me in a very educational way.

Appendix 1 - Nitrate

Nitrate manual

Errors & Warnings

The checker shows clear warning messages when erroneous conditions appear and when measured values are outside the expected range. The information below provides an explanation of the errors and warnings, and the recommended action to be taken.

Light High: There is an excess amount of ambient light reaching the detector. Please check the preparation of the zero corvette.



Light Low: There is not enough light to perform a measurement. Please check the preparation of the zero corvette.



Inverted Corvettes: The sample and the zero corvettes are inverted. Swap the corvettes and repeat the measurement.



Under Range: A blinking "0.00" indicates that the sample absorbance is too light for the zero reference. Check the measurement procedure and make sure to use the same corvette for reference (zero) and measurement.



Over Range: Maximum concentration value displayed blinking indicates the measured value is outside the limits of the method. Verify that the sample does not contain any debris. Dilute the sample and repeat the measurement.



Battery Low: Battery level is too low for the checker to function properly. Replace the battery with a new one.



Drained Battery: The battery is drained and must be replaced. Replace the battery with a new one and restart the checker.



Battery Replacement

To save the battery, the checker shuts down after 10 minutes of non-use. A fresh battery lasts for a minimum of 5000 measurements. When the battery is drained, the instrument displays "bAd" then "bAt", and turns off. To replace the battery, follow the next steps:

- Press and hold the ON/OFF button to turn the checker off.
- Turn the instrument upside down and use a screwdriver to unscrew the screws and remove the battery cover.
- Remove the old battery, replace it with a new 1.5V AAA battery, inserting the negative and first.
- Replace the battery cover, lock and tighten the screw.



Accessories

Reagent Sets

HI781-25 Reagents for 25 Marine Nitrate Low Range tests

Other Accessories

HI781-11	Marine Nitrate Low Range certified standard kit
HI73125	Corvette blank cap for Checker [®] HC colorimeters (4 pcs.)
HI73118	Cap for wiping corvettes (4 pcs.)
HI73121	Clear corvette and seal cap for Checker [®] HC colorimeters (4 pcs.)
HI740028P	1.5V AAA battery cap (12 pcs.)
HI740276	5 mL graduated syringe (1 pc.)
HI740270	Filter disc (25 pcs.)
HI740270	10 mL syringe with Luer Lock (1 pc.)
HI740271	Filter holder with Luer Lock (1 pc.)
HI740272	16 gauge blunt needle (6 pcs.)
HI740143	1 mL graduated syringe (6 pcs.)
HI740144P	Plastic tip for 5 mL syringe (10 pcs.)
HI740157P	Plastic refilling pipette (20 pcs.)
HI93763-50	Corvette cleaning solution, 230 mL

Certification

All Hanna Instruments conform to the CE European Directives. Disposal of Electrical & Electronic Equipment. The product should not be treated as household waste. Instead hand it over to the appropriate collection point for the recycling of electrical and electronic equipment which will conserve natural resources. Disposal of waste batteries. This product contains batteries, do not dispose of them with other household waste. Hand them over to the appropriate collection point for recycling. Ensuring proper product and battery disposal prevents potential negative consequences for the environment and human health. For more information, contact your city, your local household waste disposal service, the place of purchase or go to www.hannainst.com.



Recommendations for Users

Before using this product, make sure it is entirely suitable for your specific application and for the environment in which it is used. Please note that this test is not recommended for freshwater applications. Any variation introduced by the use to the supplied equipment may degrade the checker's performance. For you and the checker's safety do not use or store it in hazardous environments.

Warranty

HI781 Checker[®] HC is warranted for a period of one year against defects in workmanship and materials when used for its intended purpose and maintained according to instructions. This warranty is limited to repair or replacement free of charge. Damage due to accidents, misuse, tampering or lack of prescribed maintenance is not covered. If service is required, contact your local Hanna Instruments Office. If under warranty, report the model number, date of purchase, serial number and the nature of the problem. If the repair is not covered by the warranty, you will be notified of the charges incurred. If the checker is to be returned to Hanna Instruments, first obtain a Returned Goods Authorization (RGA) number from the Technical Service department and then send it with shipping costs prepaid. When shipping any product, make sure it is properly packaged for complete protection. Hanna Instruments reserves the right to modify the design, construction, or appearance of its products without advance notice.

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Dear Customer,
Thank you for choosing a Hanna Instruments product. Please read the instruction manual carefully before using the Checker[®] HC handheld colorimeter. For more information about Hanna Instruments and our products, visit www.hannainst.com or e-mail us at sales@hannainst.com. For technical support, contact your local Hanna Instruments Office or e-mail us at tech@hannainst.com.

Preliminary Examination

Remove the Checker[®] HC handheld colorimeter and accessories from the packing material and examine it carefully. If you require any further information, please contact Hanna Instruments technical support team.

Each HI781 is delivered in a case with custom insert and is supplied with:

- Marine Nitrate Low Range reagent starter kit (reagents for 25 tests)
- Sample corvette and cap (2 pcs.)
- Filter paper (25 pcs.)
- Filter holder (1 pc.)
- Plastic refilling pipette (1 pc.)
- Mixing vial and cap (1 pc.)
- 5 mL syringe with tip (1 pc.)
- 10 mL syringe (1 pc.)
- 1 mL graduated syringe (1 pc.)
- 16 gauge blunt needle (1 pc.)
- 1.5V AAA Alkaline battery (1 pc.)
- Instruction manual

Note: Some of packing material used you are sure that the Checker[®] HC handheld colorimeter needs carefully. Any damaged or defective item must be returned in its original packing material with the supplied accessories.

General Description & Intended Use

HI781 Marine Nitrate Low Range handheld checker is designed to accurately determine nitrate levels in aquarium and marine biology applications.

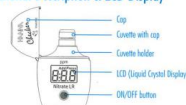
HI781 features a single-button operation system and is easy to use.

The large LCD is easy to read and the auto shut-off feature ensures the battery will not be drained.

