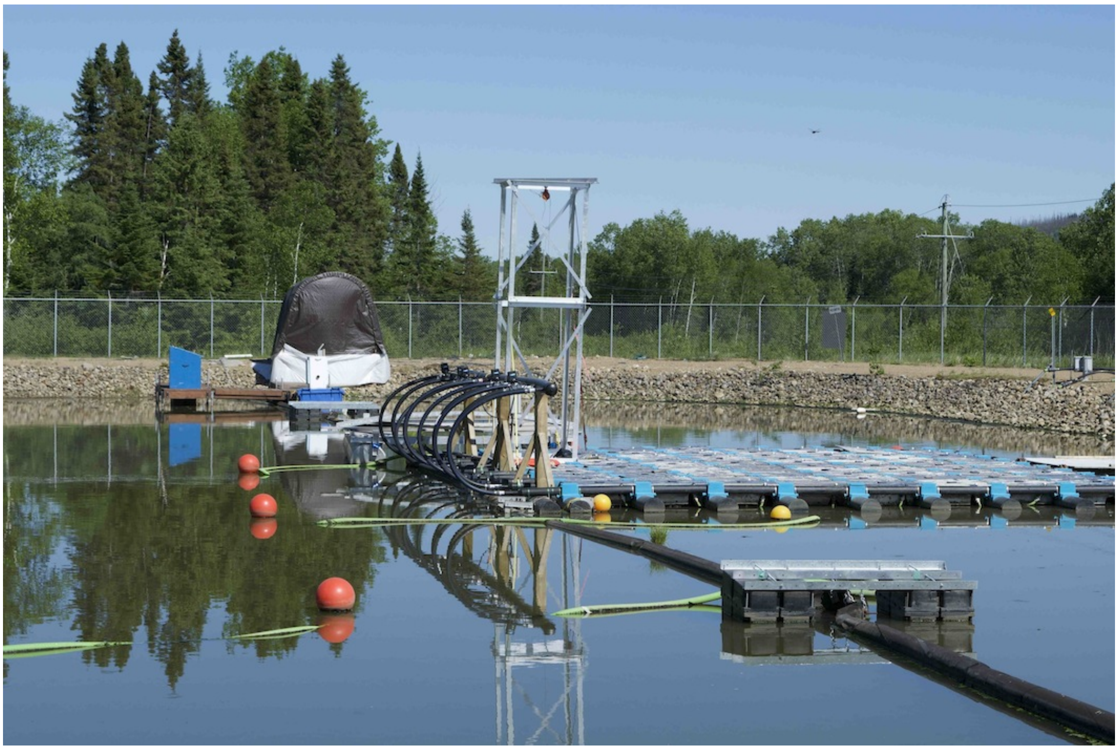
Internship at model*EAU*



Tobias Kraft

01. April - 26. July

Professur für Siedlungswasserwirtschaft
Betreuung: Prof. Dr. Max Maurer

model*EAU*
Supervision: Prof. Dr. Peter Vanrolleghem
Dr. Janelcy Alferes

Acknowledgement of the internship

Name of the intern: Tobias Kraft

Name and address of the internship location: model*EAU*, Université Laval

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Name of the supervisor: Dr. Janelcy Alferes

Time period of the internship: 01. April – 01. August 2014

We confirm the verification of this internship report.

Intern: Tobias Kraft

01.08.14

(Date and signature)

Supervisor: Dr. Janelcy Alferes

01/08/2014.

(Date and signature)

Statement to the internship report

I assure that I composed this report, which I wrote at model*EAU*, all by myself without using other references than the ones mentioned. I designated correctly all parts in the report which are literally extracted from other publications.

Quebec, Canada, 01.08.14

(Location, date and signature)

Contents

1. modelEAU; Canada Research Chair on Water Quality Modeling

model*EAU* is a research group at the University Laval in Quebec City Canada which is coordinated by Dr. Peter Vanrolleghem (model*EAU* [2014]). This research group was founded in February 2005 after Dr. Peter Vanrolleghem was assigned to the new Canada Research Chair in the modeling of Water Quality. model*EAU* deals with the development of model-based methodologies.

The research fields of model*EAU* involve the following points:

- How are the effects of the urban wastewater system on the water quality of a river? Deeper insights will be gained by developing a new generation of monitoring stations for high resolution/high quality data.
- How to guarantee reliability and accuracy of on-line data? Based on their experience in this field modelEAU is developing new data quality evaluation tools for practical use.
- How can the urban wastewater transport and treatment system be modelled? How does one select the most adequate model complexity, how are different submodels to be coupled, how to set up measurement campaigns, what is Good Modelling Practice?
- How can the modelling results be used to optimize the urban water system to further reduce urban and agricultural impacts on receiving waters, e.g. by innovative, supervisory control strategies?
- How can new, more sustainable technologies improve future wastewater transport and treatment systems?
- How can uncertainties on our understanding of the current systems and their future development be dealt with when simulating different options to maximize the water quality of rivers.

For a better understanding and prediction of these systems the use of mathematical models is a necessary part of research. The procedures of modeling is based on water quality data which is collected by automated measurement stations and measurement campaigns which have to be efficiently carried out. A very important requirement are data quality assurance methods to use correct data. Thus, this is a research area. In addition new wastewater treatment technologies are being studied to optimize sewer operations to provide an urban wastewater infrastructure which are following the preconditions of sustainable development. model*EAU* is dealing with those important model-methodological and data treatment challenges.

1.1. Project monEAU: Automated monitoring stations for water quality

This project is called mon*EAU* which is an ongoing project involving research groups, public organizations and private companies (Rieger and Vanrolleghem [2008]). mon*EAU* deals with new data evaluation methods and developing a monitoring network concept which consists of a combination of modern monitoring technology and flexible hight-quality sensors to measure water quality parameters at different locations as rivers, sewers or wastewater treatment plants.
The goal is to create a new generation of a monitoring network which consists of several in-situ, automated monitoring stations at different locations that measure water quality dynamics and transfer data on-line to a central server where all of the data is analyzed and validated by automatic data quality assessment tools (ADQATs) and in the end knowledge about whole water bodies could be gained. With such a network a lot of time can be saved because a huge amount of data with an uncertain quality is produced and the manual validation of such data is very time consuming as well as to analyze the data in the laboratory.

1.2. Project: Creating datEAUbase

model*EAU* is a big research group where many different projects are involved and especially where a lot of environmental data is produced. Therefore, the wish occurred to have a general database to store all of the collected environmental data of each project and to store all equipment information as well as contact information of each model*EAU* member. In addition, a database like this ensures a consistent storage of data in a predefined format.

Hence, the project to create such a database was initiated. The name of this database is dat*EAU*base. The requirements on dat*EAU*base was to create a consistent database in *MS Access* and to have a user interface created in *MS Excel* to avoid that each member of model*EAU* needs to learn the syntax of *MS Access*. After dat*EAU*base was created by Ms Queralt Plana soon limitations by *MS Access* occurred and it was realized that this database was not useful for model*EAU*.

Thus, the decision was made to create dat*EAU*base in *MySQL* and the interface in *Python* because of less limitations and more storage space than with *MS Access* and *MySQL* is one of the most common relational database management systems.

2. Projects and tasks during the internship

In this section is a description about my work I did in each project in which I was involved at model*EAU*. I was involved in the projects "mon*EAU*: Automated monitoring stations for water quality" and "Creating dat*EAU*base". In the project mon*EAU* I was supervised by Dr. Janelcy Alferes and I worked together with Maxime Roussel another intern from France and in the project "Creating dat*EAU*base" I was supervised by Dr. Janelcy Alferes and Dr. Thibaud Maruéjouls and I was supporting Queralt Plana a master student at the University Laval in Quebec. In the beginning I was supposed to work mainly in the project mon*EAU* and only support a little in the project "Creating dat*EAU*base" but during the internship I was working more and more in the project "Creating dat*EAU*base" because of less work in the project mon*EAU* and I have knowledge about creating databases.

2.1. Tasks in the project monEAU

My first task was to familiarize myself with the mon*EAU* project. Especially with all the old and new water quality sensors. The old sensors are the turbidity sensor Solitax, the LDO sensor from Hach, the Spectro::lyser from S::can, the conductivity sensor from Hach and the Ammo::lyser from S::can. The new sensors are all produced by the company WTW and the sensors are the conductivity sensor *TetraCon700 IQ*, the turbidity sensor *VisoTurb 700 IQ*, the ph/ORP sensor *SensoLyt 700 IQ*, the DO sensor *FDO 70 IQ* and the ammonium, nitrate and potassium sensor *VarionPlus 700 IQ*.
After I was familiarized with the sensors my job was to write SOP's for each of the new sensors except *VarionPlus 700 IQ*. An SOP (Standard operational procedures) is a document which contains procedures about how to use and maintain the sensor as well as information about the working principal of the sensor. The SOP's of the new sensors are in the appendix in the subsection A.1

The second task was to test all the new sensors following the ISO 15839:2003 protocol "Water quality - Online sensors/analysing equipment for water - Specifications and performance tests" to determine the water quality characteristics of each sensor. But before we could start with the test we, Dr. Janelcy Alferes and me, created a standard operational procedure for testing sensors in the laboratory out of the ISO 15839:2003 and the Master-thesis of Mathieu Beaupré (Beaupré [2010]) who also tested sensors following the ISO 15839:2003. This testing procedure with the title "Standard operational procedure for testing sensors in the lab" is attached in the appendix in the subsection A.2.

After the procedure was finished we, Maxime Roussel and me, started testing the conductivity sensor *TetraCon700 IQ*. The tests were conducted on five *TetraCon700 IQ* conductivity sensors which were connected to one mon*EAU* station where it was possible to visualize and store the data. The tests took a very long time because there were some problems with one of the data storage application in the mon*EAU* station system. The results of the tests are written in the report "Testing of the conductivity sensor TetraCon

700 IQ" which is attached in the appendix in the subsection A.3. Unfortunately, there was not enough time to test the other four sensors but Maxime Roussel will continue the tests of the outstanding sensors.

2.1.1. Excursion to Wemotaci

Wemotaci is a canadian native village six hours by car north western of Quebec City. This village is very isolated from the civilization therefore it is not possible to connect the wastewater system to other villages. Hence, this village has its own wastewater treatment plant which consists of two separated reservoirs which are called lagoons. The wastewater enters the first lagoon where the bigger parts settle down and some bio reactions take place. Afterwards the wastewater enters the second lagoon where some particle settling take place and after that the wastewater is lead in the river.

Figure 1: The first lagoon in Wemotaci. In the brown tent on the right is the first mon*EAU* station installed at the inlet of the lagoon and on the other side is the second mon*EAU* station installed at the outlet of the lagoon. In between are the bio-reators of *Bionest* installed.

This project was in collaboration with the company *Bionest*. This company was testing their product, bio-filters, in the first lagoon and model*EAU* was testing two mon*EAU* stations. One station was installed at the inlet and the other station at the outlet of the first lagoon as shown in figure 1. Thus, the company was using the collected data by the mon*EAU* stations to compare if there is a difference before and after the bio-filters and model*EAU* was able to test their stations. In figure 2 is one of the mon*EAU* stations shown.

Figure 2: The first mon*EAU* station at the inlet of the lagoon. The tent is for protection against wind and precipitation. The station is installed inside a big closet made out of solid metal and very thick isolation material to protect the system for freezing in the winter.

This project was conducted for one year and after that time the company decided that this site was not adequate enough because in the winter it was too cold and other circumstances lead to the decision to change to another site. Therefore, we went there for two days to deinstall all the mon*EAU* stations and to clean all the equipment including all of the sensors. A sensor is shown during the cleaning process in figure 3.

2.2. Tasks in the project ”Creating datEAUbase”

At the beginning of my work in this project they were deciding to create a database in *MySQL* and to create a user interface in *Python*. This project is mainly the project of Queralt Plana and with my knowledge about MySQL I was able to support her. First, I had to familiarize myself with the old database which was created in *MS Access*. After I was familiar with the old database and the application *MySQL Workbench*, which is a user interface to create databases, we splited up the work. Therefore, my part was to create a database in *MySQL* and Queralt Planas part was to create a user interface for the database.
I finished the dat*EAU*base and I wrote a user's guide. In the user's guide there are basic information about creating a database in *MySQL*, how dat*EAU*base is composed, how to enter data and some of the basic queries. Unfortunately, the user interface which Queralt Plana is working on is still on going. The user's guide to dat*EAU*base is attached in the appendix B.1.

Figure 3: Cleaning of one of the sensor with water. Only water is allowed to use because other liquids could cause damage on the sensor.

3. Conclusions and experiences

The internship at the research group model*EAU* was very interesting because I had the opportunity to work in different projects at the same time. Especially it was nice to learn about sensors and how they are composed and to work on the mon*EAU* stations. I gained a lot of knowledge about sensor technologies as well as monitoring procedures. What I most liked about the project mon*EAU* was the practical work in the laboratory combined with excursions to the field.

In the project "Creating dat*EAU*base" I had a lot of fun to exercise *MySQL* what I have once learned in the informatics lecture in the first semester at the ETH. In this project I learned a lot about databases and in the end I am very proud about the database I created in *MySQL* for the research group. The collaboration between Queralt Plana and me was very good which I very appreciated.

I really appreciated the meetings of model*EAU* which were held every week with the whole research group where we discussed our progress and problems of our work we have done. Those meetings were very helpful for everyone and it was also possible to hear what the other researchers are doing. Regularly during those meetings also people were presenting their work which was always very interesting.

Once, we all went together to the WWTP Beauport where the wastewater of one part of Quebec City is treated. This excursion was interesting to see a different WWTP than the ones I am used to in Switzerland. For example the whole treatment plant was inside of a building because of odor emissions.

Unfortunately, in the beginning I felt not well supervised in the project mon*EAU* because at this time it was not clear what my tasks will be in this project. Somehow, it was good so I could use this time to work on the database.

References

Beaupré, M. (2010). *Characterization of on-line sensors for water quality monitoring and process control*. PhD thesis, Université Laval.

model*EAU* (2014). About model*EAU*: http://modeleau.fsg.ulaval.ca/en/about/.

Rieger, L. and Vanrolleghem, P. (2008). moneau: a platform for water quality monitoring networks. *Water Science and Technology*, 57(7):1079–1086.

A. Project monEAU

A.1. SOP (Standard operational procedure)

A.1.1. Turbidity sensor: VisoTurb 700 IQ WTW

Cleaning and calibration of the turbidity sensor: VisoTurb 700 IQ (SW)

NOM DES APPAREILS	**SONDE XX**
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NAME	Tobias Kraft		
FUNCTION	Stagiaire		
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SIGNATURE	Tobias Kraft		

MODIFICATIONS		
REVISION	**DATE**	**DESCRIPTION OF THE MODIFICATION**

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1. Introduction

This standard operating procedure (SOP) refers to the sampling process and the calibration of the *VisoTurb 700 IQ (SW)* turbidity sensor from the company YSI.

2. Application Data

The *VisoTurb 700 IQ* is used for stationary measurements of the turbidity or suspended solids concentration (total suspended solids – TSS) in water/wastewater. The *VisoTurb 700 IQ SW* is used for measurements in seawater and brackish water, aquaculture.

The turbidity measurement in aqueous media is conducted nephelometrically in accordance with EN ISO 7027. The measurement values in formazine nephelometric units (FNU) can be converted to NTU, TEF, mg/l SiO2, ppm SiO2, g/l TSS (total suspended solids).

The measuring range of the sensor is quiet large, it is between 0 to 4000 FNU.

The sensor is also able to determine the total suspended solids content. The correlation for the given application can be determined via a reference measurement. After this adjustment, the turbidity is converted into the concentration of total suspended solids.

The sensor can be used at temperatures between 0 °C and 60 °C.

3. Definition and Principle

3.1 Turbidity

The turbidity of a fluid is a subjective optical impression. Turbidity is caused by small particles (total suspended or dissolved solids) which have a different index of refraction than the fluid or which absorb the light. Those particles are generally invisible to the naked eye, similar to smoke in air. The measurement of turbidity is a key test of water quality.

The turbidity fluid Formazine was invented to measure comparably different turbidities. All turbidity units refer to dilutions of the fluid Formazine. The most common turbidity units are:

- FAU (Formazine Attenuation Units) – Measuring of transmitted light (angle 0°) corresponding to the standards of ISO 7027
- FNU (Formazine Nephelometric Units) – Measuring of scattered light (angle 90°) corresponding to the standards of ISO 7027.

- FTU (Formazine Turbidity Unit) – Unit which is used in water treatment
- NTU (Nephelometric Turbidity Unit) – Measurement at 90° corresponding to the standards of the USA, identically to FTU

The turbidity value for clean water is around 0.03 NTU, for drinking water between 0.05 and 0.5 NTU and for waste water between 100 and 2000 NTU.

3.2 TSS – Total suspended solids

Suspended solids are the dry weight of the sum of all solids which are captured by membrane filter with a defined pore size. Suspended solids refer to small particles which remain in suspension in water as a colloid or due to the motion of the water.

4. Commissioning

4.1 Installation of the sensor

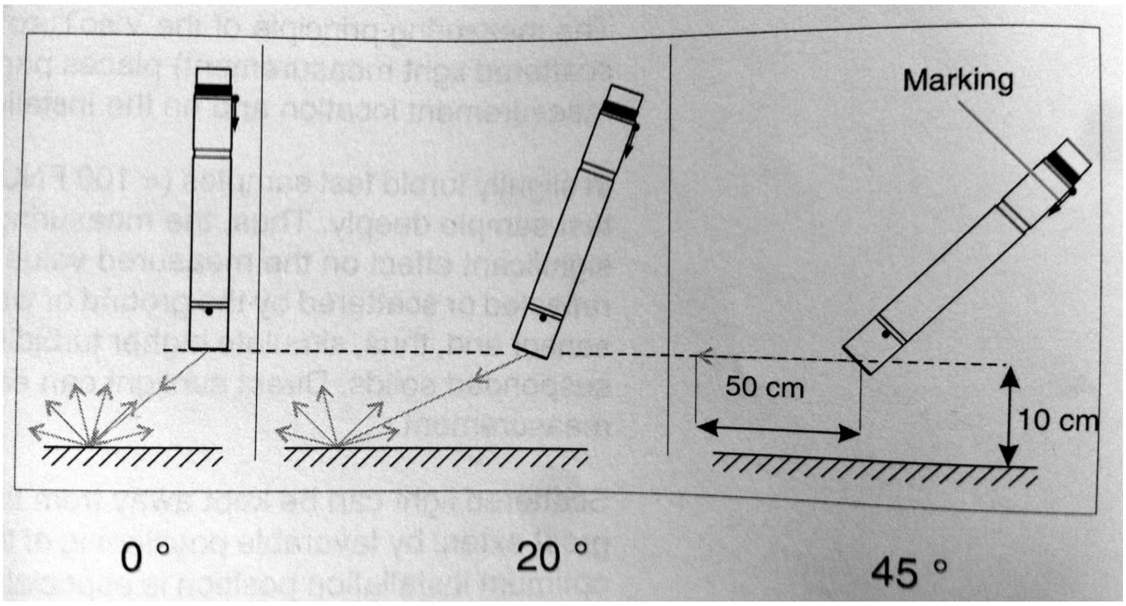
The location of the measurement and the installation of the sensor is very important to receive good results. The measuring environment can have a significant effect of the measured value displayed. Thus, it is very important to put the sensor in an optimum measuring position.

Factors which can affect the measurement:

- Inclination of the sensor
- Sensor orientation around its longitudinal axis
- Distances from ground and wall
- Light-colored, heavily light-scattering surfaces in the measuring vessel or in the measuring environment
- Unfavorable geometry of the measuring vessel or unfavorable positioning of the sensor in the measuring vessel
- Air bubbles in the test sample
- Spatial proximity of two optical sensors
- Very bright ambient light at the measuring location, e.g. direct sunlight in the open channel

4.1.1 Flow direction

The sapphire disc should be positioned clearly against the current in flowing media (angle between 20 % and 45 %)



4.1.2 Sensor orientation

The sensor has a marking (arrow symbol) which shows the direction of the infrared beam which emerges at an angle of 45°. The sensor should be positioned so that as little light as possible which is scattered or reflected by wall or ground strikes the measurement window.

