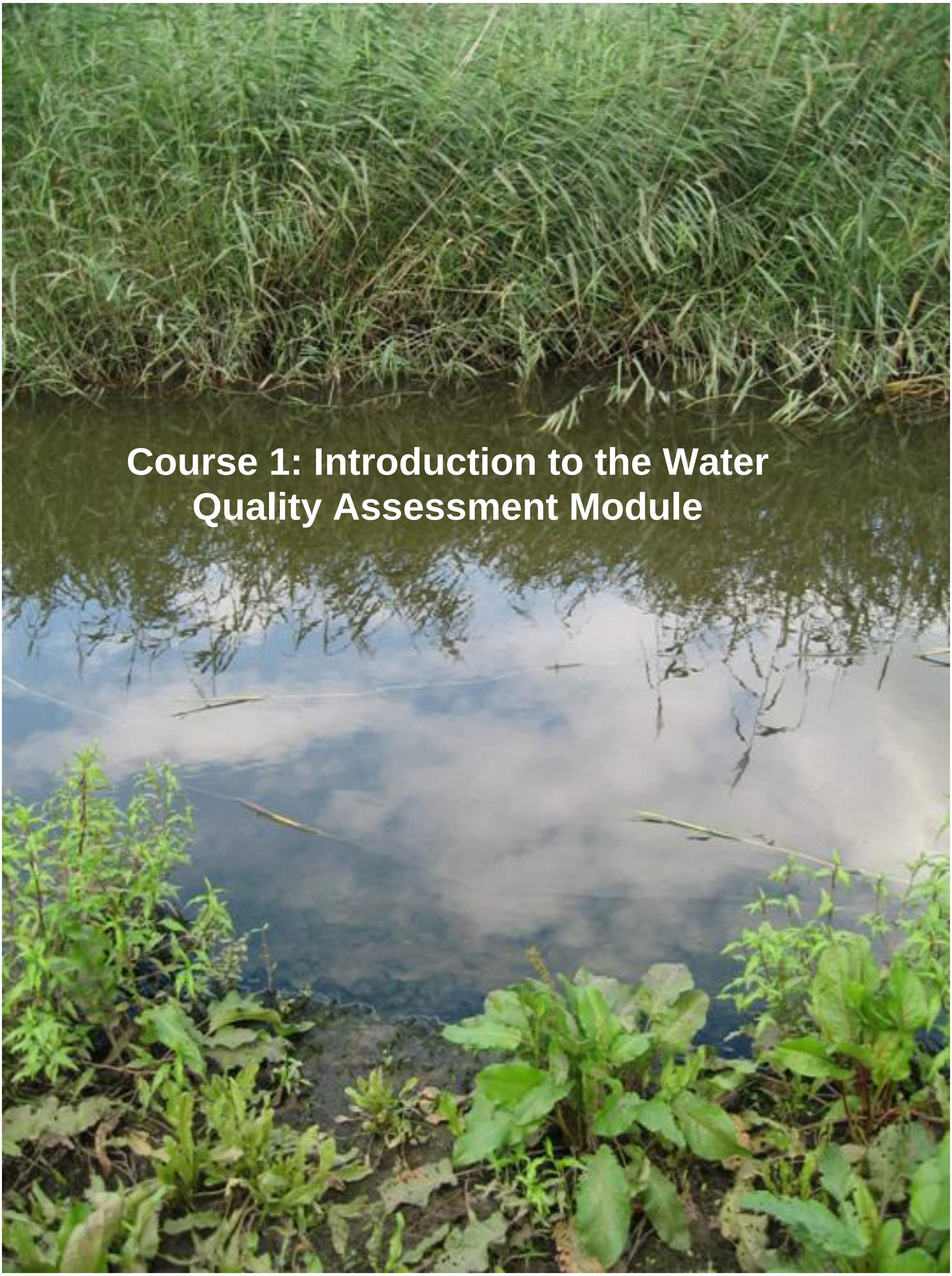
Course 1: Introduction to the Water Quality Assessment Module



Getting started

1. Open your Internet browser and surf to ecampus.unesco-ihe.org

2. Log in (upper right corner of the screen) by filling in your Username and Password that were sent to you earlier and click on the button "Login". If you would not remember your password, you can retrieve it by clicking on the link "Lost password?".

3. You are now in the welcome screen. In the left menu under "My IHE modules", you will see the list of modules that you enrolled for (probably only the Water Quality Assessment Course). In this welcome screen you can also find some links to general information about UNECO-IHE (top menu), you can see if there are messages for you (top right corner), there is a calendar and you can start/update your personal blog or check other persons messages.

GETTING THE TERMINOLOGY RIGHT

Although on our website and during our communication with you, we always referred to the online **course** Water Quality Assessment, in the Moodle system this is called the online **module** WQA. A module then consists of several courses (equivalent to chapters) and each course/chapter consists further of several units (equivalent to lectures):

ONLINE MODULE WQA
- Course 1 – Introduction
  - Unit 1
  - Unit 2
  - ...
- Course 2 – Water quality and pollution
  - Unit 1
  - Unit 2
  - ...

4. Click now on "2010-OC-Water Quality Assessment" to enter the course. In the middle section you can see the course outline with its contents (note that not all information is available right from the start, we only open a new chapter when the old chapter has been completed).

   In the left menu, you can see the following items:
   - People - participants: overview of your fellow participants
   - Activities: Feedback will allow you to give your opinion on the course; Forums will give you access to online discussions, Glossaries contains key terminology and Resources gives an overview of all materials.
   - Administration: grades allow you to check your mark, profile allows you to upgrade your personal information
   - IHE module menu: quick navigation through the course

   In the right menu, you can see the following items:
   - Messages
   - Calendar

- Events key: is linked to the calendar and shows you events at a given date which are important either for all users of Moodle, for all participants of the WQA course, for a subgroup of participants of the WQA course or for you personally (user).
- Online users: who is online?
- Latest news

5. Please take a moment after your first login to update your personal data (Go to Administration - Profile - Edit profile and after changing use the button "Update profile"). If you have one at hand, you can also upload a picture of yourself.

6. Now go to the middle section to the heading "UNESCO-IHE_Moodle_Virtual_Learning_Environment" (under the picture). You can find here a student introduction to eCampus which explains in more detail all the items mentioned under point 4. You can view this either as a simple pdf, or as a sort of movie (audiovisual). The file format of the latter one is .m4v, which requires for example QuickTime to be installed (free software which can be downloaded from: http://www.apple.com/quicktime/download/).

7. In the next menu item "Programme General Information", you can find a copy of the brochure on the OLC WQA.

8. In the next menu item "Module overview", you can find some information such as the target group, prerequisites, time frame, learning objectives, lecturing staff etc. (Note that part of this information is also available in the brochure mentioned under point 7).

9. Once you have viewed all this information, it is now time to start with the first course and the first unit. Simply scroll down a bit to Course 1 and follow the instructions from the next page onwards.

Recommended reading

1. http://email.about.com/od/emailnetiquette/tp/core_netiquette.htm
→ Electronic mail etiquette, also useful for your contributions to the discussions in the I-Learning Environment

2. www.elearners.com/advisor/index.asp
→ Although you have already started an on-line course, at this portal for on-line learning you can test your compatibility with e-learning

Course 1: Introduction to the Water Quality Assessment Module

Table of Contents

Unit 1 – Meet the course coordinators and lecturers

In this unit the course coordinators will first present themselves. Secondly some information about the UNESCO-IHE Institute for Water Education is given. And finally the other lecturers are introduced.

1.1. Course coordinators

Gretchen Gettel - Lecturer in Aquatic Biogeochemistry

Gretchen joined the department of Environmental Resources at UNESCO-IHE in May 2010. Her research activities are focused on understanding the role of aquatic and wetland ecosystems in maintaining water quality in the context of land use and climate change. Her research has focused mainly on nitrogen and carbon biogeochemistry.

Prior to arriving at UNESCO-IHE, Gretchen was employed at the University of New Hampshire as a post-doc and then as research scientist (2005 - 2010). There she studied the effects of rivers and wetlands in the processing of nitrogen and carbon at whole-basin scales. In 2006, Gretchen completed her Ph.D. 2006 from Cornell University, USA, in the program of Biogeochemistry and Environmental Change (BEC). The topic of her dissertation was nitrogen fixation in arctic lakes. In 1998, she earned a M.Sc. from the University of Minnesota in the Department of Water Resources, where she studied the effects of fish distribution on invertebrate and primary producer community structure, also in arctic lakes. She has also worked in stream ecosystems in Venezuela, Trinidad, and Puerto Rico.