Specifications

Range	0.00 to 5.00 ppm (as NO ₃) 0.0 to 50.0 ppm (calculated) using dilution
Resolution	0.01 ppm
Accuracy	±0.25 ppm ± 2% of reading @ 25 °C (77 °F) ± 2.5 ppm ± 5% of calculated reading using dilution
Light source	Light Emitting Diode (LED) 525 nm
Light detector	Silicon photodiode
Method	Colorimetric method. This reaction between nitrate and the reagent causes a pink/violet tint in the sample. This checker has been developed to work with seawater samples.
Interferences	Nitrite, copper
Environment	0 to 50 °C (32 to 122 °F); max. 95% RH non-condensing
Battery type	1.5V AAA Alkaline
Auto shut-off	After 10 minutes of non-use
Dimensions	86.0 x 61.0 x 37.5 mm (3.4 x 2.4 x 1.5")
Weight	64 g (2.3 oz)

Functional Description & LCD Display



Prepare the Filter Holder Assembly

Unscrew the two halves of the reusable filter holder and carefully place one paper filter on the lower piece. The upper piece is marked "TOP"; the lower piece has no marking. Ensure the filter paper is on top of the clear colorizer granules in the filter holder. Thread the upper piece over the lower piece and tighten securely. Ensure that the paper filter is not overlapping the threads. The filter holder assembly is now ready for use.

CLEANING: To clean zinc powder residue from the filter holder assembly, unscrew the filter holder and gently pop the small ridged disk out of the upper half. If necessary, use a small bristle brush and detergent. Rinse thoroughly with Reverse Osmosis Deionized water (RODI) or tap water and dry before use.

Filteration & Dilution

FILTERING: To prevent the filter from tearing, ensure that the filter and filter holder are dry before use. During filtering, keep a constant light pressure on the syringe plunger; it should take about 30 seconds for full filtration. Do not use excessive force.

DILUTION: (1) measure 1 mL of sample using HI740143 1 mL graduated syringe, (2) dispense into mixing vial, (3) add nitrate/nitrite-free artificial seawater up to the 10 mL mark using HI740157P droppers, (4) cap the vial and mix, (5) attach the blunt needle to the 10 mL syringe. In attach, screw the covered blunt needle and remove the cap to expose opening. (6) draw 7 mL of diluted sample into syringe and discard remaining 3 mL of sample from the mixing vial, (7) dispense 7 mL of diluted sample back into the empty mixing vial. Continue with the normal procedure by adding HI781A-0. Multiply results by 10.

Note: Measurement accuracy will be affected by dilution. Measure dilution volumes carefully!

• Press the ON/OFF button to turn the checker on. All segments will be displayed for a few seconds, followed by "bAd", "C.I." with "Press" blinking.

Note: For samples containing 5-50 ppm nitrate, follow the dilution procedure above.

• Using the 10 mL syringe, measure exactly 7 mL of sample into the large mixing vial.

• Using the 5 mL syringe, add exactly 4 mL of HI781A-0 reagent into the large mixing vial.

• Add the content of one packet of HI781B-0 reagent into the large mixing vial. Replace the cap and shake vigorously for 1 minute.

• Remove the cap of the mixing vial. Thread the covered needle onto the 10 mL syringe, remove the plastic cover and draw up the contents of the mixing vial into the syringe.

INSTRUCTION MANUAL

HI781 Marine Nitrate Low Range

Appendix 2 - Phosphate

Phosphate manual

Tips for an Accurate Measurement

- Ensure the sample does not contain any debris.
- Whenever the cuvette is placed into the checker, it must be dry outside and free of fingerprints, oil and dirt.
- Wipe the cuvette thoroughly with HI731318 microfibre cleaning cloth or a lint-free cloth prior to insertion.
- Shaking the cuvette can generate bubbles, causing higher readings. To obtain accurate measurements, remove such bubbles by swirling or by gently tapping the cuvette.
- Do not let the reagent sample stand too long after reagent has been added, as accuracy will be affected.
- Discard the sample immediately after the reading has been taken or the glass might become permanently stained.



Battery Replacement

To save the battery, the checker shuts down after 10 minutes of non-use and 2 minutes after reading.

A fresh battery lasts for a minimum of 5000 measurements. When the battery is drained, the instrument displays "bAt" then "bA", and turns off.

To replace the battery, follow the next steps:

1. Press and hold the ON/OFF button to turn the checker off.
2. Turn the instrument upside down and use a screwdriver to loosen the screw and remove the battery cover.
3. Remove the old battery, replace it with a new 1.5V AAA battery, inserting the negative end first.
4. Replace the battery cover, fasten and tighten the screw.



Accessories

Reagent Sets	
HI713-25	Reagents for 25 Phosphate Low Range tests
Other Accessories	
HI713-11	Phosphate Low Range certified standard kit
HI731225	Cuvette block cap for Checker [®] HC colorimeters (4 pcs.)
HI731318	Cloth for wiping cuvettes (4 pcs.)
HI731321	Glass cuvette and seal cap for Checker [®] HC colorimeters (4 pcs.)
HI740028P	1.5V AAA battery set (12 pcs.)
HI93703-50	Cuvette cleaning solution, 230 ml.

Certification

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Disposal of waste batteries. This product contains batteries, do not dispose of them with other household waste. Hand them over to the appropriate collection point for recycling.

Ensuring proper product and battery disposal prevents potential negative consequences for the environment and human health. For more information, contact your city, your local household waste disposal service, the place of purchase or go to www.hannainst.com.



Recommendations for Users

Before using this product, make sure it is entirely suitable for your specific application and for the environment in which it is used. Any variation introduced by the user to the supplied equipment may degrade the checker's performance. For your and the checker's safety do not use or store it in hazardous environments.

Warranty

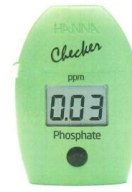
HI713 Checker[®] HC is warranted for a period of one year against defects in workmanship and materials when used for its intended purpose and maintained according to instructions. This warranty is limited to repair or replacement free of charge. Damage due to accidents, misuse, tampering or lack of prescribed maintenance is not covered. If service is required, contact your local Hanna Instruments Office. If under warranty, report the model number, date of purchase, serial number and the nature of the problem. If the repair is not covered by the warranty, you will be notified of the charges incurred. If the checker is to be returned to Hanna Instruments, first obtain a Returned Goods Authorization (RGA) number from the Technical Service department and then send it with shipping costs prepaid. When shipping any product, make sure it is properly packaged for complete protection.

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INSTRUCTION MANUAL

HI713 Phosphate Low Range



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Preliminary Examination

Remove the Checker[®] HC handheld colorimeter and accessories from the packing material and examine it carefully. If you require any further information, please contact Hanna Instruments technical support team.

Each HI713 is delivered in a case with custom insert and is supplied with:

- Sample cuvette and cap (2 pcs.)
- Phosphate Low Range reagent starter kit (reagents for 6 tests)
- 1.5V AAA Alkaline battery (1 pc.)
- Instruction manual

Note: Save all packing material until you are sure that the Checker[®] HC handheld colorimeter works correctly. Any damaged or defective item must be returned in its original packing material with the supplied accessories.