5. Maintenance

The sensor usually does not need to be cleaned. There is a continuously running ultrasound system which prevents the accumulation of pollution in almost all cases.

5.1 Cleaning the sensor shaft and sapphire disc

Clean the sensor if:

- There is any pollution
- The sensor was not in use for a longer period of time but was immersed in the measuring medium
- The measured values are suspected to be incorrect
- The SensCheck message appears in the log book

If the sensor is contaminated with sludge, loosely adhering dirt or biological films than clean it with soft cloth or brush and warm tap water.

If the sensor is contaminated with salt or lime deposits clean it with acetic acid (20%) and soft cloth or soft sponge.

6. Calibration

For measurements of the total suspended solids a calibration must be done before using the sensor.

A new calibration is required if there is any change of the characteristics of the measuring medium or any change of the environment at the measuring location.

6.1 Calibration for measuring the total suspended solids (g/l TSS)

1. Bring the sensor into the measuring position
2. In the setting table of the turbidity sensor, select the g/l TSS measuring mode and the AutoRange measuring range
3. Switch to the measured value display with “M”
4. When the measured value is stable, read and record the FNU value
5. If possible, take a sample at the same time as the turbidity measurement and, if possible, directly at the measurement windows.
6. Determine and note the concentration of total suspended solids in the according to a reference procedure.
7. Switch to the setting table of the turbidity sensor.
8. Select the value range for the total suspended solids contents determined during the reference measurement in the TSS range field.
9. Select the value range for the turbidity determined during the reference measurement in the Turbidity range field.
10. Enter the values for the concentration of total suspended solids and turbidity obtained from reference measurement.

7. Bibliography

- YSI: VisoTurb 700 IQ (SW) turbidity/suspended solids sensor Operating Manual, January 2012
- Willi Gujer. Siedlungwasserwirtschaft

- http://en.wikipedia.org/wiki/Turbidity
- http://en.wikipedia.org/wiki/Suspended_solids

A.1.2. pH/ORP sensor: SensoLyt 700 IQ WTW

UNIVERSITÉ LAVAL DÉPARTEMENT DE GÉNIE CIVIL	**Methods** **SOP-047_monEAU**	
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Cleaning and calibration of the pH/ORP sensor SensoLyt®700 IQ (SW)

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MODIFICATIONS

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1. Introduction

This standard operating procedure (SOP) refers to the sampling process and the calibration of *the SensoLyt 700 IQ (SW)* pH/ORP - sensor from the company.

2. Application Data

The *SensoLyt 700 IQ* is used for measurements in water/wastewater. The *SensoLyt 700 IQ SW* is used for measurements in seawater and brackish water.

The measuring range for pH is between 0.00 and 14.00 and for ORP between -2000 mV and +2000 mV depending on the electrode. The sensor can be used at temperatures between -5 °C and 60 °C.

3. Definition and Principle

3.1 Definition of pH

The pH of a water sample is an indication of the acidity or basicity. It measures the concentration of the hydrogen ion [H+]. Measurements of pH run on a scale from 0 to 14, with 7.0 considered neutral. Solutions with a pH less than 7 are acidic and solutions with a pH greater than 7 are basic or alkaline.

3.2 Principle of pH measurement

The principle of pH measurement is based on the potential of a pH electrode. A half-cell reaction at the pH electrode makes an electrical potential which is directly dependent on the concentration of H^+ ions. An electric tension which shows widely the pH value is produced because of the potential difference to the reference electrode. The reference electrode mostly consists of a silver – silver chloride – half cell together with the pH electrode. The reference electrode is connected to the measured solution through a diaphragm which mostly consists of glass sponge, ceramic or platinum sponge. The pH electrode is stored in a potassium chloride solution to keep the diaphragm potentially neutral and conductible.

3.3 Definition of Oxidation-Reduction Potential (ORP)

ORP declares of the cleanliness of the water and its ability to break down contaminants. Actually the sensor measures the dissolved oxygen. More contaminants in the water lead to less dissolved oxygen which means a lower ORP level.

4. Maintenance

The SensoLyt 700 IQ (SW) ph/ORP sensor operates maintenance free.

4.1 Storage

When not in use, the pH electrodes must always be stored protected with the protective cap which is included upon delivery. This plastic cap needs to be filled with a KCl solution (1 - 3M) or tap water (don't use distilled water) before fitting it over the electrodes. Drying out will damage these electrodes and will reduce measuring quality and life time of the electrode significantly. If the reference electrode is stored on air for longer time (> 48 hours) it will become inoperable.

4.2 Replacing the combination electrode

1. Unscrew the protective hood from the sensor.
2. Use the protective hood as atool to lever out the combination electrode
3. Carefully pull out the combination electrode until the plug head screwed fitting can be seen.
4. Unscrew the combination electrode from the plug head socket
5. Screw in a new combination electrode
6. Push the unit into the sensor up to the stop
7. Pull the KCL-filled cap off the combination electrode for measuring.
8. Screw the protective hood onto the sensor.
9. Calibrate the sensor and the electrode with the measuring system.

5. Calibration

The sensor has to be calibrated before every measurement. There are three ways to calibrate the sensor. The *Cal TEC AUTO* calibration enables a fully automatic calibration using buffer solutions. The *Cal CON 2P* calibration procedure enables conventional two point calibration using two different buffer solutions. The *CAL CON 1P* calibration procedure enables conventional single point calibration with any single buffer solution.

Before starting the calibration make sure the correct calibration procedure is set.

1. Switch to the measured value display with "M" and select the sensor to be calibrated.
2. Call up calibration with "C". The next step switches on the maintenance condition for the sensor. A corresponding note appears on the display.
3. Confirm the note with "OK".
   The maintenance condition is active.
   The menu-guided calibration routine starts.
   Follow the instructions on the display.
   After the cilbration routine is finished, the measured value display appears again (the measured value flashes because the sensor is still in the maintenance condition).
4. If the calibration was successful, bring the sensor into the measuring position.

5. Wait for a stable measured value.
6. Switch off the maintenance condition.

5.1 Calibration with CAL TEC AUTO

1. Have any two technical buffer solutions ready. Confirm with “OK”.

2. Rinse the sensor. Immerse the sensor in the first buffer solution and wait for a stable measured value. Follow the instructions on the display. As soon as a table measured value is reached, the next display will appear.

3. Rinse the sensor. Immerse the sensor in the second buffer solution and wait for a stable measured value. Follow the instructions on the display. As soon as a table measured value is reached, the next display will appear

4. Successfully calibrated. Confirm with “OK”.

5.2 Calibration with CAL CON 2P

1. Have a buffer pH 7.0 ± 0.5 and any second buffer solution ready.

2. Rinse the sensor. Immerse the sensor in the first buffer solution pH 7.0 ± 0.5. Wait for a stable measure. Follow the instructions on the display.

3. Enter the pH value of the first buffer solution. Confirm with “OK”

4. Rinse the sensor. Immerse the sensor in the second buffer solution. Wait for stable measure value. Follow the instructions on the display.

5. Enter the pH value of the second buffer solution. Confirm with “OK”.

6. Successfully calibrated. Confirm with “OK”.

5.3 Calibration with CAL CON 1P

1. Have any buffer solution ready. You can use any buffer solution the pH value of which is known at the current temperature.

2. Rinse the sensor. Immerse the sensor in the first buffer solution. Wait for a stable measure. Follow the instructions on the display.

3. Enter the pH value of the buffer solution. Confirm with “OK”

4. Successfully calibrated. Confirm with “OK”

The values must be within the following range:
Slope: -50 – 62 mV/pH.
Asymmetry: -45 mV – 45 mV

6. Cleaning the sensor

Needs to be written.

7. Bibliography

- YSI: IQ Sensor Net SensoLyt 700 IQ (SW). pH/ORP sensor operating manual.
- http://de.wikipedia.org/wiki/PH-Meter
- http://www.ozoneapplications.com/info/orp.htm

A.1.3. DO sensor: FDO 70x IQ WTW

UNIVERSITÉ LAVAL DÉPARTEMENT DE GÉNIE CIVIL	**Methods** **SOP-047_monEAU**	
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Cleaning and calibration of the DO sensor: FDO 70x IQ (SW)

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MODIFICATIONS

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1. Introduction

This standard operating procedure (SOP) refers to the sampling process and the calibration of the *FDO 70x IQ (SW)* DO sensor from the company YSI.

2. Application Data

The *FDO 70x IQ* is used for measurements in water/wastewater. The *FDO 70x IQ (SW)* is used for measurements in seawater, aquaculture.
The measuring range for DO is between 0 and 20.00 mg/L or 0 and 20.00 ppm with a resolution of 0.01 mg/L or 0.01 ppm.
The sensor can be used at temperatures between -5 °C and 50 °C.

3. Definition and Principle

3.1 Definition of dissolved oxygen (DO)

Oxygen saturation or dissolved oxygen (DO) is a relative measure of the amount of oxygen that is dissolved or carried in a given medium. It can be measured with a dissolved oxygen probe such as an oxygen sensor or an optode in liquid media, usually water. This parameter is one of the best indicators of the health of a water ecosystem.

Environmental oxygenation can be important to the sustainability of a particular ecosystem. If more oxygen is consumed than is produced, dissolved oxygen levels decline and some sensitive animals may move away, weaken, or die.

DO levels fluctuate seasonally and over a period of 24 hours. They vary with water temperature and altitude. Cold water holds more oxygen than warm water and water holds less oxygen at higher altitudes. Thermal discharges, such as water used to cool machinery in a manufacturing plant or power plant, raise the temperatures of water and lower its oxygen content.

The DO is expressed in milligrams the oxygen per liter of water (mg O_2/l) or parts per million (ppm).

3.2 Operation principle

Need to be added

3.3 Common ranges

Dissolved oxygen can range from 0 to 18 ppm, but most natural water systems require a range of at least 5 to 6 ppm to support a diverse population.

4. Maintenance

4.1 Cleaning the sensor

4.11 Exterior cleaning

Never use any alcohol for cleaning!

1. Rinse the sensor with tapwater.
2. Brush off the rough dirt with a soft brush. Do not brush in the area of the sensor!
3. Wipe with a soft and moist microfiber cloth the sensor cap including the sensor membrane.

4.12 Interior cleaning

Only use nonabrasive, alcohol-free detergents!

1. Remove the sensor cap.
2. Clean the head and sensor cap:
   - Rinse all inner surfaces with tapwater
   - Remove contamination containing fat and oil with warm water and household washing-up liquid.
3. Dry the sensor cap and sensor completely while protecting the sensor cap from light.

5. Calibration

The *FDO 70x IQ* is factory calibrated. The characteristics of the sensor cap should remain stable for the specified service life. Thus, the sensor does not need to be calibrated.

A function check is the simplest way to determine whether the sensor needs to be cleaned or user-calibrated.

Before a function check or a user-calibration the following adjustment needs to be prepared. The membrane has to be clean and dry for this.

- With air temperatures over 5 °C:
  Position the sensor approx. 2 cm above a water surface, for example a narrow bucket or similar container with water.

- With air temperatures under 5 °C:
  Position the sensor in air-saturated water which has a higher temperature. You obtain air-saturated water by pouring water several times in and out two vessels so that it sparkles.

5.1 Function check

1. Switch to the measured value display with “M” and select the *FDO 70x IQ* sensor.
2. Press “C”. The next step switches on the maintenance condition for the sensor.
3. Confirm the note with “OK”.
4. Select the *TEST* procedure and press “OK”.
5. Put the sensor into the calibration position.
6. Press “OK”. The *CAL* indicator flashes. The process ends automatically.
7. Put the sensor in the measuring position again.
8. Wait for the measured value to be largely stable.
9. Switch off the maintenance condition.

5.2 User calibration

1. Switch to the measured value display with “M” and select the *FDO 70x IQ* sensor.
2. Press “C”. A corresponding message appears on the display.
3. Confirm the note with “OK”. The maintenance condition is active.
4. Select the *Calibration* procedure and press “OK”.
5. Put the senor into calibration position.
6. Press “OK”. The *CAL* indicator flashes. The process ends automatically. Subsequently, the main measured value and temperature are displayed.
7. If the calibration was successful, bring the sensor into the measuring position again.
8. Wait for the measured value to be largely stable.
9. Switch off the maintenance condition.

6. Bibliography

- YSI: IQ Sensor FDO 70x IQ (SW) DO sensor operating manual.
- Queralt Plana. Cleaning and calibration of the LDO sensor (Hach), 04-04-2012
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A.1.4. Conductivity sensor: TetraCon 700 IQ WTW

Cleaning and calibration of the TetraCon700 IQ conductivity sensor

NOM DES APPAREILS	**SONDE XX**
MODEL	
N° SERIAL	
PRÉCISION ET REPRODUCTIBILITÉ	
DATE DE POSTE EN FONCTIONNEMENT	
DISTRIBUTION	
WEBSITE	http://modeleau.fsg.ulaval.ca/
PROFESSEUR RESPONSABLE	Peter Vanrolleghem

	RÉALISATION	**RÉVISION**	**APPROBATION**
NOM	Tobias Kraft		
FONCTION	Intern		
DATE	2014-07-29		
SIGNATURE	Tobias Kraft		

GESTION DES MODIFICATIONS

RÉVISION	**DATE**	**DESCRIPTION DE LA MODIFICATION**

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1. Introduction

This standard operating procedure (SOP) refers to the sampling process and the calibration of the *TetraCon 700 IQ* conductivity sensor from the company WTW.

2. Application Data

The *TetraCon 700 IQ* sensor is used for measurements in water/wastewater and the *TetraCon 700 IQ SW* is used for measurements in seawater and brackish water.

The measuring range for the conductivity is between 10.00 µS/cm and 500.0 mS/cm. The measuring range for temperature is between -5 °C and 60 °C. The pH of the test sample must be between 4 and 12.

3. Definition and Principle

3.1 Definition of the conductivity

The conductivity of an aqueous solution is a measurement of its ability to conduct electricity. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, calcium, iron, and aluminum cations (ions that carry a positive charge). Organic compounds like oil, phenol, alcohol, and sugar do not conduct electrical current very well and therefore have a low conductivity when in water.

The conductivity is depending on:

- the sort of the ions
- the charge of the ions
- the concentration of the ions
- the temperature of the water
- the viscosity of the water

The conductivity is strongly dependent on the temperature of the solution. Generally the conductivity increases with the temperature.

The (electrical) conductivity of a solution is defined as the inverse of the resistance of the solution under the prescribed circumstances and is expressed in micro Siemens per centimeter (µS/cm) or micro Mhos per centimeter (µmhos/cm).

3.2 Operation principle

The common laboratory conductivity meters employ a potentiometric method and four electrodes. Often, the electrodes are cylindrical and arranged concentrically. The electrodes are usually made of platinum metal. An alternating current is applied to the outer pair of the electrodes. The potential between the inner pair s measured. Conductivity could in principle be determined using the distance between the electrodes and their surface area using the Ohm's law but generally, for accuracy, a calibration is employed using electrolytes of well-known conductivity.

Industrial conductivity probes often employ an inductive method, which has the advantage that the fluid does not wet the electrical parts of the sensor. Here, two inductively-coupled coils are used. One is the driving coil producing a magnetic field and it is supplied with accurately-known voltage. The other forms a secondary coil of a transformer. The liquid passing through a channel in the sensor forms one turn in the secondary winding of the transformer- The induced current is the output of the sensor.

Simple conductivity sensors are constructed of an insulating material imbedded with platinum, graphite, stainless steel or other metallic pieces. These metal contacts serve as sensing elements and are placed at a fixed distance apart to make contact with solution whose conductivity is to be determined. The length between the sensing elements as well as the surface area of the metallic piece determine constantly the electrode cell, defined as length/area. The cell constant is a critical parameter affecting the conductance value produced by the cell and handled by the electronic circuitry.

A cell constant of 1.0 will produce a conductance reading approximately equal to the solution conductivity. For solutions of low conductivity, the sensing electrodes can be placed closes together, reducing the length between them and producing cell constants of 0.1 or 0.01. This will raise the conductance reading by a factor of 10 to 100 to offset the low solution conductivity and give a better signal to the conductivity meter. On the other hand, the sensing electrodes can be placed farther apart to create cell constants of 10 to 100 for use in highly conductivity solutions.

c. Common ranges

High quality deionized water has a conductivity of about 5.5 µS/m, typical drinking water in the range of 5-50 mS/m, while sea water about 5 S/m.

4. Utilisation

4.1 Measuring

For a good measurement the sensor must be surrounded by a gap of at least 5 cm at the base and sides. The sensor does not need to be prepared it is immediately ready for use.

5. Cleaning the sensor

Contamination	Cleaning agents	Reaction time at room temperature
Water-soluble substances	Tap water	Any
Fats and oils	- Warm water and household detergent; - In the case of heavy contamination: Methylated spirits	- Any - Max. 5 min.
Lime and hydroxide deposits	Acetic acid (10 %)	Max. 5 min.

6. Bibliography

- Plana Queralt, SOP-049 Cleaning and calibration conductivity sensor. 23-03-2012
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A.2. Procedure for testing sensors in the laboratory

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model*EAU* Technical Report

Standard operational procedure for testing sensors in the lab

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1 INTRODUCTION AND DEFINITIONS

This document summarises the standard and definitions test to be carried out for evaluating the performance of online water quality sensors. Tests are based on the International Standard ISO 15839 (2003). For the moment only laboratory tests will be carried out. An extra procedure can be applied to evaluate the performance of the sensors in field conditions (See Master Thesis of Mathieu Beaupré (2010), "Characterization of online sensors for water quality monitoring and process control"). Table 1 summarises the performance characteristics to be tested in the lab and in the field as reported in Lynggaard-Jensen (2002).

Within this procedure a "determinant" is defined as a property/substance that is required to be measured and to be reflected by/present in a calibration solution.

Table 1. Performance characteristics for online sensors (Lynggaard-Jensen, 2002)

Performance characteristic	Laboratory Testing	Field Testing
Response time	x	x
Delay time	x	x
Rise time	x	x
Fall time	x	x
Linearity	x	
Coefficient of variation	x	
Limit of detection	x	
Limit of quantification	x	
Repeatability	x	
Lowest detectable change	x	
Trueness	x	x
Short-term drift	x	
Long-term drift		x
Day-to-day repeatability	x	
Memory effect	x	
Interference	x	
Ruggedness	x	
Availability		x
Uptime		x

1.1 Temporal response

The next section summarises the definitions (ISO 1583:2003) used to evaluate the temporal response to up and down step changes as shown in Figure 1.