Gretchen's teaching experience includes laboratory and lecture courses in Aquatic Ecosystems (ecosystem processes and biogoechemistry focus), Water Quality Management, Stream Ecology, Limnology, and Scientific Writing,

Peter Kelderman - Senior Lecturer in Environmental Chemistry

Dr. Peter Kelderman has been attached to IHE since 1983. His academic teaching subjects include: General and Environmental Chemistry; Mathematics; Physical transport processes, Water Quality Management and Modelling and Aquatic sediments. He has also been teaching these subjects in, amongst others, Kenya, China, Taiwan and Poland.

Additionally, he is supervisor of the Chemistry laboratory sessions at IHE.

Peter Kelderman has prepared and supervised group works on Integrated River Basin Management and on Environmental Technology. In many cases, he has been course leader and mentor in regular and short courses at IHE. He has also supervised some 50 MSc and 4 PhD participants, mainly in the fields of water quality management and of wetlands for wastewater treatment.

Before 1983, he was attached to the Netherlands Institute for Ecological Research (NIOO-CEMO), where he carried out a PhD study on sediment-water interaction of nutrients in a shallow, saline lake. For this, multidisciplinary research was undertaken in the field of sediment dynamics, pore water qualities, experiments on sediment water interaction under different environmental conditions and fieldwork on the effects of light and dark conditions upon the phosphorus exchange in a producing microflora mat.
His current research activities are especially concentrated on sources of pollution and clean-up of dredged sediments in an urban environment. For this, the different mass balance terms of suspended matter and heavy metals in an inner-city canal system are systematically being assessed. This research has, up till now, resulted in more than 10 scientific publications.

Peter Kelderman has presented his work in many conferences and seminars; recently he has been member of the Programme Committee of the 9th IWA Conference on Watershed and River basin Management.

1.2. UNESCO-IHE Institute for Water Education (source: www.unesco-ihe.org)

The UNESCO-IHE Institute for Water Education is established in 2003. It carries out research, education and capacity building activities in the fields of water, environment and infrastructure. UNESCO-IHE continues the work that began in 1957 when IHE first offered a postgraduate diploma course in hydraulic engineering to practising professionals from developing countries.

The Institute is based in Delft, the Netherlands, and is owned by all UNESCO member states. It is established as a UNESCO 'category I' institute jointly by UNESCO and the Government of the Netherlands.

The Institute is the largest water education facility in the world, and the only institution in the UN system authorised to confer accredited MSc degrees.
UNESCO-IHE is instrumental in strengthening the efforts of other universities and research centres to increase the knowledge and skills of professionals working in the water sector.

Vision and mission
UNESCO-IHE envisages a world in which people manage their water and environmental resources in a sustainable manner, and in which all sectors of society, particularly the poor, can enjoy the benefits of basic services.

The mandate given by UNESCO to IHE is to:
- strengthen and mobilise the global educational and knowledge base for integrated water resources management; and
- contribute to meeting the water-related capacity building needs of developing countries and countries in transition.

Within this mandate, the mission of the Institute is to:
- contribute to the education and training of professionals and to build the capacity of sector organisations, knowledge centres and other institutions active in the fields of water, the environment and infrastructure in developing countries and countries in transition.

The functions of the Institute include:
- Serving as an international standard-setting body for postgraduate water education programmes and continuing professional training;

- Building human and institutional capacities through education, training and research;
- Setting up and managing networks of educational and water sector institutions and organisations worldwide;
- Functioning as a ‘policy forum’ for UNESCO member states and other stakeholders; and
- Providing advice on water education to partner organisations and other members of the UN water family.

Beneficiaries and clients

UNESCO-IHE provides a wide range of services to a variety of target groups in developing countries and countries in transition:

- Education, training and research – for water sector professionals, engineers, scientists, consultants and decision-makers working in the water, environment and infrastructure sectors.
- Water sector capacity building – for water sector ministries and departments, municipalities, water boards and water utilities, universities, training and research institutes, industries, non-governmental and private sector organisations.
- Partnership building and networking – among knowledge centres, public and private sector organisations.
- Standard setting for education and training – for water-related institutions, universities and other education and training agencies in the water sector.
- Policy forum on water – for UNESCO member states and other stakeholders.

1.3. Other lecturers

Mário Chilundo – Lecturer in Water Management

Mário Chilundo is an Agriculture Engineer, full time lecturer at Eduardo Mondlane University since 2003 at Rural Engineering Department (Soil and Water Division), Faculty of Agronomy and Forestry Engineering (FAEF) in Mozambique. He is currently involved in the teaching of subjects such as: Hydraulics; Irrigation Projects; Water in Agriculture and Irrigation and Drainage. He has also been involved as course facilitator on topics related to water management (eg. tropical wetlands management; climate change impacts on water resources; integrated water resources management). His academic experience was also grown through participation in cooperation activities with: Savonia University of Applied Sciences (Finland); UNESCO-IHE (Netherlands) and recently with Technical University of Lisbon (Portugal).

Mário Chilundo holds a BSc with honours in Agronomy (Rural Engineering) since 2002 and also MSc degree on Environmental Sciences (specialised on water quality management) since 2007 as a result of his training at UNESCO-IHE. He has experience in management, planning, monitoring and evaluation of irrigation projects and agricultural crops. He participated in several baseline surveys and feasibility studies for proposed agricultural and irrigation projects and carried out environmental impact assessment of agricultural and irrigation development projects. He had conducted related research including, assessment of erosion and salinization after the 2000 floods in the Limpopo River Basin from 2002 to 2004; integrated management of wetlands (community focused projects) and within the Challenge Program on Water and Food Program (2005-2009), carried out research aiming to increase water productivity in arid and semi-arid regions of Mozambique.

He has prepared and supervised students work on water management and water quality monitoring in the southern Mozambique, especially within Limpopo River Basin and urban green areas of Maputo. His current research activities are focused on the maximization of water use in agriculture (fertirrigation in sandy soils), water quality assessment (heavy metals) in transboundary basins (surface and groundwater). These activities have resulted and several scientific reports as well as conference papers.

Tamara Avellán

Mrs. Tamara Avellán commenced her academic career in biology at the Ludwig Maximilian Universität, Germany, where she obtained her Vordiplom in 2002. Two years later, she graduated with a Master of Science in Biological Science from the Wayne State University, USA, after having studied the water and aquatic ecosystem quality of a Uruguayan creek.

She was then invited to continue researching in the same institute where her focus lay on the ecotoxicological effects of heavy metals on the leaf morphology of submerged aquatic plants. During this time she was also in charge of teaching a variety of basic biology classes and guiding more than 10 undergraduate students in specific research questions. In 2007, she returned to her home country, Uruguay, where she worked as an independent environmental consultant, performing environmental quality assessments, designs and construction of wetlands and environmental education efforts.

After a short research stay at UNESCO-IHE, Mrs. Avellán now works again at the Ludwig Maximilians Universität in Munich, Germany for the department of Geography and Remote Sensing.

Diederik Rousseau - Senior Lecturer in Environmental Engineering

Dr. Diederik Rousseau has been working at the Department of Environmental Resources at UNESCO-IHE Delft since October 2005. He holds both an MSc (1999) and PhD (2005) degree from Ghent University in Belgium in Applied Biological Sciences - Environmental Technology.

Research: dr. ir. Rousseau's main expertise is natural systems for wastewater treatment, in particular constructed treatment wetlands and waste stabilization ponds, with a strong focus on the optimization of ecotechnologies' performance by means of experimental set-ups as well as model-based design. His own research as well as the results by numerous MSc and PhD fellows under his supervision has resulted in a large number of publications, among others 23 peer-reviewed papers, 4 book chapters and 28 papers in proceedings of international conferences. He is a regular reviewer for various journals and is also actively involved in the WETPOL and IWA (Constructed) Wetland conferences.

Education: dr.ir. Rousseau has 10 years of educational experience, not only with traditional forms as classroom teaching and laboratory sessions, but also with online courses and problem-based learning. He has also been teaching on numerous occasions in short courses abroad on the topics of water quality and wastewater management, among others in countries such as Colombia, Mexico, Indonesia, Egypt and Rwanda. In addition to that he also has ample experience with programme management, having been Deputy Course Coordinator and currently being MSc coordinator of the MSc in Environmental Science at UNESCO-IHE.

Action List for Unit 1
• Watch the Introduction Movie, available under C1U1_Lecture_Presentation • Now that you know us, we also very much would like to know a bit more about you. 1. Please update your profile if you have not done so yet (see page 4 - item 5). 2. Almost at the bottom of C1U1, click on the link "Assignment WQA-1: Present yourself" and follow the instructions".

Extra information
• If you want more information on UNESCO-IHE, you can find a short introduction movie on YouTube: http://www.youtube.com/watch?v=A_rQ_hPyJsI. There are also other movies available, among others about the history of the institute. Simply type the keyword UNESCO-IHE in YouTube to access this information.