General Description & Intended Use

HI713 Phosphate Low Range handheld checker is designed to accurately determine phosphate in applications such as aquarium and drinking, agricultural and wastewater.

HI713 features a single-button operation system and is easy to use. The large LCD is easy to read and the auto shut-off feature assures the battery will not be drained.

Specifications

Range	0.00 to 2.50 ppm (as PO ₄ ³⁻)
Resolution	0.01 ppm
Accuracy	±0.04 ppm ±4% of reading @ 25 °C (77 °F)
Light source	Light Emitting Diode @ 525 nm
Light detector	Silicon photodiode
Method	Adaptation of the Standard Methods for the Examination of Water and Wastewater, 20 th Edition, Ascorbic Acid Method. The reaction between phosphate and the reagent causes a blue tint in the sample.
Environment	0 to 50 °C (32 to 122 °F); max. 95% RH non-condensing
Battery type	1.5V AAA Alkaline
Auto shut-off	After 10 minutes of non-use and 2 minutes after reading
Dimensions	86 x 61 x 37.5 mm (3.4 x 2.4 x 1.5")
Weight	64 g (2.3 oz)

Functional Description & LCD Display



Measurement Procedure

- Press the ON/OFF button to turn the checker on. All segments will be displayed for a few seconds, followed by "Add", "C.I." with "Press" blinking.
- Fill the cuvette with 10 mL of un-aerated sample and replace the cap. Insert the cuvette into the checker and close the cap.
- Press the ON/OFF button. When the display shows "Add", "C.I." with "Press" blinking, the checker is zeroed.
- Remove the cuvette, unscrew the cap and add the content of one packet of HI713-0 Phosphate Low Range reagent. Replace the cap and shake gently for 2 minutes until the powder is completely dissolved.
- Insert the cuvette into the checker and close the cap. Press and hold the ON/OFF button. The display will show the countdown prior to the measurement. Alternatively, wait 3 minutes and press the button.
- When the timer ends the checker will perform the reading. The instrument displays the phosphate concentration in ppm. The checker automatically turns off 2 minutes after reading.



Errors & Warnings

The checker shows clear warning messages when erroneous conditions appear and when measured values are outside the expected range. The information below provides an explanation of the errors and warnings, and the recommended action to be taken.

Light High: There is an excess amount of ambient light reaching the detector. Please check the preparation of the zero cuvette.

Light Low: There is not enough light to perform a measurement. Please check the preparation of the zero cuvette.

Inverted Cuvettes: The sample and the zero cuvettes are inverted. Swap the cuvettes and repeat the measurement.

Under Range: A blinking "0.00" indicates that the sample absorbs less light than the zero reference. Check the measurement procedure and make sure to use the same cuvette for reference (zero) and measurement.

Over Range: Maximum concentration value displayed blinking indicates the measured value is outside the limits of the method. Verify that the sample does not contain any debris. Dilute the sample and repeat the measurement.

Battery Low: Battery level is too low for the checker to function properly. Replace the battery with a new one.

Drained Battery: The battery is drained and must be replaced. Replace the battery with a new one and restart the checker.



Appendix 3 - Colour of water

colour of water – manual

Tips for an Accurate Measurement

- Ensure the sample does not contain any debris.
- Whenever the cuvette is placed into the checker, it must be dry outside and free of fingerprints, oil and dirt.
- Wipe the cuvettes thoroughly with HI731318 microfiber cleaning cloth or a lint-free cloth prior to insertion.
- Shaking the cuvette can generate bubbles, causing higher readings. To obtain accurate measurements, remove such bubbles by swirling or by gently tapping the cuvette.
- Do not let the reacted sample stand too long after reagent has been added, as accuracy will be affected.
- Discard the sample immediately after the reading has been taken or the glass might become permanently stained.

Battery Replacement

To save the battery, the checker shuts down after 10 minutes of non-use and 2 minutes after reading.

A fresh battery lasts for a minimum of 5000 measurements. When the battery is drained, the instrument displays "bAt" then "bAr", and turns off.

To replace the battery, follow the next steps:

1. Press and hold the ON/OFF button to turn the checker off.
2. Turn the instrument upside down and use a screwdriver to unlock the screw and remove the battery cover.



3. Remove the old battery, replace it with a new 1.5V AAA battery, inserting the negative end first.
4. Replace the battery cover, listen and tighten the screw.

Dear Customer,

Thank you for choosing a Hanna Instruments product. Please read this instruction manual carefully before using the Checker HC handheld colorimeter. For more information about Hanna Instruments and our products, visit www.hanna.com or e-mail cs@hanna.com. For technical support, contact your local Hanna Instruments Office or e-mail us at tech@hanna.com.

Preliminary Examination

Remove the Checker HC handheld colorimeter and accessories from the packing material and examine it carefully. If you require any further information, please contact Hanna Instruments technical support team.

Each HI727 is delivered in a case with custom insert and is supplied with:

- Sample cuvette and cap (2 pcs.)
- 1.5V AAA Alkaline battery (1 pc.)
- Instruction manual

Note: Some old packing material until you are sure that the Checker HC handheld colorimeter works correctly. Any damaged or defective items must be returned in its original packing material with the supplied accessories.

General Description & Intended Use

HI727 Color of Water handheld checker is designed to accurately determine the color of water.

True color is caused by dissolved compounds in water. It can be natural or artificial. Dissolved and suspended solids (turbidity) cause apparent color. Ideal for water testing and quick on-the-spot analysis.

HI727 features a single-button operation system and is easy to use. The large LCD is easy to read and the auto shut-off feature ensures the battery will not be drained.

Accessories

HI40227	Filter assembly
HI40228	Filter disc (25 pcs.)
HI727-11	Color of Water certified standard kit
HI731225	Cuvette block cap for Checker HC colorimeters (4 pcs.)
HI731318	Cloth for wiping cuvettes (4 pcs.)
HI731321	Glass cuvette and seal cap for Checker HC colorimeters (4 pcs.)
HI731353	Cuvette seal cap for Checker HC colorimeters (4 pcs.)
HI740028P	1.5V AAA battery set (12 pcs.)
HI93703-50	Cuvette cleaning solution, 230 mL

Certification

All Hanna Instruments conform to the CE European Directives.

Disposal of Electrical & Electronic Equipment. The product should not be treated as household waste. Instead hand it over to the appropriate collection point for the recycling of electrical and electronic equipment which will conserve natural resources.

Disposal of waste batteries. This product contains batteries, do not dispose of them with other household waste. Hand them over to the appropriate collection point for recycling.