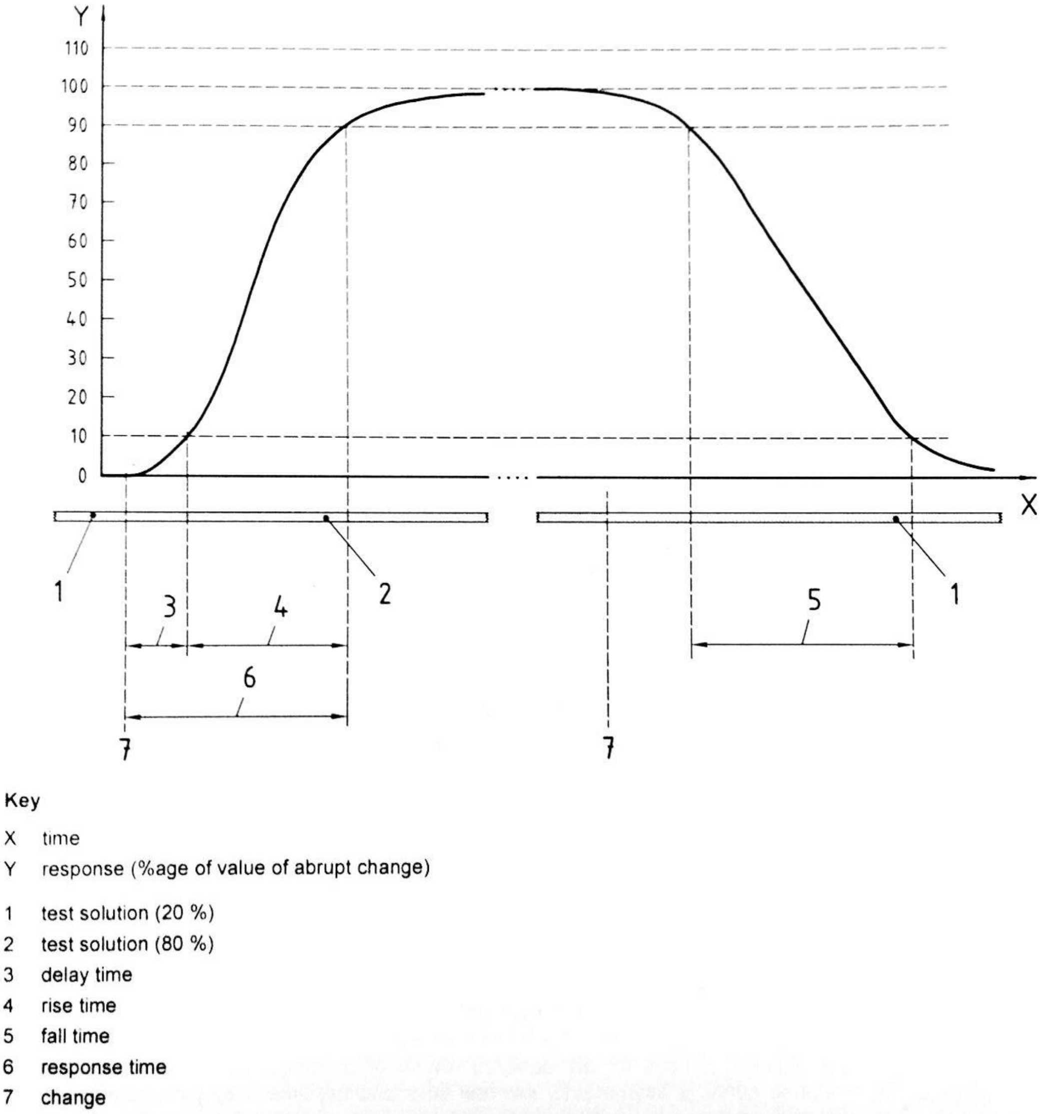

Figure 1 - Temporal response to up and down step changes (ISO 15830:2003).

1.1.1 Response time

Time interval between the instant when the online sensor/analysing equipment is subjected to an abrupt change in determinant value and the instant when the readings cross the limits of (and remain inside) a band defined by 90% and 110% of the difference between the initial and final value of the abrupt change (see Figure 1).

1.1.2 Delay time

Time interval between the instant when the online sensor/analysing equipment is subjected to an abrupt change in determinant value and the instant when the readings pass (and remain beyond) 10% of the difference between the initial and final value of the abrupt change (see Figure 1).

1.1.3 Rise time

It is the difference between the response time and the delay time when the abrupt change in determinant value is positive (see Figure 1).

1.1.4 Fall time

It is the difference between the response time and the delay time when the abrupt change in determinant value is negative (see Figure 1).

1.2 Linearity, detection limits, repeatability...

Before defining the different properties to be measured in this section some mathematical definitions that will be used within this procedure.

For a series of N measurements the mean $\bar{x}$ of the sample is calculated as:

$$\bar{x} = \frac{\sum_{i=1}^{N} x_i}{N} \tag{1}$$

The standard deviation is calculated as:

$$S_{xo} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(x_i - \bar{x}\right)^2} \tag{2}$$

where x_i the concentration of the ith standard sample and $\bar{x}$ the mean.

1.2.1 Linearity

Condition in which measurements made on calibration solutions having determinant values spanning the stated range of the on-line sensor/analysing equipment have a straight-line relationship (linear regression) with the calibration solution determinant values.

Based on the information at the Table 2 the linear regression model is calculated as:

$$y_{ij} = a + b \cdot x_i \tag{3}$$

where:

i is the determinant value level

j is the number of measurements for each determinant value level

x_i is the value of the determinant in the ith calibration solution

y_{ij} is the jth measurement of the determinant value x_i expressed in units of x

a is the intercept point of the regression line

b is the slope of the regression line

$a + b \cdot x_i$ represents the expectation of the measurement value of the ith determinant value level

Table 2. Measurements required for linearity calculation

Reference sample (i)	Reference value (x_i)	Measurements (y_{ij})			
1	x_1	$y_{1,1}$	$y_{1,2}$	…	$y_{1,p}$
2	x_2	$y_{2,1}$	$y_{2,2}$	…	$y_{2,p}$
⋮	⋮	⋮	⋮	⋮	⋮
n	x_n	$y_{n,1}$	$y_{n,2}$	…	$y_{n,p}$

The parameters of the regression line are obtained as follows:

- Mean of p measurements of the ith determinant value level

$$y_i = \frac{1}{p}\sum_{j=1}^{p} y_{ij}$$

- Mean of all determinant value levels

$$M_x = \frac{1}{n}\sum_{i=1}^{n} x_i$$

- Mean of all measurements

$$M_y = \frac{1}{n}\sum_{i=1}^{n} y_i$$

- Estimated slope b

$$b = \frac{\sum_{i=1}^{n}(x_i - M_x)\cdot(y_i - M_y)}{\sum_{i=1}^{n}(x_i - M_x)^2}$$

- Estimated intercept point a

$$a = M_y - b\cdot M_x$$

- Correlation coefficient

$$R^2 = \frac{\left(\sum_1^n (x_i - M_x)\cdot(y_i - M_y)\right)^2}{\sum_1^n (x_i - M_x)^2 \sum_1^n (y_i - M_y)^2}$$

The results can be analysed by means of the correlation coefficient R, that ideally should be equal to ±1, and by using graphs (representation of the values measured against the reference values). An example is shown in Figure 2.

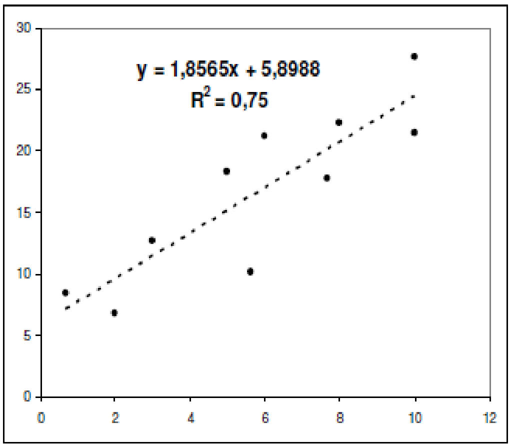

Figure 2.Example of linear regression (Mauriel M. (2010))

1.2.2 Coefficient of variation

It is the ratio between the standard deviation of the on-line sensor/analysing equipment and the mean of the working range of the equipment.

1.2.3 Limit of detection (LOD)

It is the lowest value, significantly greater than zero, of a determinant that can be detected. It is equal to three times the standard deviation (s_{xo}) of 6 measurements carried out at 5% of the measuring range.

$$LOD = 3 \cdot S_{xo(5\%)} \quad (4)$$

1.2.4 Limit of quantification (LOQ)

It is the lowest value of a determinant that can be determined with an acceptable level of accuracy and precision. It is equal to ten times the standard deviation (s_{xo}) of 6 measurements carried out at 5% of the measuring range.

$$LOQ = 10 \cdot S_{xo(5\%)} \quad (5)$$

1.2.5 Lowest detectable change (LDC)

It is the smallest significantly measurable difference between two measurements. It is equal to three times the standard deviation (s_{xo}) of 6 measurements carried out at 20% and 80% of the measuring range.

$$LDC_{20\%} = 3 \cdot S_{xo(20\%)}$$
$$LDC_{80\%} = 3 \cdot S_{xo(80\%)} \qquad (6)$$

1.2.6 Bias

It is the consistent deviation of the measured value from an accepted reference value. It is obtained by calculation of the difference between the average value of six measurements carried out at 20% and 80% of the measuring range and the value of reference measurement at each concentration respectively ($x_{20\%}, x_{80\%}$).

$$B_{20\%} = \bar{x}_{20\%} - x_{20\%}$$
$$B_{80\%} = \bar{x}_{80\%} - x_{80\%} \qquad (7)$$

1.2.7 Short-term drift

Slope of the regression line derived from a series of measurements carried out on the same calibration solution during laboratory testing, and expressed as a percentage of the measurement range over a 24 h period.

1.2.8 Long term drift

Slope of the regression line derived from a series of differences between reference and measurement values obtained during field testing, expressed as a percentage of the working range over a 24 h period.

1.2.9 Repeatability

Precision under repeatability conditions. It is equal to the standard deviation (s_{xo}) of 6 measurements carried out at 20% and 80% of the measuring range.

$$R_{20\%} = S_{xo(20\%)}$$
$$R_{80\%} = S_{xo(80\%)} \qquad (8)$$

1.2.10 Day-to-day repeatability

Precision under day-to-day repeatability conditions. It is equal to ten times the standard deviation (s_{xo}) of 6 measurements carried out at 35% and 65% of the measuring range.

$$R_{35\%} = 10 \cdot S_{xo(35\%)}$$
$$R_{65\%} = 10 \cdot S_{xo(65\%)} \qquad (9)$$

1.3 Memory effect

Temporary or permanent dependence of readings on one or several previous values of the determinant. The memory effect is typically observed as a saturation effect caused by the fact that a determinant value is well above the working range of the equipment. If the memory effect is a permanent one, it will typically introduce a positive offset in the equipment.

1.4 Interferences

Undesired output signal caused by a property(ies)/substance(s) other than the one being measured. If several interferents are identified, the interference level of at least two will be checked by spiking the 20% and 80% calibration solutions with increasing concentrations of the interferent.

2 TEST PROCEDURE

2.1 Temporal response

Two calibration solutions will be prepared with determinand values of 20% and 80% of the working range. Follow the next steps:

1. Immerse the sensor in the 20 % solution for a period equal to three times the preliminary response time
2. Immerse the sensor in the 80 % solution
3. Three preliminary response times after the changeover, change back to the 20 % solution
4. Repeat the procedure six times and record the readings.
5. Determine the values of $(t_{Response}^{+})_i$, $(t_{Delay}^{+})_i$, for a positive change, and the values of $(t_{Response}^{-})_I$ and $(t_{Delay}^{-})_i$ for a negative change.
6. Calculate each rise time as $(t_{Response}^{+})_I$ - $(t_{Delay}^{+})_I$ and each fall time as $(t_{Response}^{-})_I$ - $(t_{Delay}^{-})_i$
7. The final result is the mean value of the determined values together with the standard deviation for each of the characteristics.

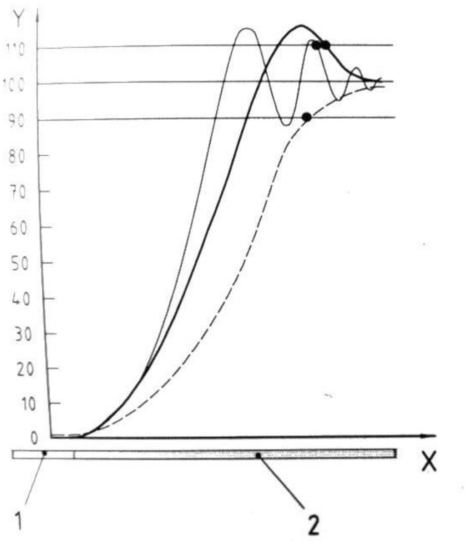

Figure 3. Determination of the response time ($t_{Response}^{+}$) from recorded readings (ISO 15839:2003).

The points on the graphs in **Figure 3** indicate the response times determined, being (1) the test solution at 20%, (2) the test solution at 80%, X the time and Y the response (% age of value of abrupt change).

2.2 Linearity, detection limits, repeatability...

Seven solutions covering the measuring range of the sensors are used to carry out the set of tests. Solutions are equally distributed (5, 20, 35, 50, 65, 80 and 95% of the measuring range). For every concentration six measurements are taken, that depending on the test can be taken on the same day separated by blanks or on different days as shown in Table 3.

Table 3. Use of measurements on scheduling

i	x_i [%]	Determinant level used for	To be measured
1	5	LOD, LOQ	On the same day separated by blanks
2	20	Repeatability, LDC, bias	On the same day separated by blanks
3	35	Day-to-day repeatability	On different days
4	50	Short-term drift	Equally distributed over shortest period between maintenance operations
5	65	Day-to-day repeatability	On different days
6	80	Repeatability, LDC, bias	On the same day separated by blanks
7	95	Linearity check only	On the same day separated by blanks

2.3 Memory effect

Expose the on-line sensor to a calibration solution with a determinant value of 200% of the working range for a period equal to five times the response time, and then change to a 20% calibration solution. Three response times after the changeover, carry out a measurement. Repeat this procedure 6 times.

Report the memory effect as the difference between the mean value of p measurements y_j for $j=1$ to p and the determinant value of the 20 % calibration solution (i.e. 20). The on-line sensor/analysing equipment is said to have a memory effect if the calculated value is bigger than the lowest detectable change (LDC_{20}).

2.4 Interferences

Expose the sensor to the 20% calibration solution spiked with interferent at 0%, 25%, 50%, 75%, 100%, 125%, etc., of the expected interference level. Then measure at each spiking level, stopping this stepwise procedure when the difference between the reading at the actual spiking level and the reading without spiking is bigger than the lowest detectable change (LDC_{20}). Report the last spiking level as the interference level for the interferent tested. Repeat the procedure for the 80% calibration solution using LDC_{80} as the threshold value.

3 APPLICATION EXAMPLE

In this section an example of the above described procedure is shown for the conductivity sensor TetraCon700IQ from WTW. The actual measuring range is between 10 µs/cm to 500.000 µs/cm. The calibration solutions are prepared for a conductivity value of 20’000 µs/cm because this it is within the range of typical wastewater. Different calibration solutions, as shown in Table 4, must be prepared using high-purity, deionized, co2-free water.

Table 4. Calibration solutions for the TetraCon700IQ sensor

Percentage of the working range [%]	Solution Value [mS/cm]	NaCl solution [g/l]
0	0	0
5	1	0.5
20	4	2.06
35	7	3.65
50	10	5.56
65	13	7.23
80	16	8.90
95	19	11.01
100	20	11.59
200	40	25.56

For temporal response tests, take the prepared NaCl calibration solutions at 20% and 80% of the working range, follow the procedure and register the results in the Table 5.

Table 5. Data sheet for recording the temporal response tests

Sequence No.	1	2	3	4	5	6	Mean	Standard deviation
Response time for positive change								
Delay time for positive change								
Response time for negative change								
Delay time for negative change								
Rise time								
Fall time								

For linearity, detection limits, repeatability, etc. tests:

1. Use the eight prepared calibration solutions covering the working range with the values of 0% (blank), 5%, 20%, 35%, 50%, 65%, 80% and 95%.
2. Expose the sensor equipment to the solutions, with the blank solution between each and, after the signal has become stable, carry out the measurements in accordance with Table 3 and Table 6. The schedule of the laboratory tests is listed in Table 7.

Table 6- Data sheet for linearity, detection limits, etc.

i	x_i [%]	Reference [µS/cm]	$y_{i,1}$ [µS/cm]	$y_{i,2}$ [µS/cm]	$y_{i,3}$ [µS/cm]	$y_{i,4}$ [µS/cm]	$y_{i,5}$ [µS/cm]	$y_{i,6}$ [µS/cm]
1	5	2500						
2	20	100000						
3	35	175000						
4	50	250000						
5	65	325000						
6	80	400000						
7	95	475000						

Table 7 - Scheduling of the laboratory tests

i	x_i [%]	Reference [µS/cm]	$y_{i,1}$ [µS/cm]	$y_{i,2}$ [µS/cm]	$y_{i,3}$ [µS/cm]	$y_{i,4}$ [µS/cm]	$y_{i,5}$ [µS/cm]	$y_{i,6}$ [µS/cm]
1	5	2500	Day 4	Day 4	Day 4	Day 4	Day 4	Day 4
2	20	100000	Day 6	Day 6	Day 6	Day 6	Day 6	Day 6
3	35	175000	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
4	50	250000	Day 5	Day 5	Day 5	Day 5	Day 5	Day 5
5	65	325000	Day 4	Day 4	Day 5	Day 6	Day 7	Day 8
6	80	400000	Day 7	Day 7	Day 7	Day 7	Day 7	Day 7
7	95	475000	Day 3	Day 3	Day 3	Day 3	Day 3	Day 3

For the memory effect test take the prepared NaCl calibration solutions at 200% and 20% of the working range, follow the procedure and register the results in the Table 8.

Table 8 - Data sheet for memory effect

x	y_1	y_2	y_3	y_4	y_5	y_6
20						

For the interferences test expose the sensor to the different spiked solutions following the procedure and reporting the results in the

Table 9 - Data sheet for interferences

Calibration solution	Interferent No.	Interferent concentration						
		0	25	50	75	100	125	Etc.
20%	1							
80%	1							
20%	2							
80%	2							
20%	3							
80%	3							

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A.3. Testing of the conductivity sensor TetraCon 700 IQ

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model*EAU* Technical Report

Laboratory Tests of TetraCon700IQ WTW conductivity sensors

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1 INTRODUCTION

In this report are the new conductivity sensors, TetraCon 700 IQ, presented. Those sensors will be used in the new monitoring stations in the project mon*EAU* which have to be tested to determine their characteristics before applying them in the field.

The laboratory tests are following the ISO 15839:2003 "Water quality – Online sensors/analysing equipment for water – Specifications and performance tests" and also the master thesis "Characterization of online sensors for water quality monitoring and process control" of Mathieu Beaupré. This protocol provides laboratory as well as tests in field conditions to determine water quality characteristics of a sensor.

The objectives of those tests are to determine the capacities of the TetraCon 700 IQ conductivity sensors, to evaluate the results and to see if there are differences concerning the characteristics of each model.

2 EXPERIMENTS AND METHODS

2.1 Definition of conductivity

The conductivity is the ability to conduct electrical current of an electrolyte solution (Wikipedia: Conductivity (2014). The functionality behind the measurement of electrical conductivity of a solution is to determine the resistance of the solution between to electrodes with a fixed distance. To avoid electrolysis an alternating voltage is used. Typical frequencies are between 1 and 3 kHz. The conductivity is dependent of temperature and therefore a temperature correction is needed.

2.2 TetraCon 700 IQ WTW

In this section the TetraCon 700 IQ conductivity sensor from WTW is presented (YSI, a xylem brand). This sensor contains four conductivity electrodes as well as a sensor for measuring the temperature. This sensor is suitable to the IQ SensorNet terminals 182, 182 XT, 182 XT-4 and 2020 XT

Figure 1 – Composition of the TetraCon700IQ WTW

TetraCon 700 IQ is especially used for measurements in wastewater treatment plants or sewer systems. The advantage of a 4-electrode measuring technique is that severe influences from polarization effects are eliminated. This results in an improved accuracy. Through the geometry of the sensor no fouling can occur as well as it is easier for cleaning.

The TetraCon 4-electrode design is composed in two separated electrode pairs whereby one of them produces a stable and constant reference potential because of a current less voltage. This drop of the voltage at the current electrodes is regulated. Hence, a more stable reading is resulting even if the conductivity is high.

Composition of the TetraCon 700 IQ sensor:

- 4-electrode design
- extremely robust and durable
- large measuring range (10 to 500 mS/cm) with a single cell
- highly resistant to fouling

2.3 The ISO 15839:2003 protocol

The protocol ISO 15839:2003 'Water quality – On-line sensors/analyzing equipment for water - Specifications and performance tests' is a guide for testing water quality sensors on their performance characteristics. This protocol consists of a part of laboratory tests and of a part of tests in the field. All of the laboratory tests are conducted with seven solutions covering the working range of the sensor. Those seven solutions are 5, 20, 35, 50, 65, 80 and 95 % of the working range.

The following characteristics can be determined by the laboratory tests:

- Response time, delay time, rise time and fall time
- Linearity, coefficient of variation, limit of detection, limit of quantification, repeatability, lowest detectable change, bias, short-term drift, day-to-day repeatability
- Memory effect
- Interferences
- Environmental and operating conditions

The following characteristics can be determined by the test in field conditions:

- Response time, delay time, rise time and fall time
- Bias based on differences
- Long-term drift
- Availability
- Up-time

2.4 Laboratory tests of TetraCon 700 IQ sensors following the ISO 15839:2003

For testing the TetraCon 700 IQ sensors only the laboratory tests were conducted (without the characteristics 'interference' and 'environmental and operating conditions').