Unit 2 – General overview of the course contents

2.1. Objectives of the course

Over large parts of the world, rivers and lakes show increasing trends of water pollution. This holds especially for developing countries under economic expansion and increasing population sizes. Evaluation of the physical, chemical and biological water quality is essential for the abatement of freshwater pollution. For this, sound and sustainable water quality assessment programmes should be aimed at integrating the different steps in the monitoring cycle, from the information needs, monitoring network design, field and laboratory procedures up to data collection and processing. The resulting water quality data can then be evaluated together with the natural water quality, human effects and water quality usages. Optimization of the water quality monitoring programmes, amongst others with respect to cost, should ensure that these programmes are sound and sustainable, also in future.

After successful completion of the course, participants will be able to:

- Understand and apply concepts of water quality and pollution processes in rivers and lakes
- Understand and apply the different steps of the monitoring cycle in rivers and lakes
- Understand the basic concepts of groundwater quality and monitoring
- Apply common statistical techniques for water quality data evaluation
- Design sound and sustainable freshwater quality monitoring and assessment programmes under specified conditions.

2.2. Module contents

This module consists of four courses and a final assignment

1. Introduction to the Water Quality Assessment Module (this course)
2. Water Quality and Pollution
3. Water Quality Monitoring and Assessment
4. Data handling and presentation
5. Final assignment

Course 1: Introduction

This course will first introduce you to UNESCO-IHE, to the teachers of this module and then will help you take your first steps in eCampus. After that we will review the contents of the module and give you an overview of the assignments that you need to do in order to successfully complete the course and receive the Certificate. Finally we will introduce you to the world of Water and Water Quality, with some general information about "Water and Life" and "Sustainable Use of Water"

Course 2: Water Quality
We will discuss the main water quality and pollution characteristics in rivers and lakes and the processes that affect these.

Course 3: Water Quality Monitoring and Assessment
In this course you will learn how to apply the different steps of the monitoring cycle in rivers and lakes. In less detail we will also consider the main factors in groundwater pollution and monitoring.

Course 4: Data handling and presentation
We will show you how to apply some simple statistical techniques in handling your monitoring data. Also we will review how to best present monitoring results.

Course 5: Final assignment
The final assignment consists in the design of a sustainable water quality monitoring programme for a specific region. You will carry out this assignment in pairs to stimulate interaction and discussion between you. This course will also contain an evaluation of this online module by you.

2.3. Target group

The module is designed for professionals actively involved in water quality monitoring and management. They may be working *e.g.* for environmental agencies, consultants, as environmental or water management officers in local, regional or national governments, as staff of NGOs, or as junior university lecturers, and may not have the time to undertake a course that lasts several weeks abroad.

2.4. How to study this course and use the learning materials

Each unit consists of a number of learning materials. For most units, the basic materials consist of powerpoint presentations with audio, lecture notes, supplementary materials and assignments. The powerpoint presentation introduces the topic. The lecture notes treat the topic more extensively. The assignments help you to review the unit. The supplementary materials are offered for further study or form the basis of an assignment.

Powerpoint presentations (with audio/video). The powerpoint presentations introduce and give an outline of the unit matter. These presentations are often accompanied by sound of the presenting unit teacher. One could start studying a unit by watching the presentation first, although some people prefer reading the lecture notes first and refer to the presentations later (this depends on your learning style). The powerpoint presentations are also made available as supplementary materials.

Lecture notes. The lecture notes form the core of each course and are compulsory reading material. They deal with the unit topic in-depth and contain references to scientific literature sources and background materials. **Note that lecture notes for an entire course are always made available in the first unit**!

Manuals. While developing this course, we have followed partly the book by D. Chapman (1996). Water Quality Assessments - A Guide to Use of Biota, Sediments and Water in Environmental Monitoring - Second Edition. Chapman&Hall, on behalf of

UNESCO, WHO and UNEP. In the lecture notes and/or powerpoints, we will refer to certain pages of this book whenever appropriate.

We will regularly refer to sections of this manual during the powerpoint presentations and also ask you to read certain sections yourself as a homework.

Assignments. Each module offers three types of assignments: (1) unit assignments; (2) course assignments and (3) module assignments. Unit assignments are questions or short assignments provided after each unit. You can use these assignments to review the topic and most important concepts of the unit. The unit assignments focus on the unit's key concepts, terminology and facts. They are meant to help you internalizing the material and testing your knowledge. By memorizing the unit's key aspects you should be able to successfully complete the unit assignments. Unit assignments are meant to be completed individually and often consist of *yes/no* or *multiple choice* type of questions. Sometimes, also more open-ended questions and tasks are formulated. These assignments may trigger you to write down questions about things you do not (yet) understand. In principle, however, you should be able to find the answers in the presentations and lecture notes.

Course assignments cover a whole course and are usually presented as a separate, final course unit. They focus on participant's understanding of the course material and on the relationships between the different course units. For this reason, course assignments are less focused on facts and terminology than unit assignments. Working out course assignments may involve several participants. Participants may be asked to reflect and report on what they have learned in the course in the discussion forum and read and comment on contributions by other participants.

The module assignment is offered at the end of the entire module and covers all of what you have learned during the module. The main objective of the module assignment is to build on and integrate your newly acquired knowledge and understanding of water quality assessment into a monitoring plan.

On-line discussions. On-line discussions (Menu item "Forums") are used to stimulate your active participation in the on-line course. Because online courses do not offer lectures that can be attended, there is a certain risk that you remain passively looking at the presentations on your computer screen and reading the lecture notes. However, you will learn much more if you use the material to actively produce reports and share it with other participants in the course. They may give you some valuable comments and suggestions. Also, you can learn a lot from reading contributions from other participants and giving them some feedback. Using on-line discussions to achieve more active participation in on-line course is described as "E-tivity".

Extra materials. Many units offer supplementary materials in the form of articles or papers, videos or case studies involving a real-life example of the concepts introduced in the unit. Reading or viewing these supplementary materials is highly recommended. It will increase your understanding of the topic and broaden your horizon. In some cases, the assignments specifically refer to the supplementary materials (which will always be clearly indicated).

Contacting the other participants, the coordinator and teachers. You can do this by using the Messages and/or Quickmail options in the right menu.

Questions to the teachers. Whenever you have a particular question about a course you can post this question in the Q&A forum which you can find at the beginning of each course.

2.5. Study load

The following table indicates the estimated study load for each course. This is the total time needed to view the presentations, read the lecture notes and complete the assignments. The total study load of the module of 140 hours is divided over a four month study period. Therefore, participants are expected to spend some 8 to 9 hours per week on average.

Course	Study load hours
Introduction	16
Water Quality	26
Water Quality Monitoring and Assessment	34
Data handling and presentation	24
Module assignment	40
TOTAL	140

Action List for Unit 2

- Look and listen to the powerpoint presentation available under “Lecture” which will give you some more details about the course contents.
- Make sure you have downloaded the book of Deborah Chapman available under C1U1_Extra_Materials

Unit 3 – Water and Life
On the importance of water

This introduction to the topic Water Quality Assessment consists of a powerpoint with audio comments. Five main items are discussed:

1. Origin of water
2. Water, an extraordinary molecule
3. Water, a multitude of appearances
4. Water, omnipresent but scarce
5. Water, a host of life

3.1. Origin of water

> Water is H_2O, hydrogen two parts, oxygen one, but there is also
> a third thing, that makes it water and nobody knows what that is.
> *D. H. Lawrence (1885—1930), British novelist.*
>
> If there is magic on this planet, it is contained in water.
> *L. Eisely, The Immense Journey, 1957*.

There is a general agreement among scientists that the occurrence of water is an absolute condition to have life (as we know it). Hence for example the continued search for water on the planet Mars: its presence could indicate (earlier) life on that planet. Also without a water supply it will be almost impossible to colonize this planet some day in the future.

There are three complementary theories about how water came to planet Earth, or rather why Earth has such a plentiful supply of water compared to other planets (source: Wikipedia):

1. The cooling of the primordial Earth to the point where the outgassed volatile components were held in an atmosphere of sufficient pressure for the stabilization and retention of liquid water;
2. Comets, trans-Neptunian objects or water-rich asteroids from the outer reaches of the asteroid belt colliding with a pre-historic Earth may have brought water to the world's oceans.
3. Conversion from chemically bound hydrogen (H) and oxygen (O) into water (H_2O): (1) Biochemically through mineralization and photosynthesis, (2) Gradual leakage of water stored in hydrous minerals of the Earth's rocks and (3) photolysis: radiation can break down chemical bonds on the surface.

3.2. Water, an extra-ordinary molecule

What makes water so special and so essential? It is the fact that it occurs in liquid form at ambient temperatures (in fact between 0 – 100 ºC). Most other molecules of similar composition and with similar small dimensions occur in the gas phase at these temperatures. This is entirely due to the structure of the water molecule and as a consequence its capacity to form bonds with other water molecules. The angle between both H atoms is not 90º but 104.5º. As a result, electrons (with negative charge) are “pushed” to the right hand side of the molecule (as depicted in Figure 1) causing a negative load on the O side, and a positive charge at the H side. This makes water molecules strong dipoles, in fact they can be considered as tiny magnets. The negative side of one molecule will then attract the positive side on another molecule and a bond will form between both molecules (right hand picture below) which is called a “hydrogen bond”. These bonds make that individual water molecules cannot escape so easily to the gas phase; hence water remains liquid at ambient temperatures.