Ensuring proper product and battery disposal prevents potential negative consequences for the environment and human health. For more information, contact your city, your local household waste disposal service, the place of purchase or go to www.hanna.com.



Specifications

Range	0 to 500 g/L PCU
Resolution	5 PCU
Accuracy	±10 PCU ±5% of reading @ 25 °C (77 °F)
Light source	Light Emitting Diode @ 470 nm
Light detector	Silicon photodiode
Method	Adaptation of the Standard Methods for the Examination of Water and Wastewater 21 st Edition, Colorimetric Platinum Cobalt Method
Environment	0 to 50 °C (32 to 122 °F); max. 95% RH non-condensing
Battery type	1.5V AAA Alkaline
Auto shut-off	After 10 minutes of non-use and 2 minutes after reading
Dimensions	86.0 x 61.0 x 37.5 mm (3.4 x 2.4 x 1.5")
Weight	64 g (2.3 oz)

Functional Description & LCD Display



Recommendations for Users

Before using this product, make sure it is entirely suitable for your specific application and for the environment in which it is used. Any variation introduced by the user to the supplied equipment may degrade the checker's performance. For years and the checker's safety do not use or store it in hazardous environments.

Warranty

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INSTRUCTION MANUAL

HI727 Color of Water



Measurement Procedure

- Press the ON/OFF button to turn the checker on. All segments will be displayed for a few seconds, followed by "Add", "C.L" with "Press" blinking.
- Fill one cuvette up to the 10 mL mark with deionized water and replace the cap. This is the blank. Insert the cuvette into the checker and close the cap.
- Press the ON/OFF button. When the display shows "Add", "C.L" with "Press" blinking, the checker is zeroed.
- Fill a second cuvette up to the 10 mL mark with unfiltered sample and replace the cap. This is the apparent color.
- Insert the cuvette into the checker and close the cap. Press the ON/OFF button. The instrument displays the value of apparent color.
- Remove the cuvette and press the ON/OFF button twice to restart the checker.
- Filter 50 mL of sample through a 0.45 µm membrane filter into a beaker.
- After measurement of apparent color, rinse the cuvette three times with filtered sample and then fill it up to the 10 mL mark with the filtered sample. Replace the cap. This is the true color.
- Follow the procedure above to re-zero the checker using the blank cuvette.
- Insert the cuvette into the checker and close the cap. Press the ON/OFF button. The instrument displays concentration in color units of the true color. The checker automatically turns off 2 minutes after reading.

Errors & Warnings

The checker shows clear warning messages when erroneous conditions appear and when measured values are outside the expected range. The information below provides an explanation of the errors and warnings, and the recommended action to be taken.

Light High: There is an excess amount of ambient light reaching the detector. Please check the preparation of the zero cuvette.



Light Low: There is not enough light to perform a measurement. Please check the preparation of the zero cuvette.



Inverted Cuvettes: The sample and the zero cuvettes are inverted. Swap the cuvettes and repeat the measurement.



Under Range: A blinking "0" indicates that the sample absorbs less light than the zero reference. Check the measurement procedure and make sure to use the same cuvette for reference (zero) and measurement.



Over Range: Maximum concentration value displayed blinking indicates the measured value is outside the limits of the method. Verify that the sample does not contain any debris. Dilute the sample and repeat the measurement.



Battery Low: Battery level is too low for the checker to function properly. Replace the battery with a new one.



Drained Battery: The battery is drained and must be replaced. Replace the battery with a new one and restart the checker.



Appendix 4 - pH and temperature

pH & temp manual

Exiting Calibration

- When in calibration mode, it is possible to exit calibration procedure by pressing c/MODE , before first-point calibration has been accepted. The tester displays "ESC" and returns to measurement mode and last calibrated data.
- When in calibration mode, it is possible to clear a previous calibration and return to default values by pressing SET/HOLD, before the first calibration point has been accepted. The tester displays "CLR" on the second LCD line, "CAL" tag disappears and tester returns to default calibration.

Measurement

Use SET/HOLD to select pH mode. Place the electrode in the solution to be tested while stirring gently. The measurement should be taken after the stability tag (S) has disappeared. The pH value is displayed on the first LCD line and the temperature on the second LCD line.



Note: Before taking any pH measurement make sure the tester has been calibrated ("CAL" tag is displayed).

Maintenance

Please read the information below to ensure the highest possible accuracy.

- Fresh buffer solution should be used for each calibration.
- For improved accuracy a two- or (HI98128 only) three-point calibration is recommended.
- If measurements are taken successively, rinse the probe thoroughly in distilled or deionized water to eliminate cross-contamination.
- Clean the electrode monthly by keeping the electrode in HI7061 General purpose cleaning solution for 30 minutes and rinsing the probe thoroughly with water.
- When not in use, add a few drops of HI70300 Storage solution to the protective cap. Never store the probe in distilled or deionized water.

Electrode Replacement

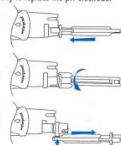
Use supplied removal tool (HI73127) to replace the pH electrode.

Insert the tool into the electrode cavity.

Rotate the tool counterclockwise.

Pull the electrode out by using the other side of the tool.

Insert a new pH electrode following the above instructions in reverse order.



Battery Replacement

Battery life percentage indicator is displayed at power on. If the battery level drops below 5%, the c/B symbol lights up indicating that the batteries should be replaced soon. If the battery level is not adequate to guarantee an accurate reading, the tester automatically turns off.

To replace the batteries, follow the next steps:

- Turn OFF the tester.
- Remove the four screws on the top of the tester to open the battery compartment (figure 1).
- Remove the old batteries.
- Insert four new 1.5V AA batteries in the battery compartment while paying attention to the correct polarity (figure 2).
- Close the battery compartment using the four screws.



Note: Only use the battery type specified in the manual. Old batteries should be disposed in accordance with local regulations.

Accessories

Electrode	
HI73127	Replaceable pH electrode
HI73128	Electrode removal tool
pH Buffer Solution	
HI70004P	pH 4.01 solution, 20 mL sachet (25 pcs.)
HI70006P	pH 6.86 solution, 20 mL sachet (25 pcs.)
HI70007P	pH 7.01 solution, 20 mL sachet (25 pcs.)
HI70009P	pH 9.18 solution, 20 mL sachet (25 pcs.)
HI70010P	pH 10.01 solution, 20 mL sachet (25 pcs.)
HI77010P	pH 10.01 & 7.01 solution, 20 mL sachet (10 pcs., 5 each)
HI77400P	pH 4.01 & 7.01 solutions, 20 mL sachet (10 pcs., 5 each)
Electrode Cleaning Solution	
HI7061M	Electrode cleaning solution, 230 mL
Electrode Storage Solution	
HI70300M	Electrode storage solution, 230 mL
Other Accessories	
HI740026P	Replacement 1.5V batteries (12 pcs.)

