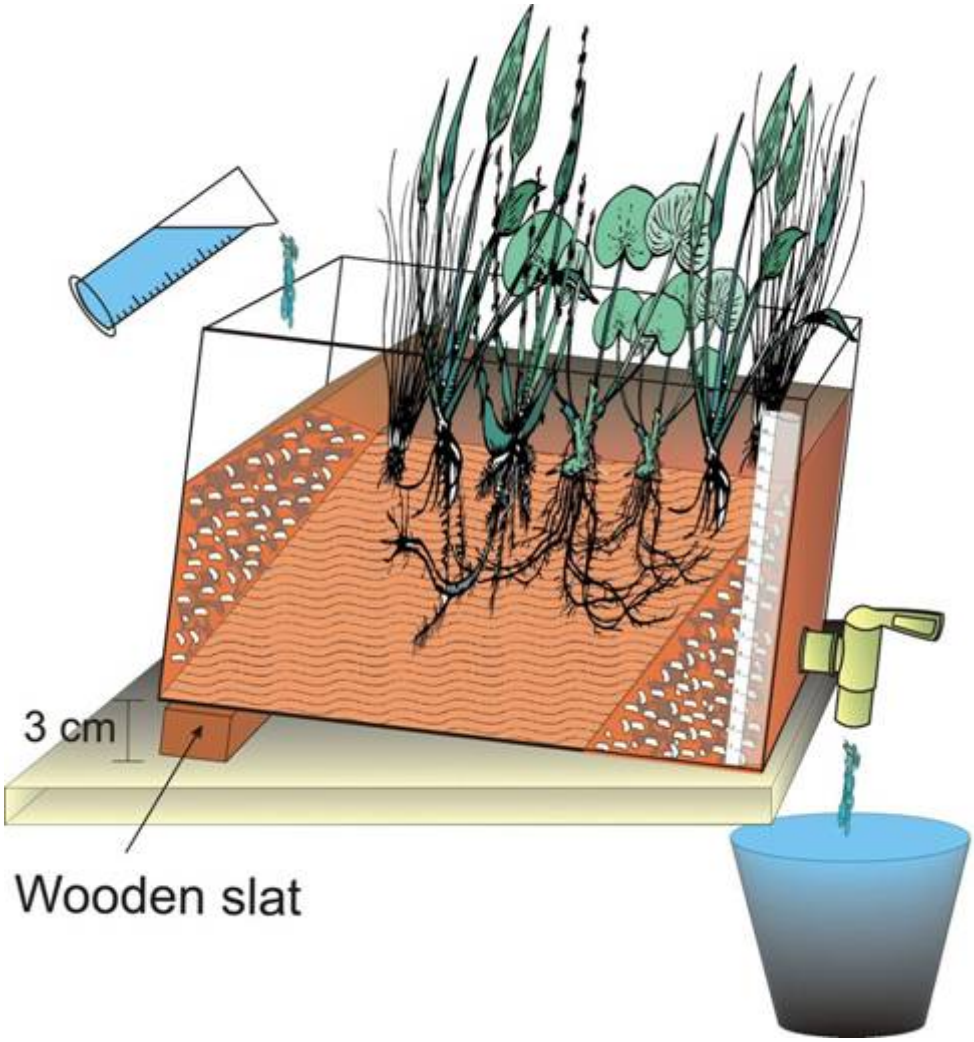
Primary school

Teaching manual

“Constructed Wetland”



BDZ

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

SIXTH FRAMEWORK PROGRAMME

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Contract Number 021028

WasteWaterResource

Play with Water: Introducing Ecological Engineering to Primary Schools to Increase Interest and Understanding of Natural Science

Instrument: Coordination Action (CA)

Thematic priority: Science and Society; Science education and careers 2004; FP6-2004-Science-and-society-11

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CONTENT

Figures

Tables

1 SUMMARY OF TEACHING UNIT PLAN "CONSTRUCTED WETLAND"

1.1 Grade level

Primary school children, class 3-5, age 9-11

1.2 Duration

The teaching unit is programmed for 6 school hours plus two half day activities. The unit consist on 17 individual activities which duration range from some minutes to ½ day.