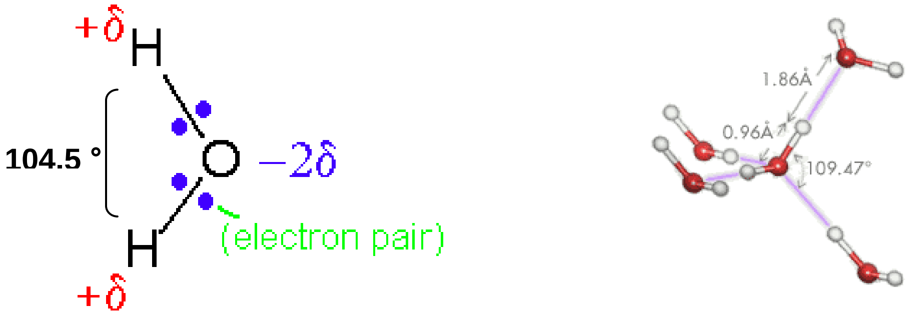


Figure 1. Water molecule showing the dipole (left) and formation of hydrogen bridges between water molecules (right)

What other consequences are there? For those that remember Chemistry classes, atoms/molecules “move” with a frequency/magnitude which is proportional to the temperature. At the absolute zero point (0 Kelvin = -273 ºC), molecules do not move at all; with rising temperatures movement increases. This is called Brownian motion (named after the Scottish botanist Robert Brown): the seemingly random movement of particles suspended in a liquid or gas. Therefore water molecules at 20 ºC move more than molecules at 10 ºC. As a consequence, the hydrogen bonds are stretched and molecules move a bit further away from each other. This means that fewer molecules will occur in the same volume or in other words this will have an effect on the density of water: the density of water decreases as the temperature increases.

At a temperature of 100 ºC, the movement of the individual molecules has become so strong that they can break the hydrogen bonds and escape to the atmosphere (they become water vapour = gas). This is called the boiling point.

At a temperature of 0 ºC, the movement has become so small that the hydrogen bonds are sort of “solidifying” and water starts forming crystals which are known as ice. Between the molecules there are large voids so water in this condition has a low density. That is why ice is floating on water (density of ice < density of liquid water).

The balance point between both processes is at 4 ºC, so at this temperature water has the highest density. A summary of all this is given in Figure 2 below, showing the so-called “density anomaly” of water. This is extremely important for aquatic life because water with the highest density will always sink to the bottom, so the water temperature of the deepest water layers (in relatively deep water bodies) will never go below 4 ºC, which is enough to allow survival of plants and animals. Imagine this would not be the case: if ice would sink, then as soon as it would be formed at the surface, it would sink down and crush all organisms below it.

This whole mechanism is also important in view of climate change! Higher temperatures will melt more ice, but since ice is floating on the oceans (e.g. icebergs); this will not change the water volume (or sea level). Of course this is not true for land ice (e.g. glaciers, the ice on Greenland). But higher temperatures also mean that water will heat up and so its density will decrease, meaning that the same mass of water will now occupy a larger volume. This could contribute to rising sea levels.

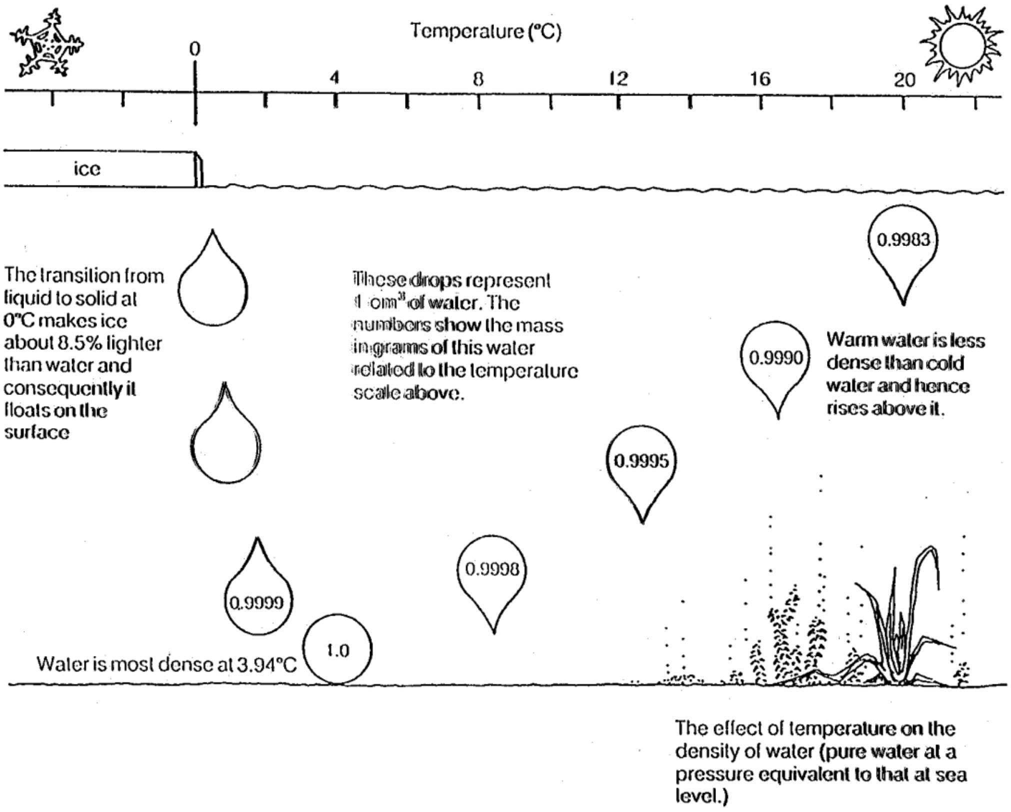


Figure 2. Density of water at different temperatures.

Different layers of water with different temperatures will have different densities. Let's take the example shown above: the deepest layer of a deep lake could have a temperature of 4 ºC and the surface layer could have a temperature of 20 ºC. The water with the highest density occurs thus in the bottom layer, the water with the lowest density occurs in the surface layer. Because "lighter" water will always stay on top, and "heavier" water always on the bottom, there will be little or no mixing between the different layers. This is called "stratification". Stratification can be annulled when a change in air temperature changes the water temperature of the surface layer and hence its density. Then a new equilibrium will be established.

It is important to point out that density differences and hence stratification can also be caused by different concentrations of dissolved solids. The most common example is the effect of salt on density: a higher salt content means a higher density, thus sea water has a higher density than freshwater. An extreme case is the Dead Sea which has very high salt levels and thus also a high density. This makes it easier to float in the water, and you can easily find pictures of people floating in the water without any effort and reading for instance their newspaper. In an estuary, where freshwater from a river "meets" sea water, two distinct layers are formed, with freshwater on top and sea water in the deeper layers.

3.3. Water, a multitude of appearances

Water occurs in many different forms: lake water, river water, ocean water, ground water, water vapor in the air, clouds, ice, in the body of animals and plants, ... All these forms of water are connected via the so-called "Hydrological Cycle", see figure below.