Certification

All Hanna Instruments conform to the CE European Directives.

Disposal of Electrical & Electronic Equipment. The product should not be treated as household waste. Instead hand it over to the appropriate collection point for the recycling of electrical and electronic equipment which will conserve natural resources.

Disposal of waste batteries. This product contains batteries, do not dispose of them with other household waste. Hand them over to the appropriate collection point for recycling.

Ensuring proper product and battery disposal prevents potential negative consequences for the environment and human health. For more information, contact your city, your local household waste disposal service, the place of purchase or go to www.hannainst.com.

Recommendations for Users

Before using these testers, make sure that they are entirely suitable for your specific application and for the environment in which they are used. Any variation introduced by the user to the supplied equipment may degrade the tester's performance. Avoid touching the electrode at all times. For yours and the tester's safety do not use or store the tester in hazardous environments.

Warranty

HI98127 and HI98128 are warranted for a period of one year against defects in workmanship and materials when used for their intended purpose and maintained according to instructions. The electrode is warranted for a period of six months. This warranty is limited to repair or replacement free of charge. Damage due to accidents, misuse, tampering or lack of prescribed maintenance is not covered. If service is required, contact your local Hanna Instruments Office. If under warranty, report the model number, date of purchase, serial number and the nature of the problem. If the repair is not covered by the warranty, you will be notified of the charges incurred. If the instrument is to be returned to Hanna Instruments Office, first obtain a Returned Goods Authorization (RGA) number from the Technical Service department and then send it with shipping costs prepaid. When shipping any instrument, make sure it is properly packaged for complete protection.

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IS798127 06/20

US DESIGN PATENT D462,024

INSTRUCTION MANUAL

HI98127 • HI98128 Waterproof pH Testers



HANNA instruments

Dear Customer,

Thank you for choosing a Hanna Instruments product. Please read this instruction manual carefully before using the tester. For more information about Hanna Instruments and our products, visit www.hannainst.com or e-mail us at sales@hannainst.com. For technical support, contact your local Hanna Instruments Office or e-mail us at tech@hannainst.com.

Preliminary Examination

Remove the tester and accessories from the packing material and examine it carefully. If you require any further information, please contact Hanna Instruments technical support team at tech@hannainst.com. Each HI98127 and HI98128 is delivered in a cardboard box and is supplied with:

- HI70004 pH 4.01 buffer solution, 20 mL sachet (2 pcs.)
- HI70007 pH 7.01 buffer solution, 20 mL sachet (2 pcs.)
- HI70601 pH & ORP electrode cleaning solution, 20 mL sachet (1 pc.)
- HI70300 Storage solution for pH & ORP electrodes, 20 mL sachet (1 pc.)
- HI73127 pH electrode
- HI73128 Electrode removal tool
- 1.5V batteries (4 pcs.)
- Instrument quality certificate
- Instruction manual

Note: Save all packing material until you are sure that the tester works correctly. Any damaged or defective item must be returned in its original packing material with the supplied accessories.

General Description & Intended Use

HI98127 (pH[®]4) and HI98128 (pH[®]TS) are compact pH and temperature testers. They feature a two-buttons operation system and are easy to use. The compact and waterproof casing is designed to float if accidentally dropped in water. The testers measure temperature in both °C and in °F. All pH measurements are temperature compensated automatically (ATC). The testers display a stability (S) tag that will disappear once the reading has stabilized. Battery level and low-battery indicator are clearly displayed on the LCD to alert the user in the event that low battery power could adversely affect readings.

BEPS (Battery Error Prevention System) Tester will automatically shut off if there is not enough power to get an accurate measurement.

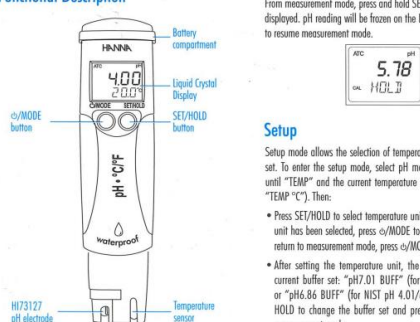
pH Probe: HI98127 & HI98128 are supplied together with HI73127 pH replaceable electrode with a stainless steel round connector and extendable cloth junction. This design has no pins to line up or that can break.

Temperature Sensor: The stainless steel temperature sensor facilitates faster and more accurate temperature measurement.

Specifications

Range	-2.0 to 16.0 pH (HI98127) -2.00 to 16.00 pH (HI98128) -5.0 to 60.0 °C (23.0 to 140.0 °F)
Resolution	0.1 pH (HI98127) 0.01 pH (HI98128) 0.1 °C (0.1 °F)
Accuracy (@25 °C/77 °F)	±0.1 pH (HI98127) ±0.05 pH (HI98128) ±0.5 °C (±1.0 °F)
Temperature compensation	Automatic
Environment	-5 to 50 °C (23 to 122 °F); RH max 100%
Calibration	Automatic, one-, two- or (HI98128) three-point with two sets of standard buffers (pH 4.01 / 7.01 / 10.01 or pH 4.01 / 6.86 / 9.18)
Electrode	HI73127 pH electrode (included)
Battery type	1.5V (4 pcs.)
Battery life	Approx. 300 hours
Auto-off	After 8 minutes of non-use
Dimensions	171 x 41 x 26 mm (6.7 x 1.6 x 1.0")
Weight	84 g (3.0 oz)

Functional Description



LCD Display



- Automatic Temperature Compensation (ATC) indicator
- Stability tag
- Battery life percentage indicator
- Low battery indicator
- Measurement unit
- First LCD line
- Second LCD line

Operational Guide

Press and hold c/MODE . All LCD segments will be displayed for a few seconds followed by battery life percentage indicator. To turn the tester off, from measurement mode, press c/MODE . "OFF" will be displayed on the second LCD line and then the tester will turn off.

HOLD Mode

From measurement mode, press and hold SET/HOLD until "HOLD" is displayed. pH reading will be frozen on the LCD. Press either buttons to resume measurement mode.