The actual measuring range of TetraCon 700 IQ is between 10 µS/cm to 500 mS/cm. Ten calibration solutions were prepared for a maximum conductivity value of 20 mS/cm which is within the range of typical wastewater. Ten calibration solutions, as shown in Table 1, were prepared using high-purity, deionized, co2-free water and sodium chloride.

Table 1 - Calibration solutions for conducting laboratory Tests of the TetraCon700IQ sensor

Percentage of the working range [%]	Solution Value [mS/cm]	NaCl solution [g/l]
0	0	0
5	1	0.5
20	4	2.06
35	7	3.65
50	10	5.56
65	13	7.23
80	16	8.90
95	19	11.01
100	20	11.59
200	40	25.56

2.4.1 Response time, delay time, rise and fall time

For determining the response, delay, rise and fall time the calibration solutions at 20% and 80% of the working range were used by doing the following steps:

1. The sensor was immersed in the 20% solution until the signal was stable.
2. The sensor was immersed in the 80% solution.
3. 30 seconds later the sensor was immersed again in the 20% solution

This procedure was repeated six times and every time recorded. The definitions and calculations are in section 6.1.

2.4.2 Linearity, Coefficient of variation, limit of detection, limit of quantification, repeatability, lowest detectable change, bias, short-term drift and day-to-day repeatability

For carrying out this set of tests the calibration solutions at 0 (blank), 5, 20, 35 50, 65, 80 and 90% of the working range were used. The sensor was exposed to each of the solutions with the blank solution in between. For every concentration six measurements were taken which were scheduled as shown in Table 3. After the signal became stable a measurement was carried out. The calculations for each characteristic are in accordance to Table 2. All definitions and calculations are in section 6.2.

Table 2 - Use of measurements on scheduling

i	x_i [%]	Determinant level used for	To be measured
1	5	LOD, LOQ	On the same day separated by blanks
2	20	Repeatability, LDC, bias	On the same day separated by blanks
3	35	Day-to-day repeatability	On different days
4	50	Short-term drift	Equally distributed over shortest period between maintenance operations
5	65	Day-to-day repeatability	On different days
6	80	Repeatability, LDC, bias	On the same day separated by blanks
7	95	Linearity check only	On the same day separated by blanks

Table 3 - Scheduling of the laboratory tests

i	x_i [%]	Reference [mS/cm]	$y_{i,1}$ [µS/cm]	$y_{i,2}$ [µS/cm]	$y_{i,3}$ [µS/cm]	$y_{i,4}$ [µS/cm]	$y_{i,5}$ [µS/cm]	$y_{i,6}$ [µS/cm]
1	5	1	Day 4	Day 4	Day 4	Day 4	Day 4	Day 4
2	20	4	Day 6	Day 6	Day 6	Day 6	Day 6	Day 6
3	35	7	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
4	50	10	Day 5	Day 5	Day 5	Day 5	Day 5	Day 5
5	65	13	Day 4	Day 4	Day 5	Day 6	Day 7	Day 8
6	80	16	Day 7	Day 7	Day 7	Day 7	Day 7	Day 7
7	95	19	Day 3	Day 3	Day 3	Day 3	Day 3	Day 3

2.4.3 Memory effect

The sensor was exposed to a calibration solution with a determinant value of 200% of the working range for a period equal to five times the response time, and then changed to a 20% calibration solution. Three response times after the changeover, a measurement was carried out. This procedure was repeated six times.

2.4.4 Reference measurement

To compare the measured values with the TetraCon 700 IQ reference measurements were carried out with a conductivity meter.

3 RESULTS AND DISCUSSION

3.1 Response time, delay time, rise and fall time

All of the tested TetraCon 700 IQ conductivity sensors are too fast to determine any response, delay, rise or fall time. The measuring interval was 1 second. So the response, delay, rise or fall time of the TetraCon 700 IQ is less than 1 second, which is very fast.

3.2 Linearity, Coefficient of variation, limit of detection, limit of quantification, repeatability, lowest detectable change, bias, short-term drift and day-to-day repeatability

A summary of all the performance characteristics of each TetraCon 700 IQ sensor are listed in Table 4. Those values were determined following the ISO 15839:2003. In the following subsections those performance characteristics are shown graphically. The measurements results of each TetraCon 700 IQ are in section 6.4.

Table 4 – Characteristics of different TetraCon 700 IQ WTW conductivity sensors

	Sensors serial number				
Performance characteristics	13411140	13411139	13411129	13411130	13411127
Linearity	0.997	0.999	0.999	0.999	0.999
Coefficient of variation [%]	5.180	5.444	2.770	3.023	3.908
Limit of detection [mS/cm]	0.058	0.012	0.053	0.016	0.029
Limit of quantification [mS/cm]	0.192	0.038	0.175	0.054	0.097
Repeatability at 20% [mS/cm]	0.039	0.013	0.019	0.021	0.035
Repeatability at 80% [mS/cm]	0.162	0.064	0.112	0.213	0.055
Lowest detectable change at 20% [mS/cm]	0.116	0.040	0.056	0.064	0.106
Lowest detectable change at 80% [mS/cm]	0.485	0.193	0.337	0.640	0.166
Bias at 20% [mS/cm]	0.667	0.067	0.043	0.015	0.009
Bias at 80% [mS/cm]	-1.070	-0.321	-0.797	-0.835	-0.849
Short-term drift [%/day]	-	-	-	-	-
Day-to-day repeatability at 35% [mS/cm]	0.090	0.062	0.120	0.081	0.119
Day-to-day repeatability at 65% [mS/cm]	0.194	0.128	0.192	0.078	0.053

3.2.1 Linearity

In Figure 2 the linearity of each TetraCon 700 IQ sensor is displayed. The linearity of each sensor is very high, almost 1. The sensor with the serial number 13411140 has the smallest linearity compared to the other fours. This sensor was the first sensor which was tested so it could be that the tests which were carried out were not as exactly conducted as the other tests which were conducted later.

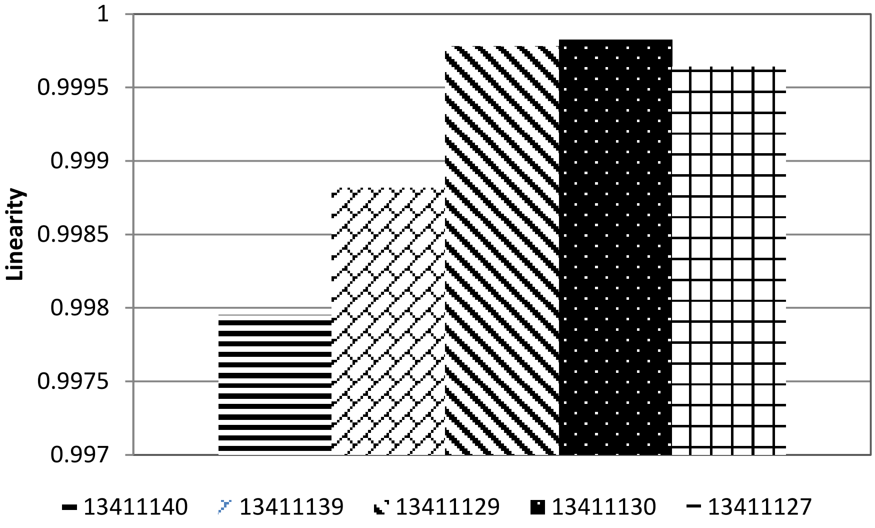

Figure 2 – Comparison of linearity of different TetraCon 700 IQ sensors

3.2.2 Coefficient of variation

In Figure 3 the coefficient of variation of each TetraCon 700 IQ is displayed. The values are between 2.77 to 5.44%.

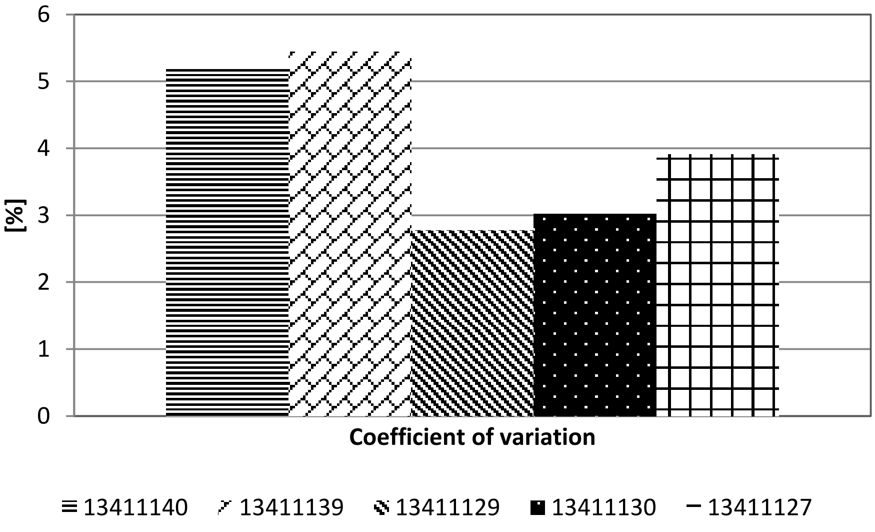

Figure 3 – Comparison of coefficient of variation

3.2.3 Limit of detection and quantification, repeatability, lowest detectable change and day-to-day repeatability

The limit of detection and quantification, repeatability, lowest detectable change and day-to-day repeatability are in the same section because they are all based on calculations with the standard deviation of the measurements.

In Figure 4 the limit of detection and the limit of quantification are displayed of all different TetraCon 700 IQ sensors. Both characteristics have the same shape but different values. This is because they are calculated out of the same data as shown in Table 2 on page 10. The values of the limit of quantification are higher than the ones of the limit of detection.

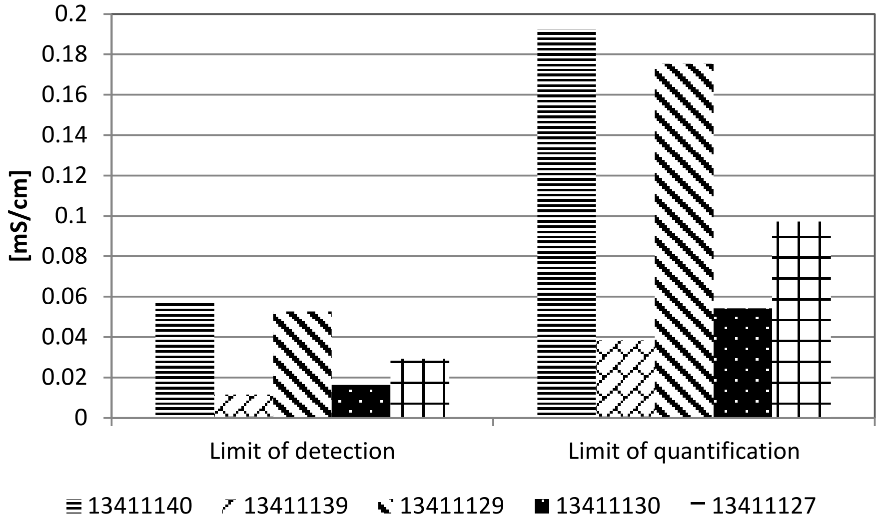

Figure 4 – Comparison of limit of detection and quantification

In Figure 5 a comparison of the repeatability at 20 and 80% of the working range of the five different TetraCon 700 IQ sensors are shown and in Figure 6 is the comparison of the lowest detectable change at 20 and 80% of the working range of the same sensors. The shapes in those two figures are the same because the repeatability is calculated by the standard deviation and the lowest detectable change is calculated by 3 times the standard deviation.

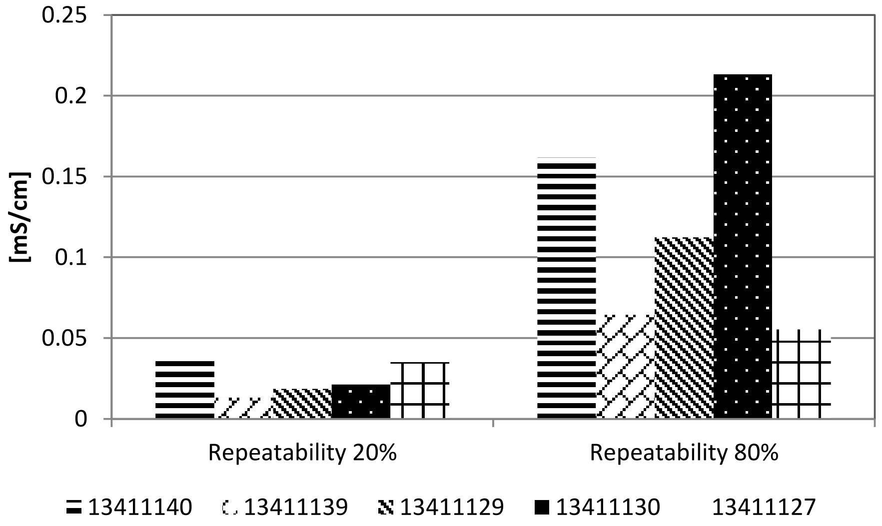

Figure 5 – Comparison of repeatability at 20% and 80% of the working range

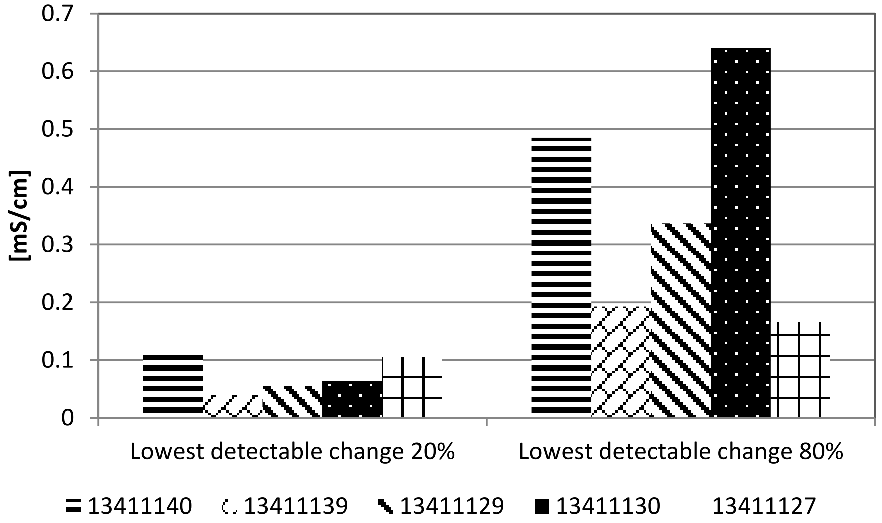

Figure 6 – Comparison of lowest detectable change at 20% and 80% of the working range

Figure 7 shows the comparison of the day-to-day repeatability at 35 and 65 % of the working range of the five conductivity sensors tested. The measurements were carried out on 6 different days. There is a big difference between the sensors with the serial numbers 1341110 and 13411127 in comparison of the day-to-day repeatability at 65% of the working range.

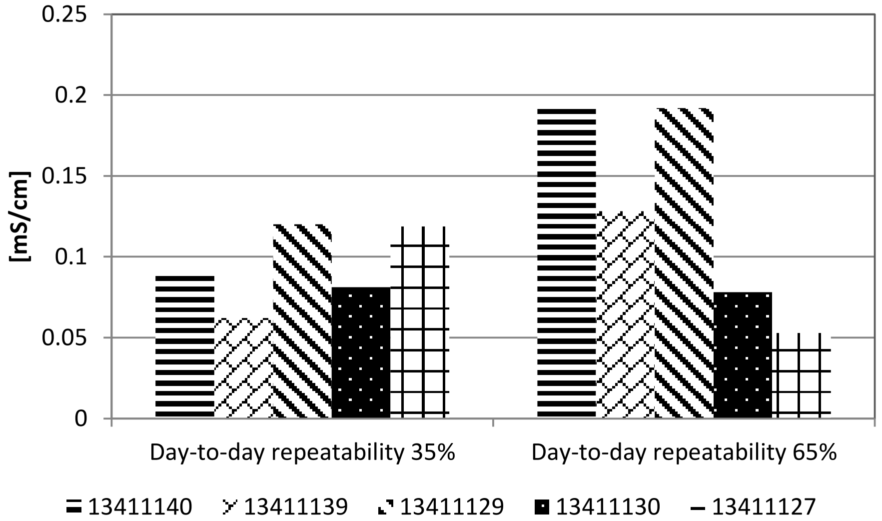

Figure 7 – Comparison of day-to-day repeatability at 35% and 65%

3.2.4 Bias

Figure 8 shows the comparison of the bias at 20 and 80% of the working range of the different conductivity sensors tested. The bias is calculated by difference between measurement of the sensor and the reference measurement. Both measurements are with uncertainties afflicted. The only sensor which has a positive value for the bias at 20% of the working range is the one with the serial number 13411140.

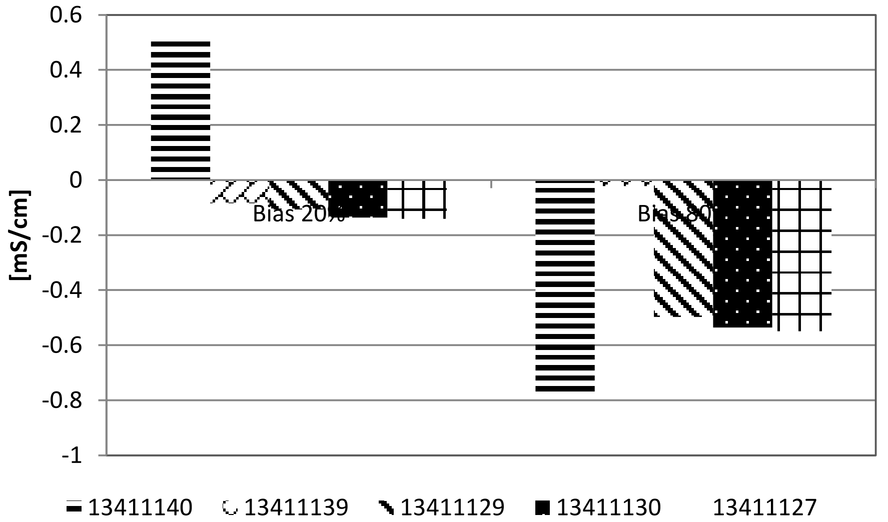

Figure 8 – Comparison of bias at 20% and 80%

3.2.5 Short-term drift

4 CONCLUSIONS

The laboratory tests of the TetraCon 700 IQ WTW sensors have shown that all of them are very good. But the tests have also shown that the there are differences between the five sensors although they are the same model of the same company. The origin of those differences could be because of contamination of the solutions during the measurements by immersing the sensors in different solutions without cleaning them in between.

5 REFERENCES

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ISO (2003). Water quality – On-line sensors/analysing equipment for water-specifications and performances tests. ISO Standard 15839. Geneva, Switzerland.

Mauriel M. (2010). Evaluation of sensors and data procesing tools. Aquafit4use report.