1.3 Main teaching goals

The teaching unit plan "Constructed wetland" is developed around a classroom model of a constructed wetland, with the special focus on the fact that constructed wetlands represent an attractive alternative for water recycling especially in arid regions with water scarcity.

The main teaching goals of the unit are to improve students':

- sensitivity and attitudes toward environmental issues, moral reasoning, and values clarification.
- environmentally responsible behaviour, motivation to participate in environmental improvement and protection.
- ecological and environmental knowledge.
- sensitivity towards socio-political and gender issues dealing with problems caused by water scarcity.
- engineering skills by setting up a classroom model of a constructed wetland.
- knowledge of using principles of nature in environmental engineering.

As a general reflection of the teaching unit, pupils study possibilities of using wastewater for both, water reuse and the contained nutrients for agricultural purposes in decentralized systems. They understand that wastewater is a resource; especially in regions with water shortage and that constructed wetlands are a modern and ecological treatment technology that fit in well with the environment and can provide habitats for plants and animals.

1.4 General description of the teaching unit “Constructed Wetland”

Within the present manual, the teaching unit is presented as individual lessons, despite the fact that an individual lesson plan with title, behavioural objectives, and specific outcomes within certain time constraints may often be inappropriate and specific objectives and timelines may only be considered at unit plan level. The splitting-up into individual lessons has been chosen because lesson plans are more fluid to be presented within a manual such as this and have the advantage of giving a clear example to the reader of how individual lessons may be structured and developed. Additionally, the proposed structure with individual lessons gives a better overview of the topics and facilitates modifying components and replacing or adding activities.

The presented lessons and activities are arranged around the constructed wetland technology as one possibility for closing local water cycles, treating wastewater and emerging sludge to an extent where water and nutrients can be reused for agriculture with minimal losses. Table 1 summarizes the individual lessons of the teaching unit plan “Constructed Wetland”.

In an introductory teaching lesson, the pupils will understand that water runs in cycles. The pupils learn that water exists in different physical states and that it evaporates and condensates as part of the natural water cycle. A small experiment and pictures demonstrate the cycle and give pupils an understanding of the self-purification of water.

In the second lesson “Water distribution and use”, pupils learn about the global distribution of water and the scarcity of fresh water. They should investigate their own relationship with water. They should become aware of the amounts of water they use in their homes every day and learn to appreciate that fresh water is a scarce source in other regions of the world.

The third lesson gives students an insight into the principles of centralized wastewater treatment and that water becomes polluted from use. They should realize where it goes when it leaves their homes and that it has to be cleaned in order to not contaminate rivers and other surface water bodies.

In the fourth lesson, students compare “our” typical situation in Northern Europe with the situation of countries where water shortage exists. Through a role-play pupils are introduced to and learn to identify problems faced by populations living under these conditions. Students learn that water reuse represents a possibility to save water and to make life more healthy and comfortable.

The fifth lesson deals with the construction of the wetland classroom model. Students build the model themselves and handle technical equipment. Thus, they will get an insight into the practical work of engineers and scientists. Students get an understanding of the set-up of a constructed wetland and the way it works, they realize that constructed wetlands are a modern ecological technology, where principles of nature are used to clean wastewater.

Table 1 Summary of teaching unit plan "Constructed Wetland"