Setup

Setup mode allows the selection of temperature unit and pH buffer set. To enter the setup mode, select pH mode and press c/MODE until "TEMP" and the current temperature unit are displayed (e.g. "TEMP °C"). Then:

- Press SET/HOLD to select temperature unit. After the temperature unit has been selected, press c/MODE to select the buffer set. To return to measurement mode, press c/MODE twice.
- After setting the temperature unit, the tester will display the current buffer set: "pH7.01 BUFF" (for pH 4.01/7.01/10.01) or "pH6.86 BUFF" (for HI98128). Press SET/HOLD to change the buffer set and press c/MODE to resume measurement mode.

Calibration & Measurement

It is recommended to calibrate the tester frequently, especially if high accuracy is required. More frequent calibrations may be required depending on the type of sample being tested. The tester should be recalibrated:

- whenever the pH electrode is replaced
- at least once a month
- after testing aggressive samples

pH Calibration Procedure

From measurement mode, press and hold c/MODE until "CAL" is displayed. The tester enters calibration mode and displays "pH 7.01 USE" or "pH 6.86 USE", if NIST buffer was selected. Buffer value will be displayed on the first LCD line and "REC" message will be displayed on the second line. If used buffer was not valid, "USE" message will be displayed for 12 seconds and replaced by "WRNG" indicating measured sample is not valid.

For one-point calibration using pH 4.01, 10.01 or 9.18 buffer solution, once the reading has stabilized, the tester automatically accepts the calibration point. Accepted buffer point and "OK 1" message are displayed and then the tester returns to measurement mode.

For one-point calibration using pH 7.01 (or 6.86) buffer solution, press c/MODE after calibration point has been accepted. The tester will display "pH 7.01" (or "pH 6.86") and "OK 1" and then returns to measurement mode.

For a two-point calibration using pH 7.01 (or 6.86) buffer solution, after the first calibration point has been accepted, "pH 4.01 USE" will be displayed for 12 seconds (unless a valid buffer is recognized).

If valid buffer solution is recognized (pH 4.01, 10.01 or 9.18), the calibration point is accepted and the accepted value and "OK 2" are displayed. The HI98127 tester then returns to measurement mode.

HI98128 only: If valid buffer solution is recognized (pH 4.01, 10.01 or 9.18) and the calibration point is accepted, press c/MODE . The accepted value and "OK 2" are displayed. The tester then returns to measurement mode.

For a three-point calibration (HI98128 only) using pH 7.01 (or 6.86) buffer value and if the first calibration point has been accepted, "pH 4.01 USE" will be displayed for 12 seconds (unless a valid buffer is recognized).

If valid buffer solution is recognized (pH 4.01, 10.01 or 9.18), the second calibration point is accepted and the meter will display "pH 10.01 USE" (or pH 9.18) or pH 4.01 USE" for 12 seconds (unless a valid buffer is recognized).

If the calibration point is accepted the accepted value and "OK 3" are displayed. The tester then returns to measurement mode.

If no valid buffer solution is recognized, "WRNG" message is displayed.

Note: When the calibration procedure is completed, the "CAL" tag is turned on.

Appendix 5 - Alkalinity

alkalinity manual

Tips for an Accurate Measurement

- Ensure the sample does not contain any debris.
- Whenever the cuvette is placed into the checker, it must be dry outside and free of fingerprints, oil and dirt.
- Wipe the cuvette thoroughly with H1731318 microfiber cleaning cloth or a lint-free cloth prior to insertion.
- Shaking the cuvette can generate bubbles, causing higher readings. To obtain accurate measurements, remove such bubbles by swirling or by gently tapping the cuvette.
- Do not let the reagent sample stand too long after reagent has been added, as accuracy will be affected.
- Discard the sample immediately after the reading has been taken or the glass might become permanently stained.

Battery Replacement

To save the battery, the checker shuts down after 10 minutes of non-use and 2 minutes after reading.

A fresh battery lasts for a minimum of 5000 measurements. When the battery is drained, the instrument displays "bAt" then "bAt", and turns off.

To replace the battery, follow the next steps:

1. Press and hold the ON/OFF button to turn the checker off.
2. Turn the instrument upside down and use a screwdriver to loosen the screw and remove the battery cover.
3. Remove the old battery, replace it with a new 1.5V AAA Alkaline battery, inserting the negative end first.
4. Replace the battery cover, fasten and tighten the screw.



Accessories

Reagent Sets	
H1775-26	Reagents for 25 Alkalinity tests, 1 syringe and 1 tip
Other Accessories	
H1775-11	Alkalinity certified standard kit
H1731225	Cuvette black cap for Checker® HC colorimeters (4 pcs.)
H1731318	Cloth for wiping cuvettes (4 pcs.)
H1731321	Glass cuvette and seal cap for Checker® HC colorimeters (4 pcs.)
H1740028P	1.5V AAA battery set (12 pcs.)
H1740142P	1 mL graduated syringe (10 pcs.)
H193703-50	Cuvette cleaning solution, 230 mL
H193755-53	Chlorine remover reagent

Certification

All Hanna Instruments conform to the CE European Directives.

CE
RoHS compliant

RoHS
compliant

Disposal of waste batteries. This product contains batteries, do not dispose of them with other household waste. Hand them over to the appropriate collection point for the recycling of electrical and electronic equipment which will conserve natural resources.

Disposal of waste batteries. This product contains batteries, do not dispose of them with other household waste. Hand them over to the appropriate collection point for recycling.

Ensuring proper product and battery disposal prevents potential negative consequences for the environment and human health. For more information, contact your city, your local household waste disposal service, the place of purchase or go to www.hannainst.com.



Recommendations for Users

Before using this product, make sure it is entirely suitable for your specific application and for the environment in which it is used. Any violation introduced by the user to the supplied equipment may degrade the checker's performance. For your and the checker's safety do not use or store it in hazardous environments.

Warranty

H1775 Checker® HC is warranted for a period of one year against defects in workmanship and materials when used for its intended purpose and maintained according to instructions. This warranty is limited to repair or replacement free of charge. Damage due to accidents, misuse, tampering or lack of prescribed maintenance is not covered. If service is required, contact your local Hanna Instruments Office. If under warranty, report the model number, date of purchase, serial number and the nature of the problem. If the repair is not covered by the warranty, you will be notified of the charges incurred. If the checker is to be returned to Hanna Instruments, first obtain a Returned Goods Authorization (RGA) number from the Technical Service department and then send it with shipping costs prepaid. When shipping any product, make sure it is properly packaged for complete protection.

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IS1775 11/20

INSTRUCTION MANUAL

H1775 Alkalinity



Dear Customer,

Thank you for choosing a Hanna Instruments product. Please read this instruction manual carefully before using the Checker® HC handheld colorimeter. For more information about Hanna Instruments and our products, visit www.hannainst.com or e-mail us at sales@hannainst.com. For technical support, contact your local Hanna Instruments Office or e-mail us at tech@hannainst.com.