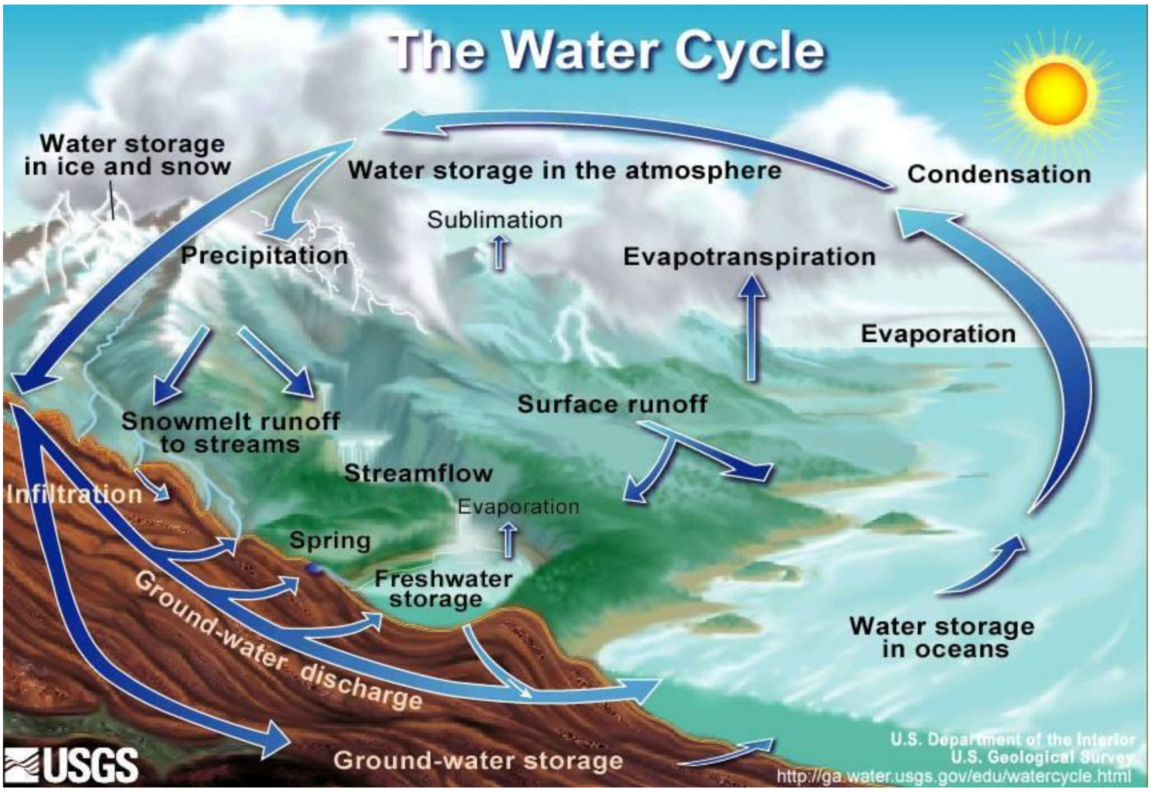


Figure 3. The water cycle (*Source: USGS*)

Precipitation: water vapour in the air can condensate and form clouds out of which precipitation can occur. Depending on the air temperature, this can occur in liquid (rain) or solid (snow, hail) form.

Runoff versus infiltration: precipitation that reaches ground level can penetrate in the soil when the soil characteristics (permeability) allow it – called infiltration -, or form runoff in case the soil is more or less impermeable. One of the main causes of flooding nowadays is the fact that in expanding cities more and more surface becomes impermeable (concrete, asphalt) so more runoff is formed which eventually exceeds the capacity of the drainage systems and results in flooding.

Groundwater and springs: water that infiltrates into the soil is called ground water. When because of local topography this ground water surfaces again, this is called a spring. Alternatively groundwater can reach rivers or oceans – ground water discharge – or remain in the soil for a long period of time – ground water storage -.

Surface flow: runoff always flows to the lowest point. When sufficient quantities of runoff come together, surface flow can occur; usually first as small brooks or rivulets, later as big rivers. The largest river on earth is the Amazon river in South-America, which is more than 6500 km long and has a final discharge of about 250.000 m^3 per second, this equals the volume of some 80 Olympic swimming pools passing per second. Brooks and rivers usually discharge into: (1) another river, (2) a lake, (3) a sea or ocean. In exceptional cases there is no discharge, such as the Okavango River in Botswana. Evaporation (see below) is so high that 97% of all water is lost to the atmosphere so once the river has reached its delta (a large wetland area), it just stops flowing.

Evapotranspiration: this is the combined process of water loss to the atmosphere by evaporation (physical process) and by transpiration (by plants). Plants living in arid areas try to minimize their transpiration losses by reducing leaf areas (needles in stead of leaves), having a wax-layer on the leaves etc.

Condensation: the conversion of water vapor into liquid water. When this happens on a large scale, clouds are formed.

Surface water is often divided into three categories depending on salt contents

- freshwater: < 0.5 ppt or ‰ dissolved salts (< 0.5 g per liter)
- brackish waters: 0.5 – 30 ppt or ‰ dissolved salts (0.5 – 30 g per liter)
- marine water: 30-50 ppt or ‰ dissolved salts (30-50 g per liter)

Approximately 71% of the Earths' surface is covered by oceans and seas, the majority of which occurs in the southern hemisphere.

Most inland water is actually freshwater, such as lakes, rivers, pond, swamps etc. Also here three categories exist:

- Aboveground (river, lake, ...) versus below ground (ground water)
- Stagnant (lake, pond, ...) versus running (river, brook)
- Natural (river, swamp, ...) versus artificial (canal, hydropower reservoir, ...)

In particular for a lake or reservoir, it can be useful to draw up a **water balance** or **water budget**. This balance takes into account all inputs and outputs of water to calculate the change in storage volume of a lake. In case the area is known this balance can also be used to calculate the change in water level. In most cases the balance will consist of the following components

INFLOWS	OUTFLOWS
+ Inflow rate Qi (m^3/day)	- Outflow rate Qo (m^3/day)
+ Catchment runoff Qc (m^3/day)	- Evapotranspiration A x ET (m^2 x m/day)
+ Precipitation A x P (m^2 x m/day)	- Infiltration A x I (m^2 x m/day)
+ Infiltration A x I (m^2 x m/day)	

Infiltration can be positive or negative, depending on whether the groundwater is feeding the lake, or vice versa. A is the surface area of the lake (in m^2).

Change in stored volume over time =

$$\frac{\Delta V}{\Delta t} = Q_i + Q_c + Q_{sm} + (P * A) - Q_o - (ET * A) \pm (I * A)$$

For the theoretical case of a cubical lake with surface area A and depth d, we can state that: V = A * d and since A is constant, we can simplify to:

$$\frac{\Delta d}{\Delta t} = (Q_i / A) + (Q_c / A) + (Q_{sm} / A) + P - (Q_o / A) - ET \pm I$$

3.4. Water, omnipresent but scarce

Despite the fact that almost three quarters of the Earth surface are covered with water, very few of that supply is actually directly consumable by humans as well as flora and fauna. We will focus on human use here.

Consider Table 1 below:

- 93.94% of all water on earth is salt water in oceans and seas, which is not fit for consumption (drinking, irrigation, ...) except when expensive and energy-demanding technologies such as membrane filtration or distillation are applied;
- 4.11% occurs as deep groundwater, which is hardly or not accessible
- 0.27% occurs as active groundwater, and could potentially be used for consumption
- 1.65% is locked in glaciers and permanent snow cover
- 0.02% of freshwater is contained in lakes
- <0.01% is present as soil moisture (bound to soil particles, not for consumption)
- <0.001% occurs as vapor in the atmosphere
- <0.0001% is present in rivers, brooklets etc.

The exact % might vary a little bit between various sources, but the main message is that only about 0.3% of all water on earth is potentially available for (almost) direct consumption! And we are polluting this water reserve at a very high pace; hence good water quality management is an absolute and urgent necessity.

Table 1 — Distribution of water in the hydrosphere (from Lvovitch, 1979)

	Volume ($km^3 \times 10^3$)	Percentage of total vol.	Per cent of fresh water	Replacement time (years)
Oceans	1370323	93.94180		3000
Deep groundwater	60000	4.11320		5000
Active groundwater	4000	0.27400	14.094	330
Ice	24000	1.64500	84.566	8000
Lakes	280	0.01900	0.987	7
Soil moisture	85	0.00580	0.299	1
Atmosphere	14	0.00096	0.049	0.027
Rivers	1.2	0.00008	0.004	0.031
Freshwater total	28380.2	1.92000		
Water, Grand total	1458703	99.99984	99.999	2800

3.5. Water, a host of life

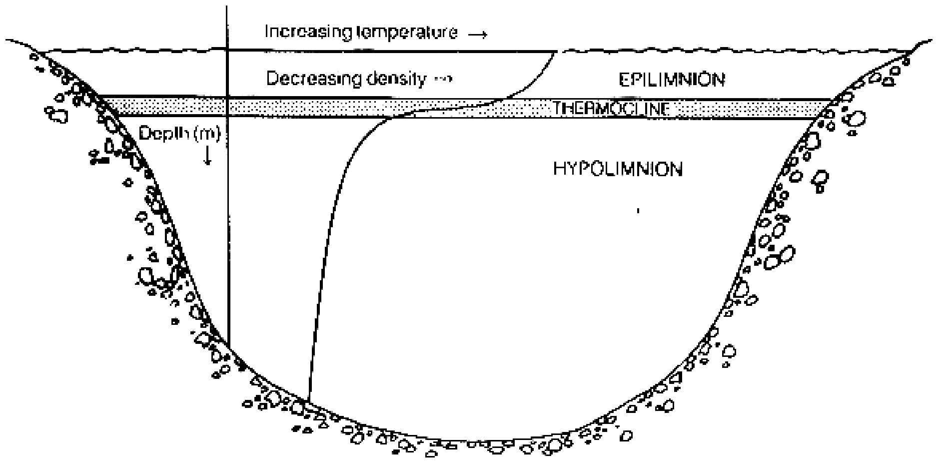
From now on, we will only consider freshwater. Management of oceans, seas and coastal zones is a discipline in itself and does not fall within the scope of this course.