Lesson No.	Name of lesson	Main teaching goal	Duration	No. of activities	Main teaching method
1	The water cycle	Pupils shall understand the global water cycle as a closed system. They learn that on its way in the cycle water becomes polluted and cleaned through natural processes.	45 min	2	Experiment, reading, writing
2	Water distribution and use	Students develop care and concern for water as a scarce resource and an awareness of the need to preserve and conserve water resources and get a feeling for different water amounts.	45 min	2	Demonstration, calculation,
3	Where is our wastewater going	Students get an insight into the principles of centralized wastewater treatment and that water becomes polluted from use. They should realize where it goes when it leaves their homes and that it has to be cleaned in order to not contaminate rivers.	½ day	1	Reading, writing, field trip
4	Water a rare good	Pupils become aware that there are areas in the world with water shortage and of the consequences of insufficient water supply and sanitation. Students will learn the basics of environmental decision making related to water reuse.	45 min	2	Reading, role play, calculation
5	Constructing a wetland	Pupils learn that constructed wetlands are a modern technology, where principles of nature are used to clean wastewater. The pupils will build the model themselves and handle technical equipment. Thus, they will get an insight into the practical work of engineers and scientists.	45 min	1	Experiment, model, reading
6	Water analysis	Students learn how to define the term "clean water", and "quality guidelines". They understand the principles of water analysis to measure different substances in water.	90 min	2	Record data, experiment, reading, writing
8	Wastewater rally	The rally is the final highlight of the teaching unit. The concept is based on the previous classroom activities and its planned to deepen their knowledge	½ day (165 min)	7	Short story, quiz, action game, role play, experimental construction work

While the wetland model has to be maintained and periodically fed with wastewater as an addition to the class exercise, a lesson on principles of analytical methods gives an insight into defining the term "clean water", "water quality guidelines" and supports the understanding of principles of water analysis.

In the last lesson of the teaching unit, pupils measure the cleaning capacities of "their" constructed filter columns and wetland models. With the tool of analytical methods, they should get an idea of the principles of filtration, sedimentation, adsorption and degradation and will get familiar with the different mechanisms of how wetlands function.

2 LESSON 1: WATER CYCLE

The amount of water on the earth is constant. Water neither gets lost nor emerges from outside the planet. It runs in continuous cycles.

If water travels, it must also get very dirty on the way. Why is it then, that we can always find clean water? This lesson will provide some answers.

2.1 Grade level

Class: 3-5

2.2 Duration

Preparation time: 25 min

Activity time: 45 min

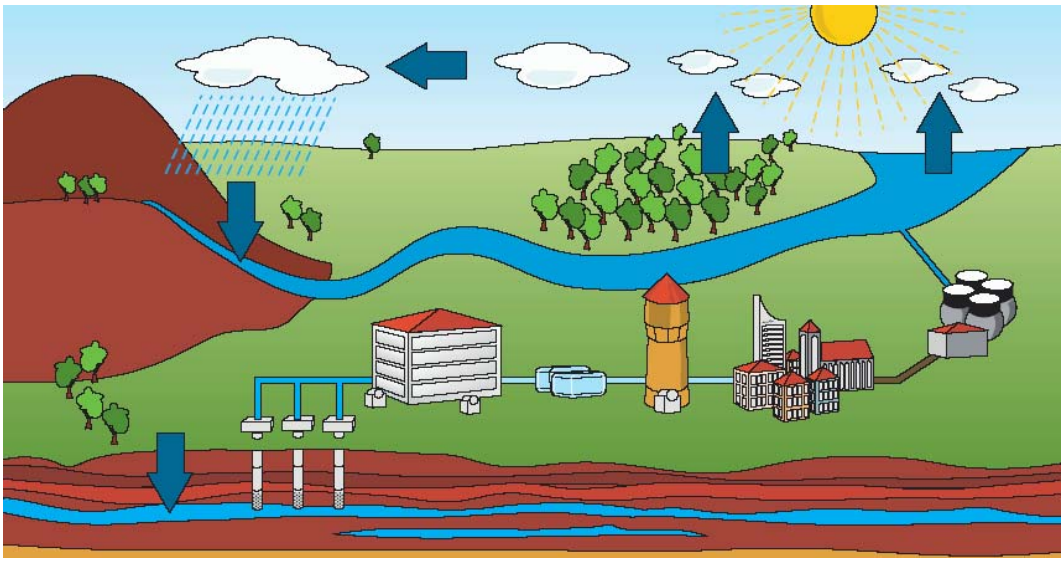
2.3 Teaching goals

- Students will understand the global water cycle as a closed system. They learn that on its way in the cycle water becomes polluted and cleaned through natural processes.
- The lesson will improve students' ecological knowledge and understanding of major ecological concepts.