Preliminary Examination

Remove the Checker® HC handheld colorimeter and accessories from the packing material and examine it carefully. If you require any further information, please contact Hanna Instruments technical support team.

Each H1775 is delivered in a case with custom insert and is supplied with:

- Sample cuvette and cap (2 pcs.)
- Alkalinity reagent starter kit (reagents for 25 tests)
- 1 mL syringe with tip
- 1.5V AAA Alkaline battery (1 pc.)
- Instruction manual

Note: Save all packing material until you are sure that the Checker® HC handheld colorimeter works correctly. Any damaged or defective item must be returned in its original packing material with the supplied accessories.

General Description & Intended Use

H1775 Alkalinity handheld checker is designed to accurately determine alkalinity levels in fresh water specimens.

H1775 features a single-button operation system and is easy to use. The large LCD is easy to read and the auto shut-off feature assures the battery will not be drained.

Specifications

Range	0 to 500 ppm (as CaCO ₃)
Resolution	1 ppm
Accuracy	±5 ppm ±5% of reading @ 25 °C (77 °F)
Light source	Light Emitting Diode @ 610 nm
Light detector	Silicon photodiode
Method	Colorimetric Method. The reaction causes a distinctive range of colors from yellow to greenish blue to develop. This checker has been developed to work with fresh water samples.
Environment	0 to 50 °C (32 to 122 °F); max. 95% RH non-condensing
Battery type	1.5V AAA Alkaline
Auto shut-off	After 10 minutes of non-use and 2 minutes after reading
Dimensions	86.0 x 61.0 x 37.5 mm (3.4 x 2.4 x 1.5")
Weight	64 g (2.3 oz)

Functional Description & LCD Display



Measurement Procedure

- Press the ON/OFF button to turn the checker on. All segments will be displayed for a few seconds, followed by "AdP", "C1" with "Press" blinking.
 - Fill the cuvette with 10 mL of unreacted sample and replace the cap. Insert the cuvette into the checker and close the cap.
 - Press the ON/OFF button. When the display shows "AdP", "C2" with "Press" blinking, the checker is zeroed.
 - Note:** Any chlorine present in the sample will interfere with the reading. To remove the chlorine interference add one drop of H193755-53 Chlorine Remover to the unreacted sample.
 - Remove the cuvette and unscrew the cap. Using a 1 mL syringe carefully add exactly 1 mL of H17755 Alkalinity reagent to the sample. Replace the cap and invert gently 5 times.
 - Note:** Pay attention not to spill reagent otherwise full color development may be inhibited.
 - Insert the cuvette into the checker and close the cap. Press the ON/OFF button. The instrument displays the alkalinity concentration in ppm of CaCO₃. Alkalinity conversion:
1 ppm CaCO₃ = 0.02 meq/L = 0.056 d/dH
- The checker automatically turns off 2 minutes after reading.

Errors & Warnings

The checker shows clear warning messages when erroneous conditions appear and when measured values are outside the expected range. The information below provides an explanation of the errors and warnings, and the recommended action to be taken.

- Light High:** There is an excess amount of ambient light reaching the detector. Please check the preparation of the zero cuvette.
- Light Low:** There is not enough light to perform a measurement. Please check the preparation of the zero cuvette.
- Inverted Cuvettes:** The sample and the zero cuvettes are inserted. Swap the cuvettes and repeat the measurement.
- Under Range:** A blinking "0" indicates that the sample absorbs less light than the zero reference. Check the measurement procedure and make sure to use the same cuvette for reference (zero) and measurement.
- Over Range:** Maximum concentration value displayed blinking indicates the measured value is outside the limits of the method. Verify that the sample does not contain any debris. Dilute the sample and repeat the measurement.
- Battery Low:** Battery level is too low for the checker to function properly. Replace the battery with a new one.
- Drained Battery:** The battery is drained and must be replaced. Replace the battery with a new one and restart the checker.

Appendix 6

Results from landowner survey

Question	Response options	Answers (n=12)
Would you be interested taking your own water samples and get less certain but immediate results?	Yes	8
	No	4
Do you think you would find these water quality tests useful for? (multiple option)	a) Communication with municipality and government agencies,	4
	b) Support management decisions,	0
	c) To better understand wetlands and water bodies,	8
	d) Something else...	as a tool in biology and chemistry education to easily conduct experiments on water quality.
What factors do you think could stop you from using this type of simpler sampling? (multiple option)	a) The time required to learn how to use the tests,	3
	b) The purchase cost,	2
	c) Little need for the results,	3
	d) Uncertainty in the results	6
	e) Something else...	lack of time

Appendix 7

Sensor protocol and recommendations:

Overview of workflow:

1. Sampling & pH measurements
2. Storage in fridge (if needed but no longer than 48h)
3. Analysis with sensors and test strips
 - 3.1 Analysis with sensors and test strips
2. Measuring colour of water
3. Measuring phosphate with filtered samples
4. Measuring alkalinity
5. Measuring nitrate
4. Safety
 - 4.1 Personal safety
 - 4.2 Environmental safety & discharge of reacted samples

1. Sampling & pH measurements

Material: a clean cup or beaker, Hanna waterproof pH tester, a clean bottle á 300-500ml per sample you will take, a long stick where the bottles can be attached (needed if the shore has shallow water or has vegetation that hinders sampling without disturbing the bottom), a cooling box (if sampling is not done directly before analysing).

General principles: Always mark up the bottle or sampling container with date and location. Always rinse the container used for sampling with sample water three times before taking the sample. Try to avoid stirring the bottom when sampling, avoid sampling of surface water if possible. Try to only get water in your water sample. In case your waterbody contains a lot of algae or other water plants, try the following method. Use the sampling bottle (on the stick or in your hand) with the opening facing upwards, stir in a circle in the water surface as if you were stirring a stew, this will create a hole in the mat of floating plants where it is possible to sample as described below.

Collecting water sample: Sampling can either be done by attaching the sampling bottle to a stick or if deep enough water is in reach, by holding the bottle in your hand. In both cases, hold the sampling bottle (or another container) upside down, lower it completely under the water surface, then turn it back so that the opening is facing upwards and the container is filled with water. Pour out the water and repeat this three times to rinse the bottle, empty the bottle away from where you are sampling and don't forget to rinse the lid. Fill the bottle in the same way again, close it and put it in a cold place e.g. a cooling box.