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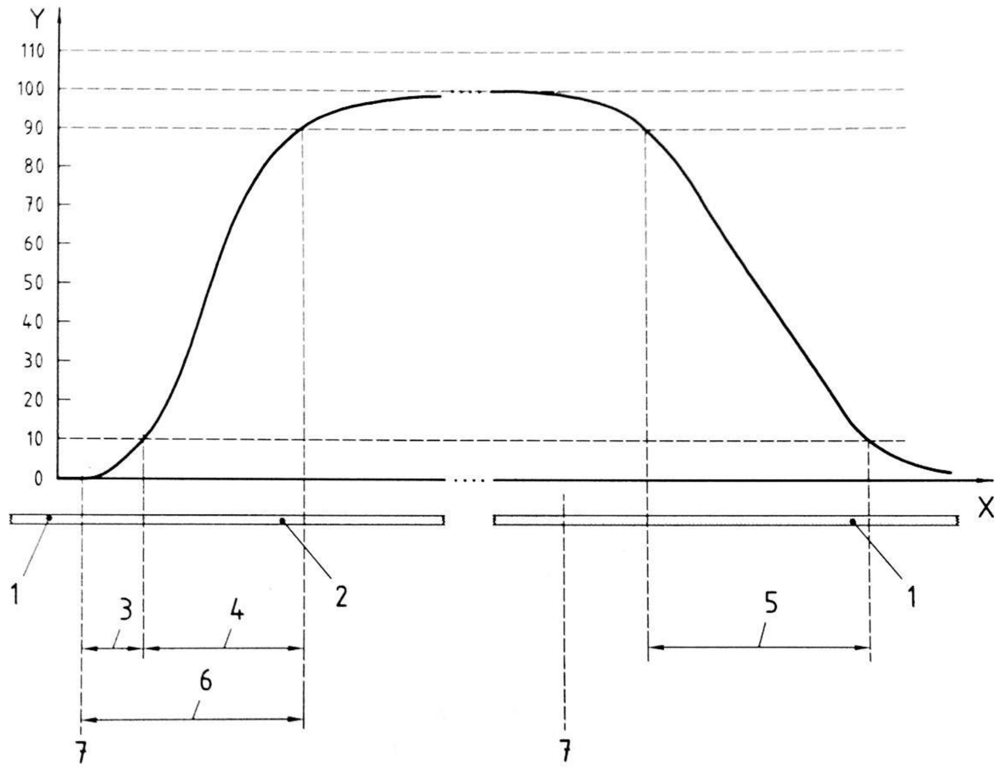
6 APPENDIX

6.1 Definitions of response time, delay time, rise and fall time

In this section the definitions (ISO15839:2003) are explained used to evaluate the temporal response to step changes as shown in Figure 9.



Key

X time
Y response (%age of value of abrupt change)

1 test solution (20 %)
2 test solution (80 %)
3 delay time
4 rise time
5 fall time
6 response time
7 change

Figure 9 - Temporal response to a step change (ISO15839:2003)

6.1.1 Response time

Time interval between the instant when the on-line sensor/analysing equipment is subjected to an abrupt change in determinant value and the instant when the readings cross the limits of (and remain inside) a band defined by 90% and 110% of the difference between the initial and final value of the abrupt change (see Figure 9).

6.1.2 Delay time

Time interval between the instant when the on-line sensor/analysing equipment is subjected to an abrupt change in determinant value and the instant when the readings pass (and remain beyond) 10% of the difference between the initial and final value of the abrupt change (see Figure 9).

6.1.3 Rise time

Difference between the response time and the delay time when the abrupt change in determinand value is positive (see Figure 9).

6.1.4 Fall time

Difference between the response time and the delay time when the abrupt change in determinant value is negative (see Figure 9).

6.2 Definitions of Linearity, Coefficient of variation, limit of detection, limit of quantification, repeatability, lowest detectable change, bias, short-term drift and day-to-day repeatability

Some mathematical definitions which were used to evaluate different characteristics of the sensor are summarized in this section.

For a series of N measurements the mean $\overline{x}$ of the sample is calculated as:

$$\overline{x} = \frac{\sum_{i=1}^{N} x_i}{N} \quad (1)$$

The standard deviation is calculated as:

$$S_{xo} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(x_i - \overline{x}\right)^2} \quad (2)$$

where x_i the concentration of the ith standard sample and $\overline{x}$ the mean.

6.2.1 Linearity

Condition in which measurements made on calibration solutions having determinant values spanning the stated range of the on-line sensor/analysing equipment have a straight-line relationship (linear regression) with the calibration solution determinant values.

Based on the information at the Table 5 the linear regression model is calculated as:

$$y_{ij} = a + b \cdot x_i \quad (3)$$

where:

i is the determinand value level

j is the number of measurements for each determinand value level

x_i is the value of the determinant in the i^th^ calibration solution

y_{ij} is the j^th^ measurement of the determinant value x_i expressed in units of x

a is the intercept point of the regression line

b is the slope of the regression line

$a + b \cdot x_i$ represent the expectation of the measurement value of the i^th^ determinant value level

Table 5. Measurements required for linearity calculation

Reference sample (i)	Reference value (x_i)	Measurements (y_{ij})			
1	x_1	$y_{1,1}$	$y_{1,2}$	...	$y_{1,p}$
2	x_2	$y_{2,1}$	$y_{2,2}$	...	$y_{2,p}$
⋮	⋮	⋮	⋮	⋮	⋮
n	x_n	$y_{n,1}$	$y_{n,2}$	...	$y_{n,p}$

The parameters of the regression line are obtained as follows:

- Mean of p measurements of the i^th^ determinant value level

$$y_i = \frac{1}{p}\sum_{j=1}^{p} y_{ij}$$

- Mean of all determinant value levels

$$M_x = \frac{1}{n}\sum_{i=1}^{n} x_i$$

- Mean of all measurements

$$M_y = \frac{1}{n}\sum_{i=1}^{n} y_i$$

- Estimated slope b

$$b = \frac{\sum_{i=1}^{n}(x_i - M_x)\cdot(y_i - M_y)}{\sum_{i=1}^{n}(x_i - M_x)^2}$$

- Estimated intercept point a

  $a = M_y - b \cdot M_x$

- Correlation coefficient

  $$R^2 = \frac{\left(\sum_1^n (x_i - M_x)\cdot(y_i - M_y)\right)^2}{\sum_1^n (x_i - M_x)^2 \sum_1^n (y_i - M_y)^2}$$

Results can be analyzed by mean the correlation coefficient R, which ideally should be equal to 1, and by using graphs (representation of the values measured against the reference values). An example is shown in Figure 10.

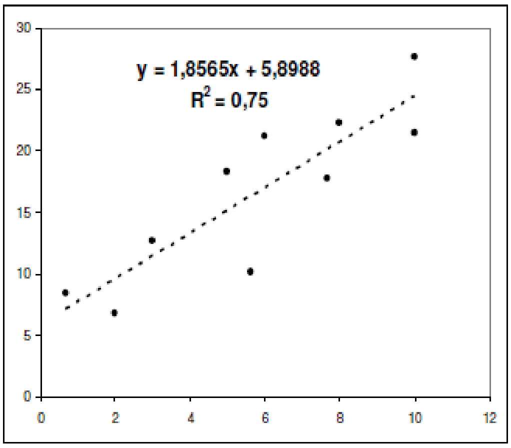


Figure 10.Example of linear regression (Mauriel M. (2010))

6.2.2 Coefficient of variation

Ratio between the standard deviation of the on-line sensor/analysing equipment and the mean of the working range of the equipment.

6.2.3 Limit of detection (LOD)

Lowest value, significantly greater than zero, of a determinant that can be detected. It is equal to three times the standard deviation (s_{xo}) of 6 measurements carried out at 5% of the measuring range.

$$LOD = 3 \cdot S_{xo(5\%)} \qquad (4)$$

6.2.4 Limit of quantification (LOQ)

Lowest value of a determinant that can be determined with an acceptable level of accuracy and precision. It is equal to ten times the standard deviation (s_{xo}) of 6 measurements carried out at 5% of the measuring range.

$$LOQ = 10 \cdot S_{xo(5\%)} \quad (5)$$

6.2.5 Lowest detectable change (LDC)

Smallest significantly measurable difference between two measurements. It is equal to three times the standard deviation (s_{xo}) of 6 measurements carried out at 20% and 80% of the measuring range.

$$LDC_{20\%} = 3 \cdot S_{xo(20\%)}$$
$$LDC_{80\%} = 3 \cdot S_{xo(80\%)} \quad (6)$$

6.2.6 Bias

Consistent deviation of the measured value from an accepted reference value. It is obtained by calculation of the difference between the average value of six measurements carried out at 20% and 80% of the measuring range and the value of reference measurement at each concentration respectively ($x_{20\%}, x_{80\%}$).

$$B_{20\%} = \bar{x}_{20\%} - x_{20\%}$$
$$B_{80\%} = \bar{x}_{80\%} - x_{80\%} \quad (7)$$

6.2.7 Short-term drift

Slope of the regression line derived from a series of measurements carried out on the same calibration solution during laboratory testing, and expressed as a percentage of the measurement range over a 24 h period.

6.2.8 Long term drift

Slope of the regression line derived from a series of differences between reference and measurement values obtained during field testing, expressed as a percentage of the working range over a 24 h period.

6.2.9 Repeatability

Precision under repeatability conditions. It is equal the standard deviation (s_{xo}) of 6 measurements carried out at 20% and 80% of the measuring range.

$$R_{20\%} = S_{xo(20\%)}$$
$$R_{80\%} = S_{xo(80\%)} \quad (8)$$

6.2.10 Day-to-day repeatability

Precision under day-to-day repeatability conditions. It is equal to ten times the standard deviation (s_{xo}) of 6 measurements carried out at 35% and 65% of the measuring range.

$$R_{35\%} = 10 \cdot S_{xo(35\%)}$$
$$R_{65\%} = 10 \cdot S_{xo(65\%)} \quad (9)$$

6.3 Memory effect

Temporary or permanent dependence of readings on one or several previous values of the determinant. The memory effect is typically observed as a saturation effect caused by the fact that a determinant value is well above the working range of the equipment. If the memory effect is permanent one, it will typically introduce a positive offset in the equipment.

6.4 Measurements and Calculations

6.4.1 TetraCon700 IQ 13411140

Table 6 – Measurements of the TetraCon700IQ with the serial number 13411140

Percentage of the working range [%]	Reference, xi [mS/cm]	yi,1 [mS/cm]	yi,2 [mS/cm]	yi,3 [mS/cm]	yi,4 [mS/cm]	yi,5 [mS/cm]	yi,6 [mS/cm]
5	1.124	1.071	1.067	1.06	1.067	1.019	1.058
20	4.15	4.644	4.691	4.708	4.607	4.652	4.697
35	6.95	6.655	6.795	6.66	6.69	6.789	6.878
50	10.11	9.726	9.581	9.493	9.358	9.09	9.125
65	13.2	12.39	12.748	12.823	12.467	12.868	12.662
80	15.7	15.092	14.993	14.978	14.957	14.618	14.944
95	19.16	17.583	18.485	18.405	18.385	18.225	18.041

Table 7 – Linearity of TetraCon 700 IQ 13411140

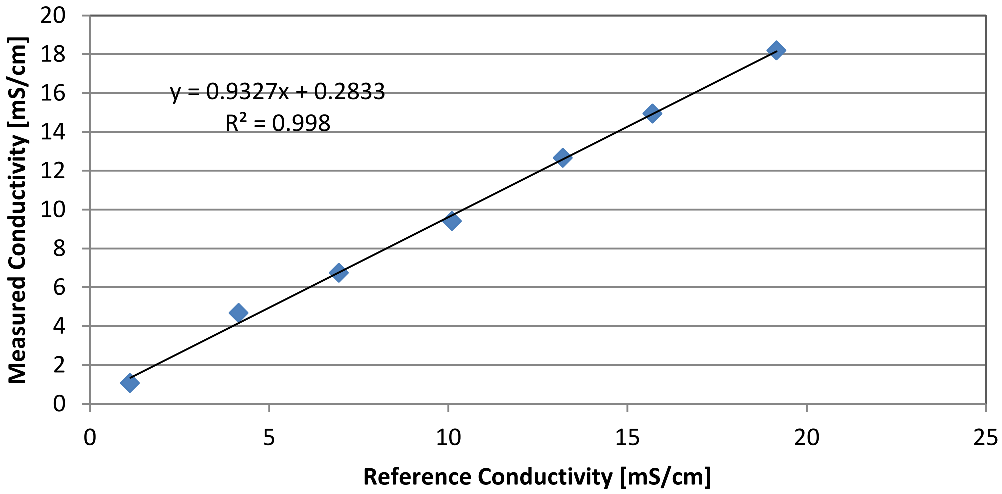


Table 8 – Results of the laboratory tests of TetraCon700 IQ 13411140

Performance characteristics	Unit	Result
Response time for positive change	s	<1
Response time for negative change	s	<1
Delay time for positive change	s	<1
Delay time for negative change	s	<1
Rise time	s	0
Fall time	s	0
Linearity		0.998
Coefficient of variation	%	5.180
Limit of detection (LOD)	mS/cm	0.058
Limit of quantification (LOQ)	mS/cm	0.192
Repeatability 20%	mS/cm	0.039
Repeatability 80%	mS/cm	0.162
Lowest detectable change (LDC) 20%	mS/cm	0.116
Lowest detectable change (LDC) 80%	mS/cm	0.485
Bias 20%	mS/cm	0.517
Bias 80%	mS/cm	-0.770
Short-term drift	%/day	
Day-to-day repeatability 35%	mS/cm	0.090
Day-to-day repeatability 65%	mS/cm	0.194
Memory effect		0.452
Interference caused by interferent 1		
Interference caused by interferent 2		
Environmental and operating conditions:		
requirement 1 (lower/upper limit)		
requirement 2 (lower/upper limit)		

6.4.2 TetraCon700 IQ 13411139

Table 9 – Measurements of the TetraCon700IQ with the serial number 13411139

Percentage of the working range [%]	Reference, xi [mS/cm]	yi,1 [mS/cm]	yi,2 [mS/cm]	yi,3 [mS/cm]	yi,4 [mS/cm]	yi,5 [mS/cm]	yi,6 [mS/cm]
5	1.124	1.086	1.077	1.076	1.079	1.082	1.077
20	4.15	4.077	4.073	4.072	4.076	4.044	4.057
35	6.95	6.823	6.807	6.908	6.942	6.96	6.879
50	10.11	10.058	9.982	10.082	9.973	10.075	10.051
65	13.2	12.79	13.001	12.983	13.096	13.15	12.918
80	15.7	15.762	15.689	15.734	15.603	15.609	15.676
95	19.16	18.65	18.216	18.572	17.357	18.612	18.662

Table 10 – Linearity of TetraCon 700 IQ 13411139

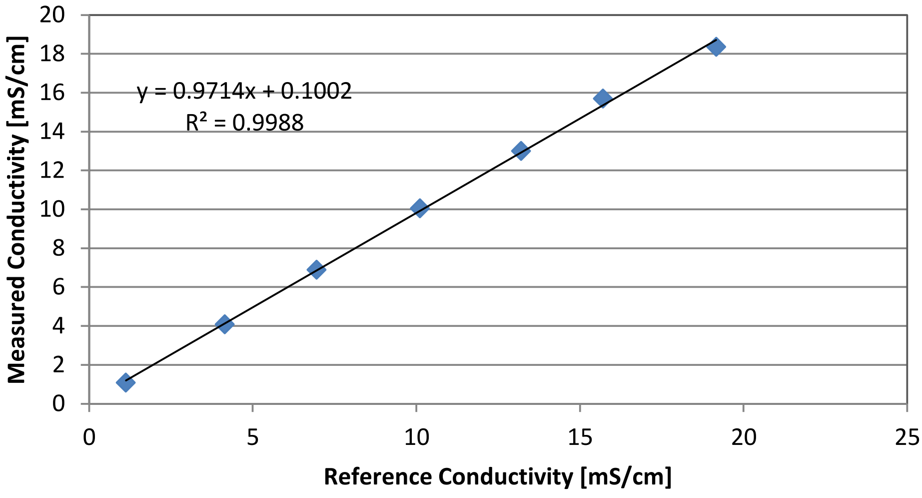


Table 11 – Results of the laboratory tests of TetraCon 700 IQ 13411139

Performance characteristics	Unit	Result
Response time for positive change	s	<1
Response time for negative change	s	<1
Delay time for positive change	s	<1
Delay time for negative change	s	<1
Rise time	s	<1
Fall time	s	<1
Linearity		0.999
Coefficient of variation	%	5.444
Limit of detection (LOD)	mS/cm	0.012
Limit of quantification (LOQ)	mS/cm	0.038
Repeatability 20%	mS/cm	0.013
Repeatability 80%	mS/cm	0.064
Lowest detectable change (LDC) 20%	mS/cm	0.040
Lowest detectable change (LDC) 80%	mS/cm	0.193
Bias 20%	mS/cm	-0.083
Bias 80%	mS/cm	-0.021
Short-term drift	%/day	
Day-to-day repeatability 35%	mS/cm	0.062
Day-to-day repeatability 65%	mS/cm	0.128
Memory effect		0.222
Interference caused by interferent 1		
Interference caused by interferent 2		
Environmental and operating conditions: requirement 1 (lower/upper limit) requirement 2 (lower/upper limit)		

6.4.3 TetraCon700 IQ 13411129

Table 12 - Measurements of the TetraCon700IQ with the serial number 13411129

Percentage of the working range [%]	Reference, xi [mS/cm]	yi,1 [mS/cm]	yi,2 [mS/cm]	yi,3 [mS/cm]	yi,4 [mS/cm]	yi,5 [mS/cm]	yi,6 [mS/cm]
5	1.124	1.032	1.060	1.076	1.055	1.080	1.071
20	4.15	4.069	4.025	4.061	4.025	4.034	4.046
35	6.95	6.626	6.903	6.926	6.930	6.923	6.914
50	10.11	9.989	10.036	10.015	9.989	9.999	10.008
65	13.2	12.566	12.930	13.051	13.055	13.044	13.030
80	15.7	15.240	15.134	15.214	15.225	15.036	15.371
95	19.16	18.417	18.664	18.638	18.613	18.644	18.524

Table 13 - Linearity of TetraCon 700 IQ 13411129

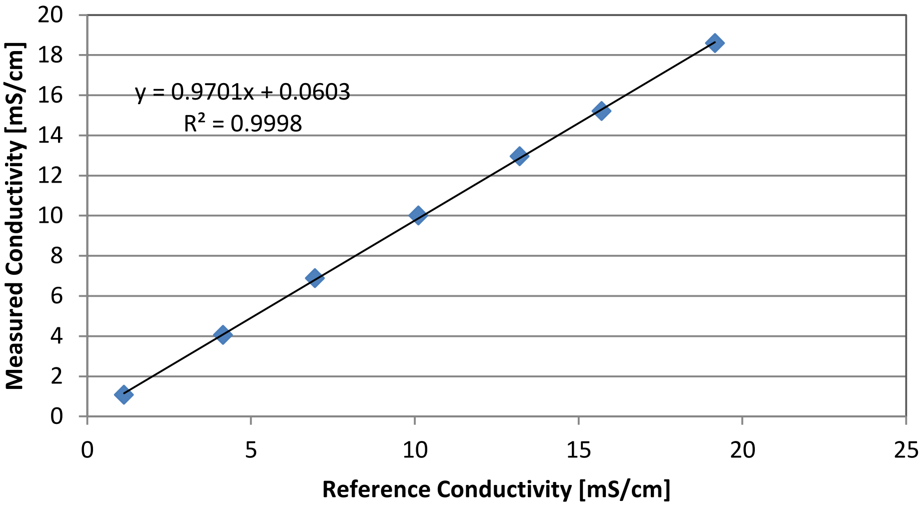


Table 14 - Results of the laboratory tests of TetraCon 700 IQ 13411129

Performance characteristics	Unit	Result
Response time for positive change	s	<1
Response time for negative change	s	<1
Delay time for positive change	s	<1
Delay time for negative change	s	<1
Rise time	s	<1
Fall time	s	<1
Linearity		1.000
Coefficient of variation	%	2.770
Limit of detection (LOD)	mS/cm	0.053
Limit of quantification (LOQ)	mS/cm	0.175
Repeatability 20%	mS/cm	0.019
Repeatability 80%	mS/cm	0.112
Lowest detectable change (LDC) 20%	mS/cm	0.056
Lowest detectable change (LDC) 80%	mS/cm	0.337
Bias 20%	mS/cm	-0.107
Bias 80%	mS/cm	-0.497
Short-term drift	%/day	
Day-to-day repeatability 35%	mS/cm	0.120
Day-to-day repeatability 65%	mS/cm	0.192
Memory effect		0.578
Interference caused by interferent 1		
Interference caused by interferent 2		
Environmental and operating conditions: requirement 1 (lower/upper limit) requirement 2 (lower/upper limit)		