2.4 Lead-in to lesson: What has water already experienced?

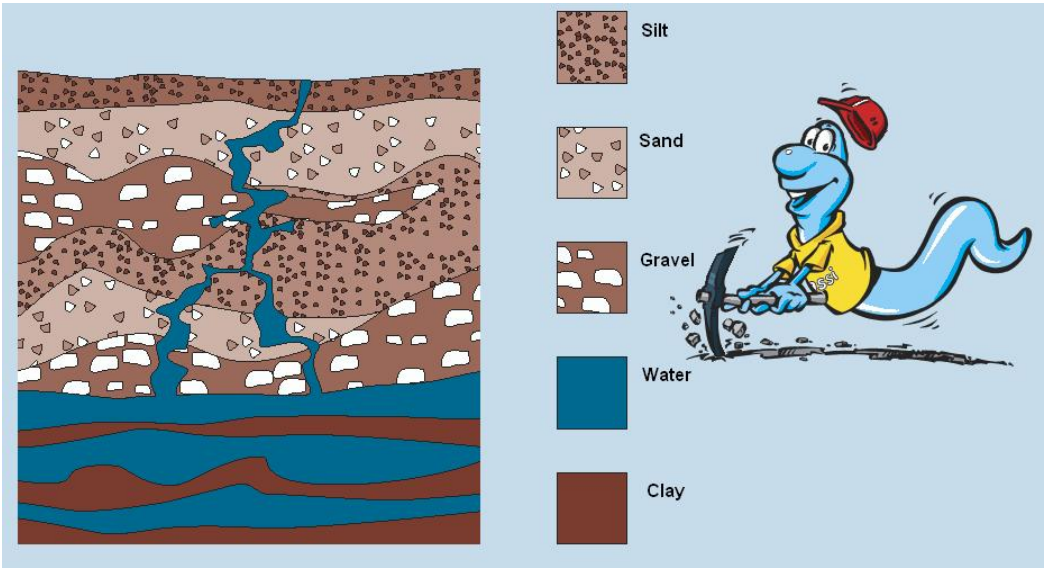
The global water cycle is driven by the sun. The sun warms up the surface of the earth and the water evaporates especially above the oceans and big lakes and rises up into the atmosphere. In high altitudes water cools down, condensates and forms clouds. The clouds move with the wind and eventually the water comes back down as rain, fog, snow or hail.

More than half of the fallen rain evaporates; the rest percolates into the ground and becomes groundwater, which flows very slowly underground until it resurfaces as wells. Both, evaporation and infiltration are mechanisms to clean water. When water becomes dirty from particles and dissolved substances, evaporation separates solid and dissolved compounds from the water. The same is true for a healthy soil that also cleans water. The soil is made up of many different layers, such as sand, gravel and clay. On its way through the ground, the water runs through all these layers and particles contained in the water are held back. The soil filters the water (see also lesson: Constructing a wetland). Other substances are "eaten" by bacteria that live in the soil.



(illustration provided by Kommunale Wasserwerke Leipzig GmbH)

Figure 1 The water cycle



(illustration provided by Kommunale Wasserwerke Leipzig GmbH)

Figure 2 Soil filter

2.5 Activity A: The water journey

A drop of water must have experienced many things. This activity gives students the possibility to discover the journey of a water drop at micro and macro scale.

Start activity putting a drop of water into a glass of water placed on the front desk. Take one of the proposed playing cards (next figure) and explain that students have to imagine a journey of this water drop from the front desk to the destination given by the card, e.g. “cow”. From the “cow” a new playing card gives the next destination of the water drop and the pupils should imagine how the drop reaches this destination.

The Water Journey

Examples of playing cards

Figure 3 **Worksheet: The water journey**

2.6 Activity B: What has water already experienced?

This activity shall help the students to understand that the global water cycle is a closed system and that water can change its physical state from vapor to liquid. The experiment demonstrates that water is a component of living organisms, like a plant and that the evaporation and soil percolation are natural cleaning processes for water.