It is important when talking about water quality assessment to know something more about the different zones in water bodies and the different communities that inhabit these zones. Intuitively you should already expect variations in water quality and variations in community composition between for instance the deeper layers of lake and the surface layer, or between a small mountain spring river and the estuary of the Amazon River.

In very general terms, life in freshwater is governed by:

- high density of the medium
- lack of salt in the medium
- high solubility for inorganic and organic materials
- formation of vertical profiles

Salinity and density and density profiles (stratification) were discussed briefly before. Density stratification very often divides a deep lake into two parts: an upper part with a high water temperature which is called the epilimnion, and a deep part with a lower water temperature which is called the hypolimnion. In between there is often a narrow zone with a sharp temperature decline which is called the thermocline, see figure 4 below for the exact indications.



In a stratified lake the water near the surface is warmer and less dense than the water towards the bottom of the lake. The narrow transition zone between the two is the thermocline; above this lies the warmer less dense water of the epilimnion; the colder, denser water sinks and forms the hypolimnion. This only applies while the water is above 4°C (see p.27)

Figure 4. Temperature profile and associated zonation in a lake.

Especially for plants however, there is another vertical profile which is extremely important, and that is the profile of light intensity. Light is an absolute requirement for photosynthesis. At the water surface, light intensity is obviously at its highest, and then decreases exponentially with depth. The euphotic zone is this zone where light intensity falls between 100 and 1%. For pure water, the euphotic zone would extend to approximately 200m below the water surface but in reality it is often less than 50m and in extreme cases even less than 1m. This decrease in light intensity with depth depends on some water characteristics: the more particles there are for instance in the water, the more quickly light will be absorbed (this is called turbidity, see later in this module). Also the colour of water will have an influence. The compensation plane is the depth at which photosynthesis equals respiration (under the influence of limited light intensities) so there is no net growth or decay at that depth. Below the compensation plane, plant growth < decay, above the compensation plane plant growth > decay.

Solubility of materials is another important factor. Nutrients (N, P, K) for instance dissolve easily in water and therefore also easily reach the plants in the water that need nutrients for growth. Another crucial element is obviously oxygen. Although concentrations in water are a lot lower than concentrations in the air, it can still dissolve in sufficient quantities to be used by fish and other animals for respiration.

3.5.1. Subdivisions and communities in lakes (taken from www.lakeaccess.org)

A typical lake has distinct zones of biological communities linked to the physical structure of the lake (Figure 5). The **littoral zone** is the near shore area where sunlight penetrates all the way to the sediment and allows aquatic plants (macrophytes) to grow. Light levels of about 1% or less of surface values usually define this depth. The 1% light level also defines the **euphotic zone** of the lake, which is the layer from the surface down to the depth where light levels become too low for photosynthesizers. In most lakes, the sunlit euphotic zone occurs within the **epilimnion**.

However, in unusually transparent lakes, photosynthesis may occur well below the **thermocline** into the perennially cold **hypolimnion**. For example, in western Lake Superior near Duluth, MN, USA, summertime algal photosynthesis and growth can persist to depths of at least 25 meters, while the mixed layer, or epilimnion, only extends down to about 10 meters.

The higher plants in the littoral zone - in addition to being a food source and a substrate for algae and invertebrates to attach to - provide a habitat for fish and other organisms that is very different from the open water environment.

The **limnetic zone** also called **pelagic zone** is the open water area where light does not generally penetrate all the way to the bottom. The bottom sediment, known as the **benthic zone**, has a surface layer abundant with organisms. This upper layer of sediments may be mixed by the activity of the benthic organisms that live there, often to a depth of 2-5 cm (several inches) in rich organic sediments. Most of the organisms in the benthic are invertebrates, such as insect larvae (midges, mosquitoes, black flies, etc.) or small crustaceans. Higher plant growth is typically sparse in sandy sediment, because the sand is unstable and nutrient deficient. A rocky bottom has a high diversity of potential habitats offering protection (refuge) from predators, substrate for attached algae (**periphyton** on rocks). A flat mucky bottom offers abundant food for benthic organisms but is less protected and may have a lower diversity of structural habitats, unless it is colonized by higher plants.

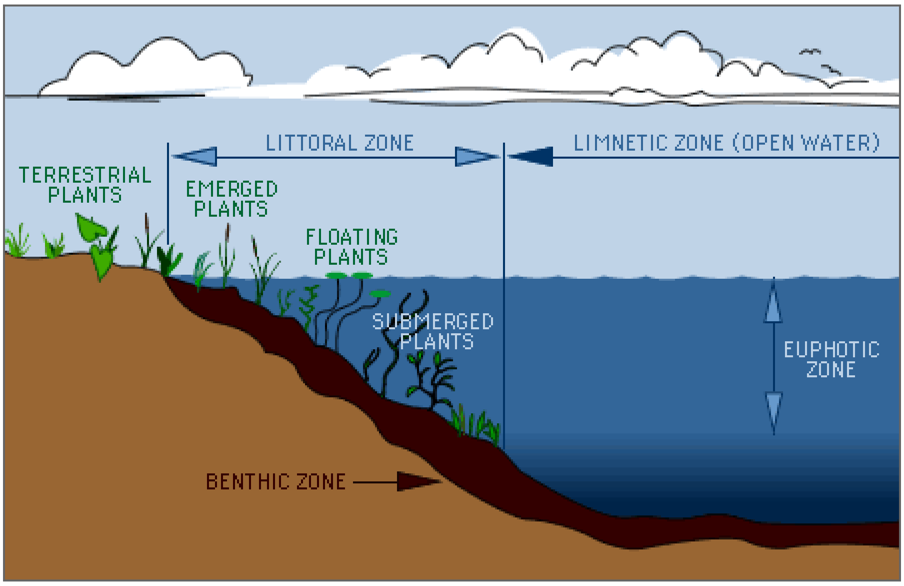


Figure 5. Lake zonation (*Source*: www.lakeaccess.org).

In each of these zones different communities of organisms occur. Table 2 below summarizes them based on two criteria: (1) living in the water or on the bottom and (2) for those living in the water their ability to swim against currents.

Table 2. Lake organisms.

THOSE THAT GO WHERE THEY CHOOSE = **NECTON**		
FISH	**AMPHIBIANS TURTLES**	**LARGER ZOOPLANKTON AND INSECTS**

THOSE THAT GO WHERE THE WATER TAKES THEM	
LIVING THINGS = PLANKTON animals - zooplankton algae - phytoplankton bacteria - bacterioplankton	**DEAD STUFF = DETRITUS** internal - produced within lake external - washed in from watershed

THOSE THAT LIVE ON THE LAKE BOTTOM		
BENTHOS = ANIMALS aquatic insects molluscs - clams, snails other invertebrates - worms, crayfish	**PLANTS** higher plants - macrophytes attached algae - periphyton	**BACTERIA & FUNGI** sewage sludge aufwuchs - mixture of algae, fungi and bacteria

THOSE THAT FLOAT ON THE WATER SURFACE = PLEUSTON
e.g. pond skaters, water hyacinth

3.5.2. Subdivisions and communities in flowing waters

The main difference between rivers and lakes is that the water is flowing, fast or slow, but in any case such that the residence time of water is much lower in a river than in a lake. This has consequences for the colonisation of rivers by organisms. Especially for fast-flowing rivers, it is easy to understand that weak organisms that do not have enough power to fight the currents (such as small planktonic organisms), will be dragged along by the water.

Plankton encountered in rivers is also called **potamoplankton** (from the Greek potamon = river). Its species composition is usually not very different from that of lake plankton, because the river plankton most often originates from still-water regions in the river. River plankton can only reach high concentrations when the residence time > generation time. For example when the doubling time of a particular species is one day and it takes the river several days before discharging in the ocean, then the algae have a change to reproduce. In the opposite case (e.g. doubling time of 3 days, only one day before reaching the ocean), then the algae population has not enough time to grow.

Some algal species have adopted another strategy to colonize rivers, i.e. by attaching themselves to a hard substrate. When you pick a rock out of a river, it is often covered by a greenish, slimy layer. This slime layer consists mostly of algae, but also bacteria and detritus, and is called **periphyton**. By attaching themselves to the hard substrate, and especially on the leeward side, these organisms can resist the drag of the water.

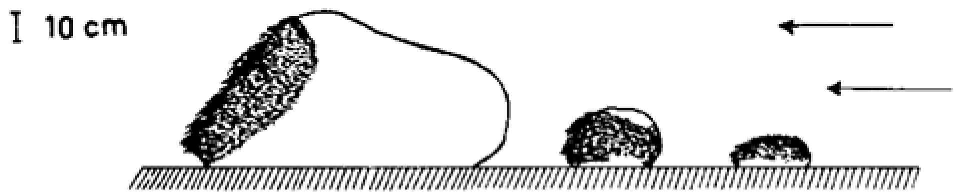


Figure 6. Colonisation of stones of different sizes with *Stigeoclonium* and *Ulothrix* in a stream; arrows show direction of current (from Backhaus, 1967).