6.4.4 TetraCon700 IQ 13411130

Table 15 - Measurements of the TetraCon700IQ with the serial number 13411130

Percentage of the working range [%]	Reference, xi [mS/cm]	yi,1 [mS/cm]	yi,2 [mS/cm]	yi,3 [mS/cm]	yi,4 [mS/cm]	yi,5 [mS/cm]	yi,6 [mS/cm]
5	1.124	1.072	1.071	1.068	1.063	1.058	1.067
20	4.15	4.041	4.005	4.014	4.002	3.987	4.039
35	6.95	6.823	6.844	6.881	6.670	6.838	6.898
50	10.11	9.950	9.972	9.910	9.971	9.964	9.971
65	13.2	12.791	12.857	12.941	12.978	12.986	12.961
80	15.7	15.220	15.338	15.228	15.097	15.336	14.769
95	19.16	18.650	18.216	18.572	18.607	18.609	18.661

Table 16 - Linearity of TetraCon 700 IQ 13411130

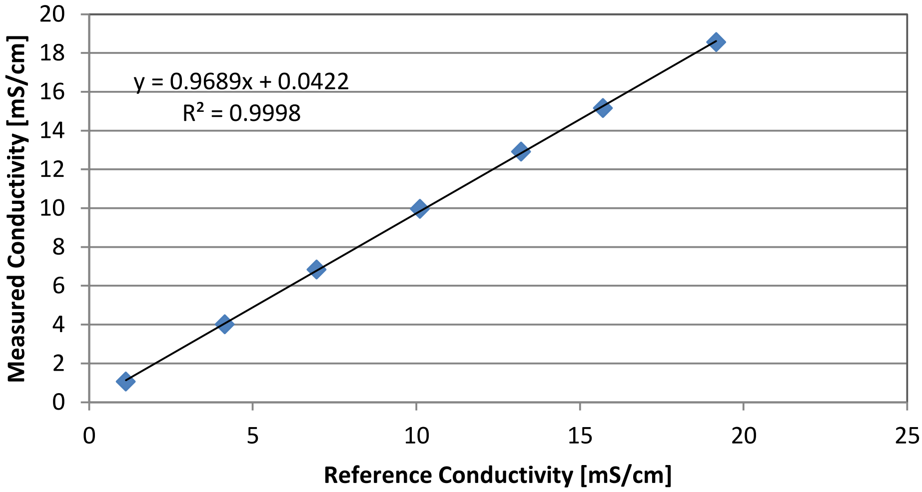


Table 17 - Results of the laboratory tests of TetraCon 700 IQ 13411130

Performance characteristics	Unit	Result
Response time for positive change	s	<1
Response time for negative change	s	<1
Delay time for positive change	s	<1
Delay time for negative change	s	<1
Rise time	s	0
Fall time	s	0
Linearity		1.000
Coefficient of variation	%	3.023
Limit of detection (LOD)	mS/cm	0.016
Limit of quantification (LOQ)	mS/cm	0.054
Repeatability 20%	mS/cm	0.021
Repeatability 80%	mS/cm	0.213
Lowest detectable change (LDC) 20%	mS/cm	0.064
Lowest detectable change (LDC) 80%	mS/cm	0.640
Bias 20%	mS/cm	-0.135
Bias 80%	mS/cm	-0.535
Short-term drift	%/day	
Day-to-day repeatability 35%	mS/cm	0.081
Day-to-day repeatability 65%	mS/cm	0.078
Memory effect		0.916
Interference caused by interferent 1		
Interference caused by interferent 2		
Environmental and operating conditions: requirement 1 (lower/upper limit) requirement 2 (lower/upper limit)		

6.4.5 TetraCon700 IQ 13411127

Table 18 - Measurements of the TetraCon700IQ with the serial number 13411127

Percentage of the working range [%]	Reference, xi [mS/cm]	yi,1 [mS/cm]	yi,2 [mS/cm]	yi,3 [mS/cm]	yi,4 [mS/cm]	yi,5 [mS/cm]	yi,6 [mS/cm]
5	1.124	1.083	1.074	1.071	1.075	1.070	1.053
20	4.15	3.959	3.995	4.021	3.990	4.030	4.060
35	6.95	6.717	6.846	6.890	6.601	6.852	6.906
50	10.11	9.926	9.974	9.982	9.953	9.974	10.003
65	13.2	12.847	12.847	12.911	12.933	12.970	12.953
80	15.7	15.138	15.119	15.086	15.125	15.219	15.219
95	19.16	18.588	18.469	18.556	18.342	18.516	17.660

Table 19 - Linearity of TetraCon 700 IQ 13411127

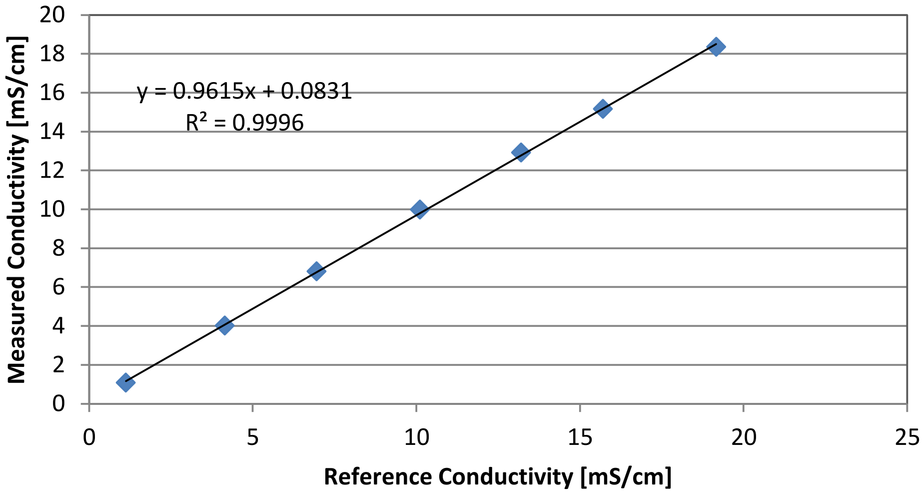


Table 20 - Results of the laboratory tests of TetraCon 700 IQ 13411127

Performance characteristics	Unit	Result
Response time for positive change	s	<1
Response time for negative change	s	<1
Delay time for positive change	s	<1
Delay time for negative change	s	<1
Rise time	s	<1
Fall time	s	<1
Linearity		1.000
Coefficient of variation	%	3.908
Limit of detection (LOD)	mS/cm	0.029
Limit of quantification (LOQ)	mS/cm	0.097
Repeatability 20%	mS/cm	0.035
Repeatability 80%	mS/cm	0.055
Lowest detectable change (LDC) 20%	mS/cm	0.106
Lowest detectable change (LDC) 80%	mS/cm	0.166
Bias 20%	mS/cm	-0.141
Bias 80%	mS/cm	-0.549
Short-term drift	%/day	
Day-to-day repeatability 35%	mS/cm	0.119
Day-to-day repeatability 65%	mS/cm	0.053
Memory effect		1.227
Interference caused by interferent 1		
Interference caused by interferent 2		
Environmental and operating conditions: requirement 1 (lower/upper limit) requirement 2 (lower/upper limit)		

B. Project: Creating datEAUbase

B.1. User's guide for datEAUbase

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modelEAU Technical Report

User's guide for datEAUbase

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1 INTRODUCTION

This is a user's guide about the database of the research group model*EAU* called dat*EAU*base. This guide gives an overview about the structure and the usage of dat*EAU*base. Especially how it is composed and how you can import, store and export environmental data of measurements as well as information about project details, equipment and sampling location.

The raw data of measurements from different projects of model*EAU* are stored in this database so every member of this research team has now access to all of the data and this ensures that each data is entered correctly and in the same way. In addition every equipment, procedure, sampling point, site, watershed, and project of the whole research team is now stored in this database.

The model*EAU*s database is created in *MySQL*. *MySQL* is one of the most common open-source relational database management systems to create and use databases. MySQL provides an interface called *MySQL Workbench* where it is much easier to create databases than in the command window. This database modelling tool is freely available on www.mysql.com as well as installation instructions and user documentations.

For convenient usage an interface was created in Python so it is possible for each member of the research team to easily import and export data without any need of knowledge about MySQL. This database is located on the shared disk of model*EAU*.

2 DATABASE BASICS: LINKS, PRIMARY KEYS AND FOREIGN KEYS

A database contains in general several tables. If tables have a relation between each other they are linked to each other. Every table contains a primary key, which is a column that uniquely identifies each row in a table. The links between the tables are made through their primary keys.

There are three types of links how tables can be related to each other:

- 1:1 – One row of the first table is related to only one row of the second table
- 1:n – One row of the first table is related to multiple rows of the second table. In the opposite direction each row of the second table is related to only one row of the first table.
- m:n – Each row of the first table can be related to multiple rows of the second table and also in the opposite direction.

In the case of a 1:1 and 1:n relation the primary key of one table becomes a column in the other table and this new column is called foreign key because it is not a primary key in this table but it is the primary key in the other table. In the case of a m:n relation between two tables the two primary keys of both tables are added to a new separate table. This table is connected to the those tables with a 1:n link.

2.1 Data types

Each column of a table in a database a data type has to be defined. This means if in column only natural numbers should be entered a data type must be defined that defines this. In Table 1 - Explanation of different data types is a short overview on different data types which are used in MySQL.

Table 1 - Explanation of different data types

Data type	Description	Example
INT	Short for integer. Only numbers without decimal points.	'56234'
FLOAT	Only decimal numbers can be entered	'12345.893456'
DOUBLE	Same as FLOAT but more accurate	'312234234234.9599003099234'
DATE	The data must be entered in the date format.	YYYY-MM-DD: '2014-06-27'
TEXT	Only text can be entered.	'This is an example of TEXT.'
VARACHAR(100)	A string which is 100 bit long can be entered	'ABcdç%56,Ed245-?'
TINYTEXT	Same as TEXT but shorter	'This is a short text.'

2.2 Database example

In Figure 1 is an example of a database how to store information about students, universities, lectures and addresses.

The table Student contains a primary key, *Student_ID*, which is a unique number to identify each student, the last and first name of the student and two foreign keys called *Address_ID* and *University_ID*. The foreign key *Address_ID* is the link between the Student table and the Address table. Those two tables have a 1:1 relation between each other. This means that each student has only one address and each address belongs to one student.

The *Address* table contains a primary key called *Address_ID*, which is a unique number in this table to identify each row, street name and number, province and country.

In the *Student* table is also another foreign key called *University_ID*. This *University_ID* is the link between the *Student* table and the *University* table. Those two tables have a 1:n relation between each other. This means that each student belongs to one university but each university can have many different students and not only one.

The University table contains a primary key called *University_ID*, which is a unique number to identify each university and a column called University_name.

The lecture table contains a primary key called *Lecture_ID*, *Lecture_name* and *Proffessor*. Between the student and the lecture table there is a table called *Lecture_has_Student* because the relation between students and lectures is a m:n. So the table *Lecture_has_Student* has to be added to identify which student has which lectures and which lectures are visited by which students. This means that a student can visit several lectures and a lecture can be visited by multiple students.

Between the *Lecture* and the *University* table is also a 1:n relation. This means that a university can have multiple lectures but a lecture can only be held in one university.

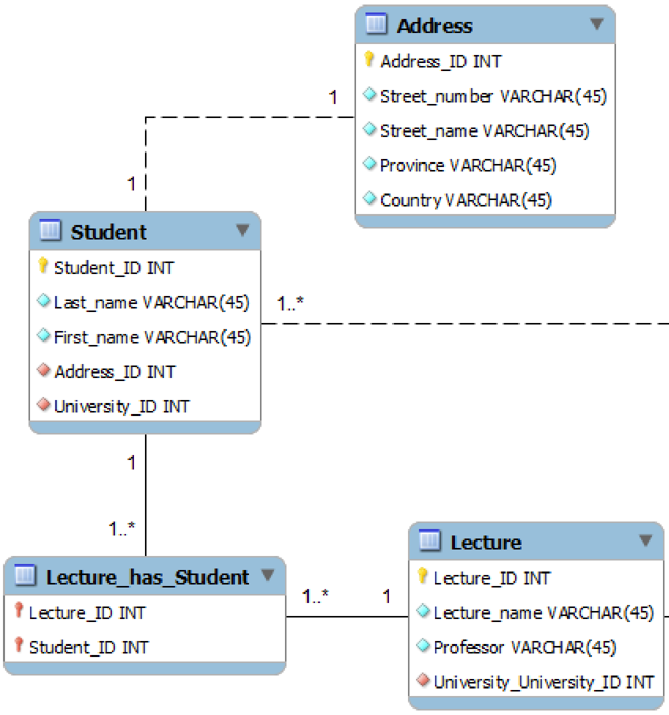

Figure 1 - Example of a model to show the three different links between tables

All of the universities are stored In Table 2. In this example there are only two universities. Each of those universities has a unique University_ID.

Table 2 - University table

University_ID	University_name
1	University Laval
2	University of Quebec

All of the students are stored in Table 3. In this example are three students. Each of those students has its own unique *Student_ID*.

John Smith has the *Address_ID* "1" and the *University_ID* "1". This means that John Smith is a student at the University Laval and his address is: 12 Rue d'Eglise, Quebec, Canada.

Carole Miller is also at the University Laval and her address is 34 Rue St. Jean, Quebec, Canada. Jessica Contini is at the University of Quebec and her address is 56 Rue St. Joseph, Quebec, Canada.

Table 3 - Student table

Student_ID	Last_name	First_name	Address_ID	University_ID
1	Smith	John	1	1
2	Miller	Carole	2	1
3	Contini	Jessica	3	2

All addresses are stored in Table 4 and each address has its own and unique *Address_ID*.

Table 4 - Address table

Address_ID	Street_number	Street_name	Province	Country
1	12	Rue d'eglise	Quebec	Canada
2	34	Rue St. Jean	Quebec	Canada
3	56	Rue St. Joseph	Quebec	Canada

All lectures are stored in Table 5. Each lecture has a unique id, a name of the lecture, a professor and a University_ID. This means that Mathematics is only held at University Laval, Physics only at University of Quebec, Economics only at University Laval and Civil law only at University of Quebec.

Table 5 - Lecture table

Lecture_ID	Lecture_name	Professor	University_ID
1	Mathematics	Schwartz	1
2	Physics	Heidenberg	2
3	Economics	Dion	1
4	Civil law	Tremblay	2

In Table 6 all students and their lectures are stored. This means that John Smith visits the lectures Mathematics and Economics, Carole Miller visits only the lecture Mathematics and Jessica Contini visits the lectures Physics and Civil law.

Table 6 - Lecture_has_student table

Lecture_ID	Student_ID
1	1
2	3
3	1
4	3
1	2

2.3 Basic Queries

Some basic but important MySQL queries are shown in Table 7.

Table 7 - Some important basic queries in MySQL

Query	Function of the Query
SHOW DATABASES;	All existing databases will be shown
DROP DATABASE datEAUbase;	Deletes the database with the name datEAUbase
USE datEAUbase;	To work with a database the database has to be selected first
SELECT * FROM table_name;	The whole content of the selected table will be shown
SELECT column1, column2, column3 FROM table_name;	If only some columns of a table should be shown than the names of those columns must be selcted
SELECT * FROM table_name WHERE id=1;	Gives the whole row of the selected table where the id is 1
SELECT * FROM table_name WHERE column1 = 'word';	To search for a word the word has to be between two high commas
SELECT * FROM table_namen WHERE id BETWEEN 10 AND 20;	To show data with the ids between 10 and 20

3 STRUCTURE OF DAT*EAU*BASE

dat*EAU*base is based on 23 different tables. Figure 2 shows a model of dat*EAU*base in which all tables and their relations to each other are shown. This model was created with *MySQL Workbench*.

The orange tables are the main tables of the database where all data and the concerning metadata is stored. All other tables are directly or indirectly linked to the *Metadata* table. The tables in pink are where every equipment and procedure of model*EAU* is stored. The tables in green are where all of the sampling locations of model*EAU* are stored. The tables in yellow are where all projects and their links of model*EAU* are stored. In the blue table all kinds of purposes are stored. In the purple table all kinds of weather conditions are stored.

Each table is labeled with a title. The primary key of a table is marked by a yellow sign as *Purpose_ID* in the blue table *Purpose* in Figure 2. If the primary key in a table is marked with a red sign as *Watershed_ID* in the green table *Urban_characteristics* or *Hydrological_characteristics* in Figure 2 than this primary key is also a foreign key of another table. In this case it is the foreign key of the table Watershed. If a sign in a table is not filled out with a colour as *Parameter_ID* in the orange table *Metadata* in Figure 2 it means that this column can be left blank. In all of the tables in Figure 2 each column name the associated data type is mentioned.

In dat*EAU*base there are four different kinds of links: 1:1, 0:n, 1:n and n:m. An example of a 1:1 link is shown in Figure 2 between the tables *Watershed* and *Urban_characteristics*. An expmple of a 0:n link is shown in Figure 2 between the tables *Comments* and *Value*. This means that it is not necessary to add a comment to each value in the *Value* table. An example of a 1:n link is shown in Figure 2 between the tables *Site* and *Sampling_points*. An example of a n:m link is shown in Figure 2 between the tables *Project* and *Contact*. Between those tables is a table called *Project_has_Contact* which is automatically created by MySQL between two tables with a n:m relation. In this table called *Project_has_Contact* you are shown which contacts belong to which projects and in the opposite as well.

In every table are column names and after each column name there is a data type mentioned for example INT. The data type tells you in which format the data can be entered in the concerning column.

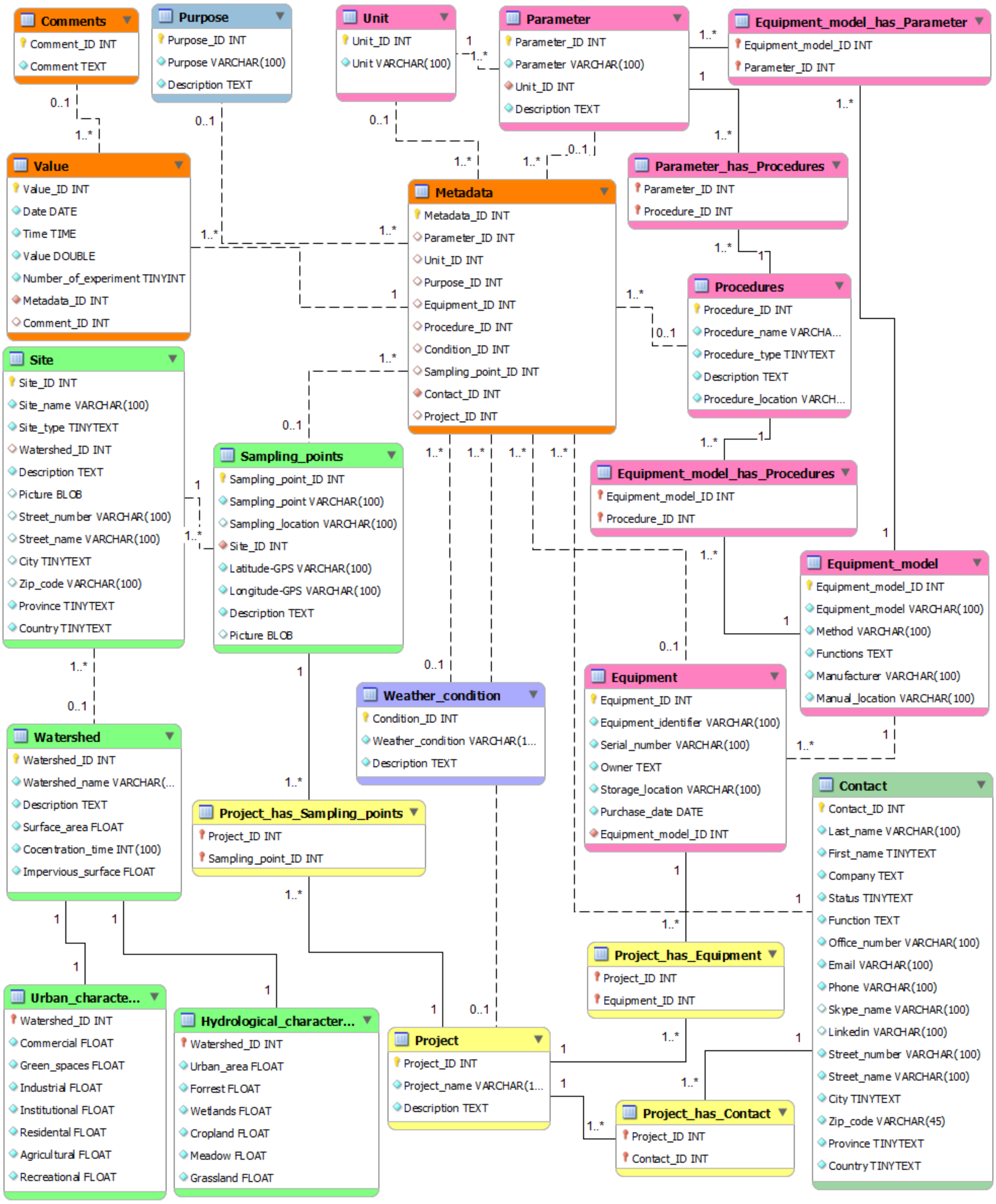

Figure 2 - dat*EAU*base model with the links between the tables

3.1 Explanation of the tables

This section gives a more detailed overview of each table of dat*EAU*base, how they are composed, which data types are used and in which format the data must be entered. All the tables of the database are explained in Table 8 - Table 30. In each of the following tables is an explanation of each column of the database table, which data type is used, which characteristics each column has and in which format the data must be entered. The characteristics of each column illustrates if the column is a primary key, foreign key, not null (must be filled out) or auto increment (this column is filled out by MySQL automatically).