PH measurement:

- Fill a cup or a beaker with sampling water, place it on a steady place and try to avoid direct sun light.
- Start the pH checker and put it in the water, wait until the values for pH and temperature has stabilised. Take a picture or write down the measurements.
- Rinse off the checker if needed and put on the lid with storage solution. Don't forget to calibrate the checker as described in the instructions monthly.

2. Storage in fridge (if needed but no longer than 48h)

If the samples are not analysed with the sensors and strips directly after sampling, make sure to store them cold in for example a fridge or a cooling box. Do not analyse later than 48h after sampling.

3. Analysis with sensors and test strips

Materials: The following Hanna checkers with belonging accessories and reagents for measuring Colour of water (HI727), Alkalinity (HI775), Phosphate (HI713). Hach nitrate strips, Deltares reference card, a smartphone with Deltares app 'Aquality'. Two cuvettes per sample and one extra, two beaker or cups, a 50 ml syringe, at least one 0.45 µm membrane filter per sample, a microfiber cloth or a lint free paper cloth and alcohol (without gel or similar compounds). At last, a flat working surface with good ventilation, a discharge container and a timer with seconds is needed.

General principles: To avoid cross contamination, always rinse the cuvettes with water from the sample to be measured three times before filling the cuvette with the sample. When rinsing the cuvettes, there is no need to fill them; simply pour in a little sample water, close the lid, shake, open the lid and pour out the water. Do not use any detergent to clean the cuvettes, as it can contain phosphate and therefore contaminate your sample.

Any dirt on the cuvettes outside, debris or bubbles on the inside or scratches in the glass may interfere with the photosensors measurement. To avoid interference, do the following steps with all cuvettes before putting them in a checker:

- Before filling the cuvettes make sure that they are intact and free from cracks or scratches.
- When filling the cuvettes, make sure that no debris, such as plant parts or plankton enters. If this is impossible, make a note and be aware that this can affect your results. Using filtered sample for all measurements except for non-filtered colour of water, can be considered but need to be done for all samples to be comparable.
- Before measuring, make sure the cuvettes are clean from fingerprints or other dirt by wiping it off with a microfiber cloth or a paper towel soaked in ethanol, also make sure that the cuvette is completely dry before inserting in the checker.

Comparability is important in environmental monitoring. To make your samples comparable with each other and with samples taken by other samplers follow these instructions as closely as possible. If you need to make any adjustments do so for all your samples and make sure to note how it differs from the instructions.

3.1 Measurement preparations

Read through the instructions for each sensor. Place a timer or a clock where its visible but without risk of getting spilled on. Make sure to have paper or a cloth in reach. Place your discharge container where it is not at risk to be tipped but is within reach. For each sample place two cuvettes (HI731225). To avoid mixing them up write the name of the sample and whether it is filtered or not on a note and place it in front of the sample, do not stick it to the cuvette.

3.2 Measuring colour of water

Materials: Colour of water (HI727), two cuvettes (HI731225) per sample and one extra for the blank, a 50 ml syringe, at least one 0.45 µm membrane filter per sample, if needed two beaker or cups.

Measurement procedure:

- Prepare a blank cuvette, by using deionised water to rinse the extra cuvette three times and then fill it to the 10 ml mark, close it with the lid and wipe it off. Make sure the cuvette used for the blank is the same kind as the ones used for the samples.
- Fill up one of the two cuvettes with 10ml sample water, after rinsing the cuvette three times with sample water.
- Rinse and fill up the second cuvette in the same way but with filtered sample water. To filter the sample; fill the 50 ml syringe with sample water and attach a filter to the tip of the syringe, push the water through the filter directly into the cuvette, first for rinsing as described above, then filling it with 10 ml of the filtered sample water.

It is possible that the filter will become full before all the water has been pushed through (e.g. if your sample is cloudy) this will make it impossible to get more water through. If this happens take a new filter.

If the syringe does not fit the opening of the sample bottle, it's possible to first pour up the sample in a beaker or a cup. If you find it tricky to filter the sample directly into the cuvette, use a second beaker. If you use beakers, make sure to rinse them well between the samples and do the same procedure for all samples to increase the comparability.

- Now follow the measurement procedure described in the manual using the cuvettes prepared as described above, where the deionised water is the blank, the nonfiltered sample is used to measure apparent colour and the filtered sample to measure true colour.

Save the filtered sample for the phosphate measurement and the non-filtered for alkalinity measurement.

3.3. Measuring phosphate with filtered samples

Materials: Phosphate (HI713), a cuvette with filtered sample, one package with phosphate low range reagent (HI713-0) per sample and a timer with seconds.

Measurement procedure:

- After measuring colour of water, use the cuvette with filtered sample and follow the instructions in the manual to measure phosphate.

Source of error to avoid: If your sample is cloudy (rare after filtering) there is a risk that the reagent cause precipitation and the reacted sample become clearer than the measured blank. If this happens make a note and be aware that the results will be less reliable.

3.4 Measuring alkalinity

Materials: Alkalinity (HI775), a cuvette with sample water (non-filtered), a 1ml syringe, Chlorine remover reagent (HI93755-53) and Alkalinity reagent (HI775S).

Measurement procedure:

- After measuring colour of water use the cuvette with non-filtered sample and follow the instructions in the manual to measure alkalinity.

Source of error to avoid:

3.5 Measuring nitrate

Materials: Hach nitrate strips, Deltares reference card, a smartphone with Deltares app 'Aquality'.

Measurement procedure:

- Open the app, click on the blue plus sign, then click on the 'i' to see the instructions and follow them. More detailed instructions are also available at (<https://publicwiki.deltares.nl/spaces/wqapp/pages/127634730/Tips+Tri+cks>).

Source of error to avoid:

- Shadows on the reference card can affect the reading, therefore make sure you are in a light place, preferable with day light, where no shadows will cover or partly cover your reference card when you take the picture.
- low temperatures may affect the accuracy. If the samples were stored in the fridge let them warm up in room temperature while doing the other measurements.
- Also, make sure to take the picture 60 seconds after dipping the strip as Deltares recommends.

4. Safety

The reagent used is toxic if inhaled and can cause severe skin burns and eye damage, so care must be taken when handling. The Safety Data Sheet is available for download from <https://sds.hannainst.com/>.

4.1 Personal safety

Use a fume hood or stand in a well-ventilated place when operating the phosphate sensor. Be aware that the reagent (HI713-0) is dangerous to breathing in.

4.2 Environmental safety & discharge of reacted samples

Dispose the reacted phosphate sample as hazard waste.

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