Higher vegetation also has different colonization strategies. Aquatic mosses for instance follow the example of periphyton and also attach themselves to a hard substrate. Submerged plants are firmly rooted into the sediment and are very flexible so that they can “bend” themselves according to the flow direction.

Freshwater **benthic macroinvertebrates**, or more simply "**benthos**", are animals without backbones that are larger than 0.5 mm (and therefore by definition visible with the unaided eye). These animals live on rocks, logs, sediment, debris and aquatic plants during some period in their life. The benthos include crustaceans such as crayfish, molluscs such as clams and snails, aquatic worms and the immature forms of aquatic insects such as stonefly and mayfly nymphs.

These animals are widespread in their distribution and can live on all bottom types, even on manmade objects. Many species of benthos are able to move around and expand their distribution by drifting with currents to a new location during the aquatic phase of their life or by flying to a new stream during their terrestrial phase. Most benthic species can be found throughout the year, but the largest numbers occur in the spring just before the reproductive period. In colder months, many species burrow deep within the mud or remain inactive on rock surfaces. Many aquatic insects undergo a complete metamorphosis - the transition from egg to larva to pupa and finally to adult. They remain in the water for most of their lives (typically one month to four years). After becoming adults, the majority of insects live for only a brief time, usually a few hours to a few days, while they locate mates and reproduce.

Benthos is an important part of the food chain, especially for fish. Many invertebrates feed on algae and bacteria, which are on the lower end of the food chain. Some shred and eat leaves and other organic matter that enters the water. Because of their abundance and position as “middlemen” in the aquatic food chain, benthos plays a critical role in the natural flow of energy and nutrients.

These organisms are very often used as indicators of the water quality, as we will see later in Course 3 – Water Quality Monitoring.

Macroinvertebrates adapt themselves to flowing waters by:
- finding shelter against the currents in the sediment, underneath rocks, in between aquatic vegetation etc.
- adapting the body morphology: many aquatic insect larvae have a flattened body which reduces the drag from the water

Fishes finally are also an important community in flowing waters. The flow velocity, water temperature and river bed structure are three important factors that determine the type of fish community present in a certain stretch of a river, as can be seen in the Table 3 below.

Table 3. Fish habitat zones.

Habitats	Description	Biocoenosis
Crenal	Source zone	Crenon
Rhitral	Mountain river or salmonid zone: max. 20 °C - Epirhitral upper zone (upper trout zone) - Metarhitral middle zone (lower trout zone) - Hyporhitral lower zone (grayling zone)	Rhitron
Potamal	Lowland river zone: max. > 20 °C - Epipotamal upper zone (barbel zone) - Metapotamal middle zone (bream zone) - Hypopotamal lower zone (flounder zone)	Potamon
Cryal	Habitats of glacier streams: melting ice	Cryon

Action List for Unit 3
• Look and listen to the powerpoint presentation available under “Lecture”. • Watch the YouTube illustrations given below

YouTube illustrations
• Origin of oceans on Planet Earth http://www.youtube.com/watch?v=bIEv0cd_x4k • Properties of water http://www.youtube.com/watch?v=QH1yphfgfFI • Illustration of the density differences between warm and cool water http://www.youtube.com/watch?v=_Ww6BIy3nc0

Unit 4 – Sustainable Use of Water
On the uses and abuses of water

This topic on the Sustainable Use of Water consists of a powerpoint with audio comments. Three main items are discussed:

1. Water, a matter of life and death
2. Use and abuse of water
3. United Nations GEMS/Water Programme

4.1. Water, a matter of life and death

The human body consists for on average 55-60% of water. Without food you can survive several weeks, without water just a few days (depending on ambient temperatures and activities). So water, after oxygen, is the most crucial substance for human beings. This water should also be of a minimum quality in order to be potable and not cause diseases among those people that drink it.

Yet, more than 1 billion people on the planet lack access to a steady supply of clean water; and this is further exacerbated by the fact that more than 2.4 billion people do not have proper sanitation, which results in further pollution and thus degradation of water resources. As a consequence, more than 250 million people suffer from water-borne diseases such as diarrhoea, schistosomiasis etc., resulting in a death toll of over 2.2 million each year!

Water resources are unequally distributed over the world. Compare for example the arid Middle-East with the humid tropics of the Amazon region. Climate change and population increase are likely to enhance this inequality. In 2003, about 40% of the world's population was living in areas with moderate to high water stress; the projection for 2025 is that 66% of the population will live in such areas.

In reality though, most regions do have enough water to meet everyone's need, but there are many problems in terms of:

- ***Quantity***: unequal/unfair distribution over agricultural, industrial and domestic uses but also inefficient use (e.g. 60% of water used in agriculture is lost due to inefficient irrigation)
- ***Quality***: pollution of water resources thus making them less useful

This unequal distribution of water can be the cause of conflicts between countries or regions in case of transboundary water resources. For example a dam on the upstream part of a river will reduce water availability for downstream users. Just type the keyword "water wars" in any internet search engine to get a wide range of examples.

In fact there are about 263 international basins that are being shared amongst 145 nations. In these international basins live about 40% of the world's population and they contain some 60% of the global freshwater flow. Fortunately real conflicts in these basins are rather rare because of increasing international cooperation. During the last 50 years there have been "only" about 40 acute disputes involving violence, whereas more than 150 treaties were signed to peacefully resolve conflicts.

Some examples of international management of river basins are:
- International Commission for the Protection of the Rhine (http://www.iksr.org/)
- Danube Commission (http://www.danubecom-intern.org/)
- Mekong River Commission (http://www.mrcmekong.org/)
- Amazon Cooperation Treaty Organisation (http://www.otca.org.br/en/)

To focus the attention on all these issues, and to search for sustainable solutions, among others the United Nations has triggered many initiatives:

- UN Water Conference held in Mar del Plata in **1977** agreed that all peoples have the right to have access to drinking water to meet their basic needs.

- The **1986** Declaration on the Right to Development, adopted by the UN General Assembly, includes a commitment that States shall ensure equality of opportunity for all in their access to basic resources.

- The concept of meeting basic water needs was further strengthened during the **1992** Earth Summit in Rio de Janeiro and expanded to include ecological needs.

- In Agenda 21, governments agreed that "in developing and using water resources, priority has to be given to the satisfaction of basic needs and the safeguarding of ecosystems. Beyond these requirements, however, water users should be charged appropriately."

- World Water Day on **22 March** of each year

- **2002** General Comment No. 15 on the implementation of Articles 11 and 12 of the 1966 International Covenant on Economic, Social and Cultural Rights: the Committee noted that "the human right to water is indispensable for leading a life in human dignity. It is a prerequisite for the realization of other human rights."

- **2003** was anounced the International Year of Freshwater

- Millennium Development Goal number 7: Ensure Environmental Sustainability
    - Target 1: Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources
    - Target 2: Reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss
    - Target 3:
      Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation

- ...

Of course many other initiatives exist across continents, regions, countries and cities to protect freshwater resources and ensure equal and sufficient access to water resources for all.

4.2. Uses of water

The reason why the protection of our water resources is so important is among others that they have many functions, not only for man but also for ecosystems. A summary is given below, with some anecdotal information per topic.

Source of drinking water for man and animals**:** Water consumption varies considerable between countries, based on cultural habits but obviously also on water availability.

In Belgium for example, the average consumption is in the order of 120 litres per person per day. Only 2.5% of that volume is really used for drinking and cooking, the rest is used for the shower, laundry machine, toilet flushing etc.

When you think carefully about it, this is not very sustainable: a lot of money is invested to produce potable water of the highest quality, to transport it over large distances, after which is used for ... toilet flushing. Therefore in many countries alternative water resources are increasingly being used for this, such as rainwater.

In economically weaker countries in arid regions, water consumption can be limited to just a few litres per day. Women have to walk sometimes several kilometres to encounter a spring or well or standpost and can only carry home a limited amount of water.

Water consumption can also be influenced by the season. Some countries (such as Australia) have sufficient water during winter time (or wet season), but lack water during summer time (dry season). Restrictions might be put in place, such as an interdiction use drinking water for washing your car, irrigating the lawn etc.
Of course water is also important for animals. We all know the typical pictures of large herds of animals gathering around the water holes in the Serengeti or in Botswana's Okavango Delta, as shown in Figure 7. The most extreme example is of course the camel, which can go for several days without water, but can also drink 100-150 litres at a time when water is available.

Figure 7. Animals gathering around a watering hole during the dry season.

***Bathing water*:** use in bath tubs, showers, public baths etc. Public baths were already used by the ancient Greeks for example in the sixth century BC.

Washing water: water used for doing the laundry, washing your car, cleaning the house etc.