All data which is collected by model*EAU* is stored in a table of the database called *Value*. The composition of the *Value* table is shown in Table 8. In this table all the collected data is stored and all the associated metadata is stored in another table called *Metadata* as shown in Table 9. Those two tables are the heart of the database and all other tables are linked to those two tables and they give more detailed background information which is not directly related to the collected data.

It is very important while adding data to the database to use the correct spelling. For example the date in the *Value* table must be added in the right way as shown in Table 8 (YYYY-MM-DD).

Table 8 - Value table

Table columns	Data type	Characteristic	Description
Value_ID	INT	Primary key, not null, auto increment	A unique ID is generated automatically
Date	DATE	Not null	Date of collected data: 'YYYY-MM-DD'
Time	TIME	Not null	Time in 24h of collected data: 'hh:mm:ss'
Value	DOUBLE	Not null	Value of collected data
Number_of_experiment	TINYINT	Not null	Number of replica of an experiment
Metadata_ID	INT	Foreign key, not null	Metadata related to collected value. Link to the Metadata table
Comment_ID	INT	Foreign key	Comment of value. Link to the Comments table

In the *Metadata* table all the important information which is related to the collected data are stored here. Here it is defined which parameter was measured, in which unit the value is displayed, which is purpose of the conducted measurement, witch equipment was used, which procedure was followed, how the weather condition was, where the measurement was conducted, who the responsible person for this measurement is and for which project the measurement was taken. In the *Metadata* table only ids are stored. All of those ids are linked to the corresponding tables where those ids are explained in detail what they mean.

Table 9 - Metadata table

Table columns	Data type	Characteristic	Description
Metadata_ID	INT	Primary key, not null, auto increment	A unique ID is generated automatically by MySQL
Parameter_ID	INT	Foreign key	Measured Parameter. Link to Parameter table
Unit_ID	INT	Foreign key	Unit of parameter. Link to the Unit table
Purpose_ID	INT	Foreign key	Purpose of the Data collection. For example: Measurement, Lab-analysis, Calibration or Cleaning. Link to Purpose table
Equipment_ID	INT	Foreign key	Equipment which was used. Link to Equipment table
Procedure_ID	INT	Foreign key	Procedure corresponding to the purpose and/or the equipment. Link to Procedure table
Condition_ID	INT	Foreign key	Weather condition during the measurement. Link to Weather_condition table
Sampling_point_ID	INT	Foreign key	Sampling point where the data was collected. Link to Sampling-point table
Contact_ID	INT	Foreign key, not null	Person who is responsible for the measurement. Link to Contact table
Project_ID	INT	Foreign key	Name of the project for which the data was collected. Link to Project table

If a comment needs to be added related to a value in the *Value* table this comment has to be stored in the *Comments* table which is explained in Table 10.

Table 10 - Comments table

Table columns	Data type	Characteristics	Description
Comment_ID	INT	Primary key, not null, auto increment	A unique ID is generated automatically by MySQL
Comment	TEXT	Not null	Comment on Data in the Value table

All different types of Parameters which are used in projects of model*EAU* are stored in the *Parameter* table which is explained in Table 11.

Table 11 - Parameter table

Table columns	Data type	Characteristics	Description
Parameter_ID	INT	Primary key, not null	A unique ID is generated automatically by MySQL
Parameter	VARCHAR(100)	Primary key, Not null	Name of the Parameter
Unit_ID	INT	Foreign key, not null	SI-unit of the parameter. Link to the *Unit* table
Description	TEXT	Not null	Description of the parameter

In the *Unit* table which is explained in Table 12 all different kinds of units are stored. The *Unit* table is linked to the *Metadata* table as well as to the *Parameter* table.

Table 12 - Unit table

Table columns	Data type	Characteristics	Description
Unit_ID	INT	Primary key, not null	A unique ID is generated automatically by MySQL
Unit	VARCHAR(100)	Not null	SI-units only

All equipment of model*EAU* is stored in the *Equipment* table which is explained in Table 13. An example of an equipment identifier is: TetraCon700IQ_001. In this table all information concerning to each equipment as the identifier of the equipment, the serial number of the equipment, the owner of the equipment, the storage location of the equipment, the purchase date of the equipment and an *Equipment_model_ID* is stored. With the *Equipment_model_ID* the Equipment table is linked to the *Equipment_model* table.

Table 13 - Equipment table

Table columns	Data type	Characteristics	Description
Equipment_ID	INT	Primary key, not null	A unique ID is generated automatically by MySQL
Equipment_identifier	VARCHAR(100)	Not null	Identification name of the equipment
Serial_number	VARCHAR(100)	Not null	Serial_number of the equipment
Owner	TEXT	Not null	Name of the owner of the Equipment
Storage_location	VARCHAR(100)	Not null	Location where the Equipment is stored
Purchase_date	DATE	Not null	Date when the Equipment was bought: 'YYYY-MM-DD'
Equipment_model_ID	INT	Not null	Name of the model of this equipment. Link to the Equipment_model table

All different kinds of equipment models which are used by model*EAU* are stored in the *Equipment_model* table which is explained in Table 14. An example of an equipment model is: TetraCon 700 IQ. In this table to each equipment model the method behind the model, the functions of the model, the manufacturer of the model and the location of the manual are stored.

Table 14 - Equipment_model table

Table columns	Data type	Characteristics	Description
Equipment_model_ID	INT	Primary key, not null	A unique ID is generated automatically by MySQL
Equipment_model_name	VARCHAR(100)	Not null	Name of the equipment model. For example: Ammolyser
Method	VARCHAR(100)	Not null	Method behind the equipment
Functions	TEXT	Not null	Description of the functions of the equipment
Manufacturer	VARCHAR(100)	Not null	Name of the manufacterer
Manual_location	VARCHAR(100)	Not null	Location where the manual is stored

All different kinds of procedures which are used by model*EAU* are stored in the *Procedures* table which is explained in Table 15. Here are all measurement procedures, cleaning procedures, calibration procedures and all kind of SOPs stored. Each procedure is stored with its name, type, a description about the procedure and where the procedure is stored physically.

Table 15 - Procedures table

Table columns	Data type	Characteristics	Description
Procedure_ID	INT	Primary key, not null, auto increment	A unique ID is generated automatically by MySQL
Procedure_name	VARCHAR(100)	Not null	Title name of the procedure
Procedure_type	TINYTEXT	Not null	Type of the procedure. For example SOP
Description	TEXT	Not null	Description of the procedure
Storage_location	VARCHAR(100)	Not null	Where is the procedure stored

To identify which equipment model can measure which parameters the id of an equipment model and the concerning id of a parameter must be added in the table *Equipment_model_has_Parameter* which is explained in Table 17. In this table only ids are added. So it is possible to know that the equipment model *TetraCon 700 IQ* can measure the parameters conductivity and temperature.

Table 16 - Equipment_model_has_Parameter table

Table columns	Data type	Characteristics	Description
Equipment_model_ID	INT	Primary key, foreign key, not null	Link to Equipment_model table
Parameter_ID	INT	Primary key, foreign key, not null	Link to Parameter table

To identify which equipment model has which procedures the id of an equipment model and the concerning id of a procedure must be added in the *Equipment_model_has_Procedures* table which is explained in Table 17. In this table only ids are stored. So it is possible to know that the equipment model TetraCon 700 IQ has the procedure *Cleaning of TetraCon 700 IQ*.

Table 17 - Equipment_model_has_Procedures table

Table columns	Data type	Characteristics	Description
Procedure_ID	INT	Primary key, foreign key, not null	Link to *Procedure* table
Equipment_model_ID	INT	Primary key, foreign key, not null	Link to *Equipment_model* table

To identify which procedure is used to measure which parameter the id of a procedure and the concerning id of a parameter must be added in the *Parameter_has_Equipment* table which is explained in Table 18. In this table only ids from the *Parameter* and the *Procedure* table are added.

Table 18 - Parameter-has-Procedure table

Table columns	Data type	Characteristics	Description
Parameter_ID	INT	Primary key, foreign key, not null	Link to Parameter table
Procedure_ID	INT	Primary key, foreign key, not null	Link to Procedure table

All different kinds of purposes which are used by model*EAU* are stored in the *Purpose* table which is explained in Table 19. A purpose of a data collection is to differ if it is a measurement in the field, in the lab, a cleaning process of a sensor or a calibration of a sensor etc.. In this table each possible purpose and a description of it is stored.

Table 19 - Purpose table

Table columns	Data type	Characteristics	Description
Purpose_ID	INT	Primary key, not null	A unique ID is generated automatically by MySQL
Purpose_name	VARCHAR(100)	Not null	Purpose of the Data collection. For example “Measurement”, “Lab-analysis”, “Calibration” or “Cleaning”
Description	TEXT	Not null	Description of the Purpose

All possible weather conditions are stored in the *Weather_condition* table which is explained in Table 20. For example dry weather, wet weather, storm event etc. Each condition is stored with a description.

Table 20 - Weather_condition table

Table columns	Data type	Characteristics	Description
Condition_ID	INT	Primary key, not null, auto increment	A unique ID is generated automatically by MySQL
Condition	VARCHAR(100)	Not null	Type of weather condition
Description	TEXT	Not null	Description of the condition

All of the sampling points where model*EAU* takes measurements are stored in the *Sampling_point* table which is explained in Table 21. For example: “Biofiltration inlet”. To each sampling point there is a Site_ID which tells in which site belongs to this sampling point, latitude and longitude GPS of the sampling point, a description about the sampling point and a picture.

Table 21 - Sampling_point table

Table columns	Data type	Characteristics	Description
Sampling-point_ID	INT	Primary key, not null, auto increment	A unique ID is generated automatically by MySQL
Sampling-point	VARCHAR(10)	Not null	Where the sample was taken. For example: "Inlet", "Outlet" or "Upstream"
Sampling-location	VARCHAR(100)		Where the sample was taken. For example: "Biofiltration", "Sewer_01", "Retention-tank"
Site_ID	INT	Foreign key, not null	The site where the sampling point is located. Link to the site table.
Latitude_GPS	VARCHAR(100)	Not null	GPS coordinates: For example: 47°19'30.1854"
Longitude_GPS	VARCHAR(100)	Not null	GPS coordinates: For example: 15°21'12.6782"
Description	TEXT	Not null	Description of the sampling point
Picture	BLOB		Picture of the sampling point

Every site which is in a project of model*EAU* is stored in the *Site* table which is explained in Table 22. Of each site the site name, the type of the site, the watershed where the site belongs to, a description of the site, a picture and the address of the site are stored in this table.

Table 22 - Site table

Table columns	Data type	Characteristics	Description
Site_ID	INT	Primary key, not null	A unique ID is generated automatically by MySQL
Site_name	VARCHAR(100)	Not null	Name of the site
Site_type	TINYTEXT	Not null	For example WWTP, River or Sewer-system
Watershed_ID	INT	Foreign key	Name of the Watershed in which the site is located. Link to Watershed table
Description	TEXT	Not null	Description of the Site
Picture	BLOB		An image can be added here
Street_number	VARCHAR(100)		Address: Number of the street
Street_name	VARCHAR(100)		Address: Name of the street
City	TINYTEXT		Address: Name of the city
Zip_code	VARCHAR(100)		Address: Zip code
Province	TINYTEXT	Not null	Address: Name of the Province
Country	TINYTEXT	Not null	Address: Name of the Country

Each watershed which is used in a project of model*EAU* is stored in the *Watershed* table which is explained in Table 23. To each watershed name there is a description about the watershed, the surface area of the watershed, the concentration time in the watershed and the impervious surface of the watershed stored.

Table 23 - Watershed table

Table columns	Data type	Characteristics	Description
Watershed_ID	INT	Primary key, not null, auto increment	A unique ID is generated automatically by MySQL
Watershed_name	VARCHAR(100)	Not null	Name of the Watershed
Description	TEXT	Not null	Description of the watershed
Surface_area	FLOAT	Not null	Surface area of the watershed [ha]
Concentration_time	INT(100)	Not null	Concentration time in minutes [min]
Impervious_surface	FLOAT	Not null	Percentage of the impervious surface of the watershed in percentage [%]

Each watershed should have either information about urban characteristics or hydrological characteristics. The information about urban characteristics are stored in the Urban_characteristics table which is explained in Table 24.

Table 24 - Urban_characteristics table

Table columns	**Data type**	**Characteristics**	**Description**
Watershed_ID	INT	Primary and foreign key, not null	Linked to the Watershed table
Commercial	FLOAT	Not null	Percentage [%] of commercial areas. For example stores or bank areas.
Green_spaces	FLOAT	Not null	Percentage [%] of green spaces
Industrial	FLOAT	Not null	Percentage of industrial areas. For example factories
Institutional	FLOAT	Not null	Percentage [%] of institutional areas. For example schools, police station or town hall
Residential	FLOAT	Not null	Percentage [%] of residential areas. For example houses or apartment buildings
Agricultural	FLOAT	Not null	Percentage [%] of agricultural land use. For example farm land
Recreational	FLOAT	Not null	Percentage [%] of recreational areas. For example parks and sports fields

The information about hydrological characteristics are stored in the Hydorlogical_characteristics table which is explained in Table 25.

Table 25 - Hydrological_characteristics table

Table columns	**Data type**	**Characteristics**	**Description**
Watershed_ID	INT	Primary and foreign key, not null	Linked to the Watershed table
Urban_area	FLOAT	Not null	Percentage [%] of urban areas.
Forrest	FLOAT	Not null	Percentage [%] of areas with forrest
Wetland	FLOAT	Not null	Percentage [%] of wetlands
Cropland	FLOAT	Not null	Percentage [%] of croplands
Meadow	FLOAT	Not null	Percentage [%] of areas with meadow
Grassland	FLOAT	Not null	Percentage [%] of grasslands

All people who are in any kind of a relation to model*EAU* are stored in the *Contact* table which is explained in table Table 26. Each contact which is stored in this table contains the last and first name of the person, the company name where the person works, the status of the person, the function of the person, the office number, the email address, the telephone number, the skype name, the linkedin profile name and the address of the person.

Table 26 - Contact table

Table columns	**Data type**	**Characteristics**	**Description**
Contact_ID	INT	Primary key, not null, auto increment	A unique ID is generated automatically by MySQL
Last_name	VARCHAR(100)	Not null	Last name of the contact
First_name	TIINYTEXT	Not null	First name of the contact
Company	TEXT	Not null	Company name
Status	TINYTEXT	Not null	Status of the person. For example: Master student, Postdoc, Intern etc.
Function	TEXT	Not null	More detailed description about the functions
Office_number	VARCHAR(100)	Not null	Number of the office
Email	VARCHAR(100)	Not null	E-mail address
Phone	VARCHAR(100)	Not null	Phone number
Skype_name	VARCHAR(100)		Skype name. This cell can be left empty
Linkedin	VARCHAR(100)		Linkedin account. This cell can be left empty
Street_number	VARCHAR(100)	Not null	Address: Number of the street
Street_name	VARCHAR(100)	Not null	Address: Name of the street
City	TINYTEXT	Not null	Address: Name of the city
Zip_code	VARCHAR(45)	Not null	Address: Zip code
Province	TINYTEXT	Not null	Address: Name of the state
Country	TINYTEXT	Not null	Address: Name of the Country

All projects of model*EAU* are stored in the *Project* table which is explained in Table 27. Here are all projects listed as well as a detailed description of each project.

Table 27 - Project table

Table columns	Data type	Characteristics	Description
Project_ID	INT	Primary key, not null, auto increment	A unique ID is generated automatically by MySQL
Project_name	VARCHAR(1000)	Not null	Name of the Project
Description	TEXT	Not null	Description of the Project

To identify which sampling points are used in which project the id of a sampling point and the id of the concerning project must be added in the *Project_has_Sampling_points* table which is explained in Table 28. In this table only ids from the *Project* and the *Sampling_pints* table are added.

Table 28 - Project-has-Sampling-points table

Table columns	Data type	Characteristics	Description
Project_ID	INT	Primary key, foreign key, not null	Link to Project table
Sampling-point_ID	INT	Primary key, foreign key, not null	Link to Sampling-point table

To identify which people belong to which projects the id of a contact and the concerning id of project must be added in the *Project_has_Contact* table which is explained in Table 29. In this table only ids from the *Project* and the *Contact* table are added.

Table 29 - Project_has_Contact table

Table columns	Data type	Characteristics	Description
Project_ID	INT	Primary key, foreign key, not null	Link to Project table
Contact_ID	INT	Primary key, foreign key, not null	Link to Contact table

To identify which equipment is used in which projects the id of an equipment and the concerning id of a project are added in the *Project_has_Equipment* table which is explained in Table 30. In this table only ids of the *Project* and the *Equipment* table are added.

Table 30 - Project-has-Equipment table

Table columns	Data type	Characteristics	Description
Project_ID	INT	Primary key, foreign key, not null	Link to Project table
Equipment_ID	INT	Primary key, foreign key, not null	Link to Equipment table

3.2 Adding data to dat*Eau*base

For adding data to the database in MySQL it is important to follow the right order otherwise it is not possible to fill the tables and MySQL will answer error messages. So the correct order to enter data to the tables of dat*EAU*base is the following:

1. Unit
2. Parameter
3. Purpose
4. Equipment_model
5. Equipment
6. Procedures
7. Parameter_has_Procedures
8. Equipment_model_has_Parameter
9. Equipment_model_has_Procedures
10. Weather_condition
11. Watershed
12. Urban_characteristics
13. Hydrological_characteristics
14. Site
15. Sampling_points
16. Contact
17. Project
18. Project_has_Sampling_points
19. Project_has_Equipment
20. Project_has_Contact
21. Metadata
22. Comments
23. Value

3.3 Example how to ad data to dat*EAU*base

The order how of adding data is the one which is explained in the subsection 3.2. First the units which will be used have to be entered in the *Unit* table as shown in Table 31. The *Unit_ID* is not allowed to be filled out this is be filled out by MySQl automatically.

Table 31 - Adding data to the Unit table

Unit_ID	Unit
1	mS/cm
2	K
3	mg/l

Next the parameters which will be used have to be entered in the *Parameter* table as shown in Table 32. The *Parameter_ID* is not allowed to be filled out this is filled out by MySQL automatically. The *Unit_ID* has to be entered manually because MySQL does not know which unit belongs to which parameter.

Table 32 - Adding data to the Parameter table

Parameter_ID	Parameter	Unit_ID	Description
1	Conductivity	1	The conductivity is…
2	Temperature	2	The temperature is..
3	Ammonium	3	Ammonium is…

Next the purposes which will be used have to be entered in the *Purpose* table as shown in Table 33. The Purpose_ID is not allowed to be filled out this is filled out by MySQL automatically.

Table 33 - Adding data to the Purpose table

Purpose_ID	Purpose_name	Description
1	Sensor-testing	Testing of sensors in the laboratory
2	Measurement	Measurement in the field

Next the equipment models which will be used have to be entered in the Equipment_model table as shown in Table 34. The Equipment_model_ID is not allowed to be filled out this is filled out by MySQL automatically.