Irrigation of arable land: Archaeological investigation has identified evidence of irrigation in Mesopotamia and Egypt as far back as the 6th millennium BC, where barley was grown in areas where the natural rainfall was insufficient to support such a crop. Since then of course the practice has spread to practically every country around the globe. As an illustration, some country-specific information cited in Wikipedia is given below:

- *Australia*: Water consumption by the agriculture industry was 12,191 gigalitres (GL) in 2004-05, accounting for 65% of total water consumption in Australia during that period. Since 2005 climatic conditions and reduced allocations have caused the total water consumed to decline by 30% from the 2004-2005 figure down to 8,521 GL in 2006-2007. The total gross value of irrigated agricultural production in 2004-05 was $AUD 9,076 million. Common crops produced using irrigation include rice, cotton, canola, sugar, various fruits and other tree crops and pasture, hay and grain for use in beef and dairy production.
- *Colombia*: Colombia has approximately 900,000 hectares of irrigated agriculture, which represents 16.3% of all agricultural land. Most of this is simple gravity irrigation.
- *Saudi Arabia*: Centre Pivot Irrigation in Saudi Arabia is typical of many isolated irrigation projects scattered throughout the arid and hyper-arid regions of the Earth. Fossil water is mined from depths as great as 1 km. This water is however not being replenished under current climatic conditions and projects, therefore, will have limited production as the reservoirs are drained. Other sources are: (1) a network of dams trapping seasonal floods; (2) Desalination; (3) treated urban and industrial run-off. These efforts collectively have helped transform vast tracts of the desert into fertile farmland. Land under cultivation has grown from under 1600 km^2 in 1976 to more than 32,000 km^2 in 1993.

***Fisheries and aquaculture*:** According to the FAO, in 2004, the total world production of fisheries was 140.5 million tonnes of which aquaculture contributed 45.5 million tonnes or about 32% of the total world production. The growth rate of worldwide aquaculture has been sustained and rapid, averaging about 8 percent per annum for over thirty years, while the take from wild fisheries has been essentially flat for the last decade. A well-known exception has been the cod fishing in Newfoundland (Canada) which due to intense overfishing has completely collapsed in the 1990s.

***Industrial and municipal supplies*:** Water is obviously needed during various industrial production processes, directly for instance for the production of drinks, but also indirectly for instance for rinsing recycled glass bottles, rinsing machines etc.

***Cooling water*:** a particular form of industrial use, used for cooling machinery but also used in power plants for cooling the generated steam etc.

Production of hydro-electricity: Hydropower is by definition power that is derived from the force or energy of moving water. Most commonly known are the hydropower dams that are widely used for electricity production. At present, the Three Gorges dam on the Yangtze river in China is the largest hydro-electric power station in the world. Once completed (~2011), it will generate 22,500 MW. There are however also other forms of hydropower, such as water wheels (Figure 8) and water mills which were used already centuries ago, tidal power plant that make use of the sea level difference at low

and high tide, and wave power turbines harnessing power from ocean surface wave motion (Figure 9).
Worldwide, hydroelectricity supplied an estimated 816 GW in 2005. This was approximately 20% of the world's electricity, and accounted for about 88% of electricity from renewable sources. The “champion” in this field is Norway, where more than 98% of all electricity is generated by hydropower.

Figure 8. Water wheel

Figure 9. Wave power turbines

***Navigation and transport*:** transport of goods and people by ship

Fishing and body-contact recreation: use of water for recreational purposes, such as swimming, diving, fishing, surfing, ...

Municipal and industrial waste(water) disposal: Many water bodies have been and are still used for disposing of solid waste and wastewater. The impact of this will be an important topic of further study during this course.

Feeding of surface and ground water: As we have seen before (see Hydrological Cycle), precipitation can infiltrate into the soil and replenish the groundwater, and/or can gather to form small streams and rivers or lakes. Where precipitation is scarce, sometimes other sources are used for groundwater replenishment, such as treated domestic wastewater.

***Carrier of ecosystems and biodiversity*:** Both freshwater and marine water support a vast range of fauna and flora. Here truly the credo “Water is Life” becomes true. Some of the most magnificent ecosystems on Earth can be found under water, i.e. the coral reefs. The largest one is the Great Barrier Reef off the coast of Queensland, Australia.

***Aesthetic value*:** Many pieces of art are centred on water, including paintings, sculptures, music pieces, etc.

4.3. Abuses of water

As we have just discussed, water bodies have been and are still often used to dispose of solid and liquid waste products, causing pollution.

Pollution of the aquatic environment means the introduction by man, directly or indirectly, of substances or energy which result in such deleterious effects as:

- harm to living resources
- hazards to human health
- hindrance to aquatic activities including fishing
- impairment of water quality with respect to its use in agricultural, industrial and often economic activities
- reduction of amenities

Different substances result in different types of pollution. A short overview is given in the table below, details will be discussed later during the course. Obviously different types of pollutants can occur at the same time and interactions between different types of pollution are a real possibility.

Table 4. Pollutants and related pollution types.

Type of pollutant	Type of pollution
Nutrients (N, P, K)	Eutrophication
Organic matter	Saprobiphication
Heavy metals	Toxicity
Pesticides, herbicides, ...	Toxicity
Pharmaceuticals	Toxicity
Microorganisms	Pathogenic diseases
Acid rain	Acidification
Salts	Salinization
Nuclear waste	Radioactivity
Inert substances	Turbidity
Heat	Heat pollution

4.4. United Nations GEMS/Water Programme

The Global Environmental Monitoring System (GEMS) was initiated in 1974 as a means of promoting and coordinating the collection of environmental data nationally, regionally, and globally. While GEMS aims at assisting governments to develop monitoring systems for their own use, its other objectives are to improve the validity and comparability of environmental data globally and to provide for the collection and assessment of environmental data. Within GEMS, major programs were developed for climate-related monitoring, monitoring of natural resources, monitoring of the oceans, and health-related monitoring.

As part of the latter group of projects, the global water quality monitoring project, briefly GEMS/Water, was established in 1976 jointly by WHO, UNESCO, WMO and UNEP. The objectives of the project were:

- to collaborate with Member States in the establishment of new water monitoring systems and to strengthen existing ones;
- to improve the validity and comparability of water quality data within and between Member States, and

- to assess the incidence and long-term trends of water pollution by selected persistent and hazardous substances.

The global water quality monitoring project is based on the active participation of Member States which routinely monitor the quality of their water resources at selected locations and provide the data for global syntheses and dissemination. Wherever possible, the stations for the global network were selected from existing national or local networks. Where such stations did not exist, new ones were established. Priority was given to water bodies (rivers, lakes and groundwater aquifers) which are major sources of water supply for municipalities, irrigation, livestock, and selected industries. A number of stations were also included to monitor international rivers and lakes, rivers discharging into ocean and seas, and water bodies not yet affected by man's activities (baseline stations).

The target for the first stage of the project (1977-1981) was the establishment of a skeleton network of approximately 300 monitoring stations on rivers, lakes, and in groundwater aquifers. At that time it was estimated that a total of about 1200 stations might ultimately be required to achieve representative global coverage. Measurements of water quality variables at these stations include natural as well as anthropogenic constituents.

The years 1977 to 1979 were used as a preparatory phase during which time guidelines were prepared, specialists were trained in the different regions, and national, regional and global centres were established. National institutions were identified in agreement with the governments and designated as the focal points for GEMS/WATER activities within each country. In addition, laboratories were designated to conduct the routine sampling and analysis at the selected monitoring sites.

GEMS/Water is implemented by UNEP, Nairobi and WHO, Geneva, with the assistance of WHO Regional Offices. Technical support is provided by two WHO regional centres for environmental health. In addition, institutes have been designated as regional reference laboratories for implementing the analytical quality assurance component of the project. The Global Data Centre is located at the Canada Centre for Inland Waters, Burlington, Canada, which was designated both a WHO Collaborating Centre on Surface and Ground Water Quality and a UNEP GEMS Collaborating Centre for Freshwater Monitoring and Assessment. The Danish Institute for the Water Environment (VKI) in Horsholm, Denmark served as the global centre of analytical quality control. UNESCO participated in the field of training and measurement methodology. WMO has concentrated on network design criteria and hydrological monitoring methods.

Action List for Unit 4

- Look and listen to the powerpoint presentation available under “Lecture”.

- Have a look at the GEMS/Water website: www.gemswater.org

- Go to the GEMS/Water Statistics website: www.gemstat.org
    - Use the Search Data option in the left menu to find your own country (or a neighbouring one if your own country is not participating in GEMS)
    - Use “Search for Summary Data on Country Level”
    - Select one of the physico-chemical parameters (Temperature, Dissolved Oxygen, pH, ...)
    - Report the summary data to your fellow participants via the discussion platform (Reply to thread **WQA-2**).

- Do the self-evaluation test of Course 1 (yes/no and multiple-choice questions) which is available in the Course Conclusion.