Table 34 - Adding data to the Equipment_model table

Equipment_model_ID	Equipment_model	Method	Functions	Manufacturer	Manual_location
1	TetraCon 700 IQ	Electrolysis	Measures Conductivity and Temperature	WTW	PLT-1234
2	Ammolyser	Null	Ammonium	Hach	PLT-1234

Next the equipment which will be used has to be entered in the Equipment table as shown in Table 35. The Equipment_ID is not allowed to be filled out this is filled out by MySQL automatically but the Equipment_model_ID has to be entered manually because MySQL does not know which equipment belongs to which equipment model.

Table 35 - Adding data to the Equipment table

Equipment_ID	Equipment_identifier	Serial_number	Owner	Storage_location	Purchase_date	Equipmentmodel_ID
1	TetraCon700IQ_001	123456	modelEAU	PLT-1234	2014-02-23	1
2	Ammolyser_001	1234	modelEAU	PLT-2345	2009-05-16	2

Next the procedures which will be used have to be entered in the Procedures table as shown in Table 36. The Procedure_ID is not allowed to be filled out this is filled out by MySQL automatically.

Table 36 - Adding data to the Procedures table

Procedure_ID	Procedure_name	Proceure_type	Description	Procedure_location
1	ISO15839:2003	ISO	How to test sensors	PLT-1234
2	SOP:Measuring Ammonium	SOP	How to measure ammonia with the ammolyser	PLT-1234

Next the parameters which were added before have to be identified with a procedure as shown in Table 37. This means that with the procedure SOP:Measuring Ammonium you can determine the parameter ammonium.

Table 37 - Adding data to the Parameter_has_Procedures

Parameter_ID	Procedure_ID
3	2

Next the parameters which were added before have to be identified with an equipment model to know which equipment model can measure which parameters as shown in Table 38. This means that the Tetra Con 700 IQ can measure the parameters conductivity and temperature and the Ammolyser can measure the parameter ammonium.

Table 38 - Adding data to the Equipment_model_has_Parameter table

Equipment_model_ID	Parameter_ID
1	1
1	2
2	3

Next the procedures which were added before have to be identified with an equipment model to know which equipment model can use which procedures as shown in Table 39. This means that the Ammolyser belongs to the procedure SOP:Measuring Ammonium.

Table 39 - Adding data to the Equipment_model_has_Procedures table

Equipment_model_ID	Procedure_ID
2	2

Next the weather conditions which will be used have to be entered in the Weather_condition table as shown in Table 40. The Condition_ID is not allowed to be filled out this is filled out by MySQL automatically.

Table 40 - Adding data to the Weather_condition table

Condition_ID	Weather_condition	Description
1	Dry-weather	No precipitation
2	Wet-weather	A lot of precipitation

Next the watersheds which will be used have to be entered in the Watershed table as shown in Table 41. The Watershed_ID is not allowed to be filled out this is filled out by MySQL automatically.

Table 41 - Adding data to the Watershed table

Watershed_ID	Watershed_name	Description	Surface_area	Concentration_time	Impervious_surface
1	St.Sacrement	very nice Area	1234	35	26
2	Cheveau	a small watershed	3456	27	17

Next the urban characteristics of each watershed which will be used have to be entered in the Urban_characteristics table as shown in Table 42. The Watershed_ID must be filled out because MySQL does not know which watershed is meant.

Table 42 - Adding data to the Urban_characteristics table

Watershed_ID	Commercial	Green_spaces	Industrial	Institutional	Residential	Agricultural	Recreational
1	14.5	16.75	2.25	20.5	23.8	17.2	5
2	14	56	0	13	4	6	7

Next the hydrological characteristics of each watershed which will be used have to be entered in the Hydrological_characteristics table as shown in Table 43. The Watershed_ID must be filled out because MySQL does not know which watershed is meant.

Table 43 - Adding data to the Hydrological_characteristics table

Watershed_ID	Urban_area	Forrest	Wetlands	Cropland	Meadow	Grassland
1	14	56	12	6	3	9
2	56	39	2	3	0	0

Next the sites which will be used have to be entered in the Site table as shown in Table 44. The Site_ID is not allowed to be filled out this is filled out by MySQL automatically but the Watershed_ID must be added manually because MySQL does not know which watershed belongs to which site.

Table 44 - Adding data to the Site table

Site_ID	Site_name	Site_type	Watershed_ID	Description	Picture	Street_number	Street_name	City	Zip_code	Province	Country
1	Quebec-Est	WWTP	1	340 m^3/d		1234	Rue de Beauport	Quebec	1234	Quebec	Canada
2	Quebec-West	WWTP	2	420 m^3/d		1234	Rue de l'eglise	Quebec	1234	Quebec	Canada

Next the sampling points which will be used have to be entered in the Sampling_points table as shown in Table 45. The Sampling_point_ID is not allowed to be filled out this is filled out by MySQL automatically but the Site_ID must be added manually because MySQL does not know which watershed belongs to which site.

Table 45 - Adding data to the Sampling_points table

Sampling_point_ID	Sampling_point	Sampling_location	Site_ID	Latitude_PGS	Longitude_GPs	Description	Picture
1	Inlet	Biofiltration_1	1	12°34'12.3456"	56°56'45.2345"	in the middle of the inlet of the biofiltraion	
2	Outlet	Primary_clarifier	2	13°23'45.1234"	56°55'34.4567"	in the primary clarifier	

Next the contacts which will be used have to be entered in the Contact table as shown in Table 46 and Table 47. The Contact_ID is not allowed to be filled out this is filled out by MySQL automatically.

Table 46 - Adding data to the Contact table (first part)

Contact_ID	Last_name	First_name	Company	Status	Function	Office_number	Email	Phone
1	Alferes	Janelcy	modelEAU	Post doc	Working with the monitoring stations...	2834	janelcy(at)ulaval.ca	123456789
2	Maruéjouls	Thibaud	modelEAU	Researcher	Doing research	2834	Thibaud(at)ulavla.ca	1234345

Table 47 - Adding data to the Contact table (second part)

Skype_name	Linkedin	Street_number	Streeet_name	City	Zip_code	Province	Country
Janelcyalferes	Janelcy Alferes	456	Rue de St. Jean	Quebec	G12 V89	Quebec	Canada
		12	Rue St. Joseph	Quebec	A23 I89	Quebec	Canada

Next the projects which will be used have to be entered in the Project table as shown in Table 48. The Project_ID is not allowed to be filled out this is filled out by MySQL automatically.

Table 48 - Adding data to the Project table

Project_ID	Project_name	Description
1	monEAU	Automated monitoring stations
2	retEAU	Retention tanks

Next the sampling points which were added before have to be identified with a project to know which sampling point model belongs to which project as shown in Table 49. This means that the sampling point "Inlet_Biofiltraiton_1" belongs to the project mon*EAU* and the sampling point "Outlet_Primary_clarifier" belongs to the project ret*EAU*.

Table 49 - Adding data to the Project_has_Sampling_points

Project_ID	Sampling_point_ID
1	1
2	2

Next the equipment which was added before have to be identified with a project to know which equipment belongs to which project as shown in Table 50. This means that the equipment

"TetraCon700IQ_001" belongs to the project mon*EAU* and the equipment "Ammolyser_001" belongs to the project mon*EAU* and ret*EAU*.

Table 50 - Adding data to the Project_has_Equipment table

Project_ID	Equipment_ID
1	1
1	2
2	2

Next the contacts which were added before have to be identified with a project to know which contact belongs to which project as shown in Table 51. This means that the contact "Alferes Janelcy" belongs to the projects mon*EAU* and ret*EAU* and the contact "Maruéjouls Thibaut" belongs to the project ret*EAU*.

Table 51 - Adding data to the Project_has_Contact table

Project_ID	Contact_ID
1	1
2	1
2	2

Next the metadata to the measured data must be entered in the Metadata table as shown in Table 52. The translated Metadata table looks as shown in Table 53.

Table 52 - Adding data to the Metadata table

Metadata_ID	Parameter_ID	Unit_ID	Purpose_ID	Equipment_ID	Procedure_ID	Condition_ID	Sampling_point_ID	Contact_ID	Project_ID
1	1	1	1	1	1			1	1
2	3	3	2	2	2	1	2	2	2

Table 53 - Translated Metadata table

Metadata_ID	Parameter	Unit	Purpose	Equipment	Procedure	Condition	Sampling_point	Contact	Project
1	Conductivity	mS/cm	Sensor-testing	TetraCon700IQ_001	ISO15839:2003			Alferes	monEAU
2	Ammonium	mg/l	Measurment	Ammolyser	SOP:Measuring ammonium	Dry-weather	Outlet	Maruéjouls	Thibaut

Next the comments belonging to the values will be added in the Comment table as shown in Table 54. The Comment_ID is filled out automatically by MySQL.

Table 54 - Adding comments in the Comment table

Comment_ID	Comment
1	Sensor was not cleaned well
2	Sensor was not in the immersed

Next the values can be entered in the Value table as shown in Table 55. The Value_ID is automatically generated by MySQL but the Metadata_ID and Comment_ID have to be added manually.

Table 55 - Adding data to the Value table

Value_ID	Date	Time	Value	Number_of_experiment	Metadata_ID	Comment_ID
1	2014-07-13	10:00:00	15.034	1	1	
2	2014-07-13	10:00:05	17.398	1	1	
3	2014-07-13	10:00:10	17.258	1	1	
4	2014-07-13	10:00:15	17.401	1	1	
5	2014-07-13	10:00:20	17.399	1	1	
6	2014-07-13	10:00:25	34.562	1	1	1
7	2014-07-13	10:00:00	25	1	2	
8	2014-07-13	10:00:05	25.3	1	2	
9	2014-07-13	10:00:10	25.2	1	2	
10	2014-07-13	10:00:15	25.4	1	2	
11	2014-07-13	10:00:20	3	1	2	2

3.4 Queries of all n:m relations in dat*EAU*base

In this section there examples of queries of all n:m relations in the dat*EAU*base without visible IDs of the tables.

3.4.1 Query: Connect Value, Comment and Metadata table

This query shows one table in which the Value, the Comment, the Metadata and all tables which are connected to the Metadata table are connected but not all columns are displayed. Only those columns are displayed which are written in the Query after the code SELECT. Under the code WHERE is defined which dates and times have to be shown. This could also be sorted by names, projects, parameters etc.

<u>Query:</u>

```
USE dateaubase;

SELECT Date, Time, Value, Number_of_experiment, Comment, Parameter, Unit, Purpose,
Equipment_identifier, Procedure_name, Weather_condition, Sampling_point, Sampling_location,
Site_name, Site_type, Watershed_name, Last_name, Project_Name

FROM Value

LEFT JOIN Comments ON Value.Comment_ID = Comments.Comment_ID
LEFT JOIN Metadata ON Value.Metadata_ID = Metadata.Metadata_ID
LEFT JOIN Parameter ON Metadata.Parameter_ID = Parameter.Parameter_ID
LEFT JOIN Unit ON Metadata.Unit_ID = Unit.Unit_ID
LEFT JOIN Purpose ON Metadata.Purpose_ID = Purpose.Purpose_ID
LEFT JOIN Equipment ON Metadata.Equipment_ID = Equipment.Equipment_ID
LEFT JOIN Procedures ON Metadata.Procedure_ID = Procedures.Procedure_ID
LEFT JOIN Weather_condition ON Metadata.Condition_ID = Weather_condition.condition_ID
LEFT JOIN Sampling_points ON metadata.sampling_point_ID =
Sampling_points.Sampling_point_ID
LEFT JOIN Site ON Sampling_points.site_ID = Site.Site_ID
LEFT JOIN Watershed ON Site.Watershed_ID = Watershed.Watershed_ID
LEFT JOIN Contact ON Metadata.Contact_ID = Contact.Contact_ID
LEFT JOIN Project ON Metadata.Project_ID = Project.Project_ID

WHERE Value.Date between '2014-07-13' and '2014-07-13'
```

```
and Value.Time between '10:00:00' and '10:00:25'

order by Value_ID;
```

Result:

The result of the query is displayed in Table 56, Table 57 and Table 58.

Table 56 - Result of the query (Part 1)

Date	Time	Value	Number_of_experiment	Comment
2014-07-13	10:00:00	15.034	1	
2014-07-13	10:00:05	17.398	1	
2014-07-13	10:00:10	17.258	1	
2014-07-13	10:00:15	17.401	1	
2014-07-13	10:00:20	17.399	1	
2014-07-13	10:00:25	34.562	1	Sensor was not cleaned well
2014-07-13	10:00:00	25	1	
2014-07-13	10:00:05	25.3	1	
2014-07-13	10:00:10	25.2	1	
2014-07-13	10:00:15	25.4	1	
2014-07-13	10:00:20	3	1	Sensor was not in the immersed

Table 57 - Result of the query (Part 2)

Parameter	Unit	Purpose	Equipment_identifier	Procedure_name	Weaterh_condition
Conductivity	mS/cm	Sensor-testing	TetraCon700IQ_001	ISO15839:2003	
Conductivity	mS/cm	Sensor-testing	TetraCon700IQ_001	ISO15839:2003	
Conductivity	mS/cm	Sensor-testing	TetraCon700IQ_001	ISO15839:2003	
Conductivity	mS/cm	Sensor-testing	TetraCon700IQ_001	ISO15839:2003	
Conductivity	mS/cm	Sensor-testing	TetraCon700IQ_001	ISO15839:2003	
Conductivity	mS/cm	Sensor-testing	TetraCon700IQ_001	ISO15839:2003	
Ammonium	mg/l	Measurment	Ammolyser	SOP:Measuring ammonium	Dry-weather
Ammonium	mg/l	Measurment	Ammolyser	SOP:Measuring ammonium	Dry-weather
Ammonium	mg/l	Measurment	Ammolyser	SOP:Measuring ammonium	Dry-weather
Ammonium	mg/l	Measurment	Ammolyser	SOP:Measuring ammonium	Dry-weather
Ammonium	mg/l	Measurment	Ammolyser	SOP:Measuring ammonium	Dry-weather

Table 58 - Result of the query (Part 3)

Sampling_point	Sampling_location	Site	Site_type	Watershed_name	Last_name	Project_name
					Alferes	monEAU
					Alferes	monEAU
					Alferes	monEAU
					Alferes	monEAU
					Alferes	monEAU
					Alferes	monEAU
Outlet	Primary_clarifier	Quebec-West	WWTP	Cheveau	Maruéjouls	retEAU
Outlet	Primary_clarifier	Quebec-West	WWTP	Cheveau	Maruéjouls	retEAU
Outlet	Primary_clarifier	Quebec-West	WWTP	Cheveau	Maruéjouls	retEAU
Outlet	Primary_clarifier	Quebec-West	WWTP	Cheveau	Maruéjouls	retEAU
Outlet	Primary_clarifier	Quebec-West	WWTP	Cheveau	Maruéjouls	retEAU

3.4.2 Query: Connect the Project with the Contact table

This query shows one table in which the Project and the Contact table are connected but not all columns are displayed. Only those columns are displayed which are written in the Query after the code SELECT. Under the code WHERE is defined which contact has to be shown.

Query:

```
USE dateaubase;

SELECT Last_name, First_name, Project_name

FROM contact

LEFT JOIN project_has_contact ON contact.Contact_ID = project_has_contact.Contact_ID
LEFT JOIN project ON project_has_contact.project_ID=project.Project_ID

WHERE contact.last_name='Alferes';
```

Result:

In Table 59 the result of the query is displayed. So all projects in which Janelcy Alferes is working are shown.

Table 59 - Result of the query

Last_name	First_name	Project
Alferes	Janelcy	monEAU
Alferes	Janelcy	retEAU

3.4.3 Query:Connect Sampling_points table with Project table

This query shows one table in which the Project and the Sampling_points table are connected but not all columns are displayed. Only those columns are displayed which are written in the Query after the code SELECT. Under the code WHERE is defined which project has to be shown.

Query:

```
USE dateaubase;

SELECT Sampling_point, Sampling_location, Site_name, Site_type, Watershed_name,
Project_Name

FROM sampling_points

LEFT JOIN site ON sampling_points.site_ID = site.Site_ID
LEFT JOIN watershed ON site.Watershed_ID = watershed.Watershed_ID
LEFT JOIN project_has_sampling_points ON sampling_points.sampling_point_ID =
project_has_sampling_points.sampling_point_ID
LEFT JOIN project ON project_has_sampling_points.project_ID=project.Project_ID

WHERE project.project_name='monEAU';
```

Result:

In Table 60 the result of the query is shown. In this table are all Sampling_points of the project mone*EAU* displayed.

Table 60 - Result of the query

Sampling_point	Sampling_location	Site_name	Site_type	Watershed_name	Project_name
Inlet	Biofiltration_1	Quebec-Est	WWTP	St.Sacrement	monEAU

3.4.4 Query: Connect the Project with the Equipment table

This query shows one table in which the Project and the Equipment table are connected but not all columns are displayed. Only those columns are displayed which are written in the Query after the code SELECT. Under the code WHERE is defined which Equipment has to be shown.

Query:

```
USE dateaubase;

SELECT Equipment_identifier, Equipment.storage_location, Project_name

FROM equipment

LEFT JOIN project_has_equipment ON equipment.Equipment_ID =
project_has_equipment.equipment_ID
LEFT JOIN project ON project_has_equipment.project_ID=project.Project_ID

WHERE equipment.equipment_identifier='TetraCon700IQ_001';
```

Result:

In Table 61 is the result of the query shown. In this table it is shown in which project the TetraCon700IQ_001 is used.

Table 61 - Result of the query

Equipment_identifier	Storage_location	Project_name
TetraCon700IQ_001	PLT-1234	monEAU

3.4.5 Query: Connect Parameter table with the Unit table, Equipment_model table and the Equipment table

This query shows one table in which the Parameter, the Unit, the Equipment_model and the Equipment table are connected but not all columns are displayed. Only those columns are displayed which are written in the Query after the code SELECT. Under the code WHERE is defined which Equipment_identifier has to be shown.

Query:

USE dateaubase;

SELECT Parameter, Unit, Equipment_model, Equipment_identifier

FROM parameter

LEFT JOIN unit ON parameter.unit_Id=unit.unit_ID

LEFT JOIN equipment_model_has_parameter ON parameter.parameter_ID = equipment_model_has_parameter.parameter_ID

LEFT JOIN equipment_model ON equipment_model_has_parameter.Equipment_model_ID=equipment_model.equipment_model_ID

LEFT JOIN equipment ON equipment_model.Equipment_model_ID=equipment.Equipment_model_ID

WHERE equipment.Equipment_identifier='Ammolyser_001';

Result:

In Table 62 the result of the query is shown. This table shows which parameters the Ammolyser_001 can measure.

Table 62 - Result of the query

Parameter	Unit	Equipment_model	Equipment_identifier
Ammonium	mg/l	Ammolyser	Ammolyser_001

3.4.6 Query: Connect the Procedures table with the Equpment_model and the Equipment table

This query shows one table in which the Procedures, the Equipment_model and the Equipment table are connected but not all columns are displayed. Only those columns are displayed which are written in the Query after the code SELECT. Under the code WHERE is defined which Equipment_identifier has to be shown.

Query:

USE dateaubase;

SELECT Procedure_name, Procedure_location, Equipment_model, Equipment_identifier

```
FROM procedures

LEFT JOIN equipment_model_has_procedures ON procedures.Procedure_ID =
equipment_model_has_procedures.procedure_ID
LEFT JOIN equipment_model ON
equipment_model_has_procedures.Equipment_model_ID=equipment_model.equipment_model_ID
LEFT JOIN equipment ON
equipment_model.equipment_model_ID=equipment.equipment_model_ID

WHERE equipment.Equipment_identifier='Ammolyser_001';
```

Result:

In Table 63 the result of the query is shown. In this table all procedures which are linked to the Ammolyser_001 are shown.

Table 63 - Result of the query

Procedure_name	Procedure_location	Equipment_model	Equipment_identifier
SOP:Measuring ammonium	PLT-1234	Ammolyser	Ammolyser_001

4 REFERENCES

Plana Puig Q. (2012). Efficient on-line monitoring of river water quality using automated measuring stations. Master thesis, Université Laval, 2012.