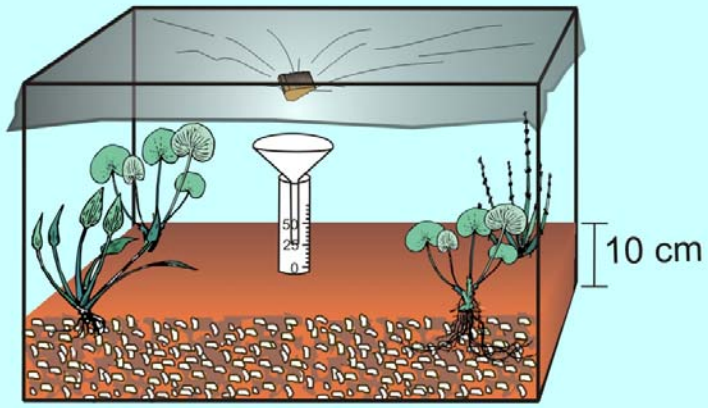
Divide the class into groups and hand out the material and the worksheet. Have each group carefully construct the water cycle model.

After the boxes are placed close to the classroom window, water will condensate on the walls an the plastic film that covers the box. Ask students to explain this observation and the water movement in the closed box. Challenge the pupils to compare the water cycle in the box with processes in nature (rain, evaporation, clouds, ground water, rivers, lakes etc). Continue the experiment over several days and let pupils measure the “rainfall” accumulated in the test tube.

Table 2 Material: What has water already experienced (Evapotranspiration)?

Material per group	Cost (EUR)
1 Transparent plastic box (20 L)	3 - 4
3-5 Stones	0
5L Sand or expanded clay (LICA)	1 - 2
1 Plastic bucket 10 liter	0.5 – 2.5
1L Soil	0
Plants: e.g. indoor plants	0
1 Transparent plastic film	0.5 - 1
1 Measuring cup 1 liter	1
1Test tube (5 cm high, with mL markings)	2 - 3
1 Funnel (5 cm)	0.5
1 Roll adhesive tape	1 - 2
Additional equipment (scissors, pen, sponge, towel, paper, etc)	0
Artificial wastewater (see lesson: Wastewater Analysis)	0

What has water already experienced?



Group name: ……..…… **Date:** ……

1) Fill the plastic box with 10 cm of sand or expanded clay (LICA)

2) Remove some soil of the plant roots and implant them in the corners of the box. The plants shouldn't be taller than the height of the box

3) Place the test tube in the middle of the box, put the funnel into the tube and pour some water (500 mL) into the box. Thereafter pour 1 L of artificial wastewater (see lesson: Water analysis) into the box

4) Close the box with the plastic film, stretch it and close it tightly with the adhesive tape.

5) Gently push down the film and place one ore more stones in center of the film. The film should form a funnel above the test tube.

Figure 4 **Worksheet: What has water already experienced? (Evapotranspiration)**

What has water already experienced?

Group name: ……. **Date: …….**

Date	Time	Water level in the tube (mL)	Observation	Pupil's name

Figure 5 **Datasheet: What has water already experienced? (Evapotranspiration)**

2.7 Photo documentation evapotranspiration

Test tube and funnel

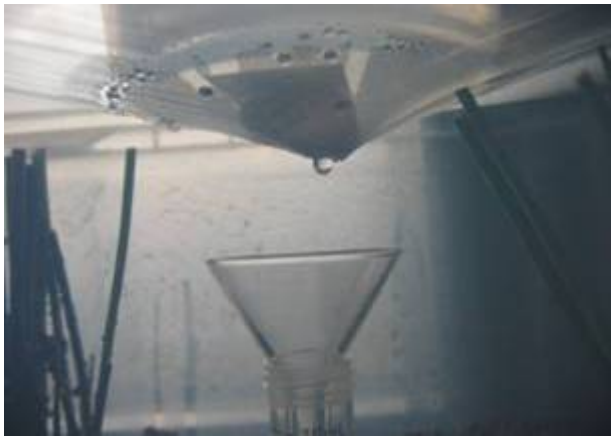
Covering the box

Pouring wastewater

Preparing the place for the stones

The ready system

Water (rain) harvesting



2.8 Evaluation of lesson: What has water already experienced?

Students should fill out the water cycle diagram

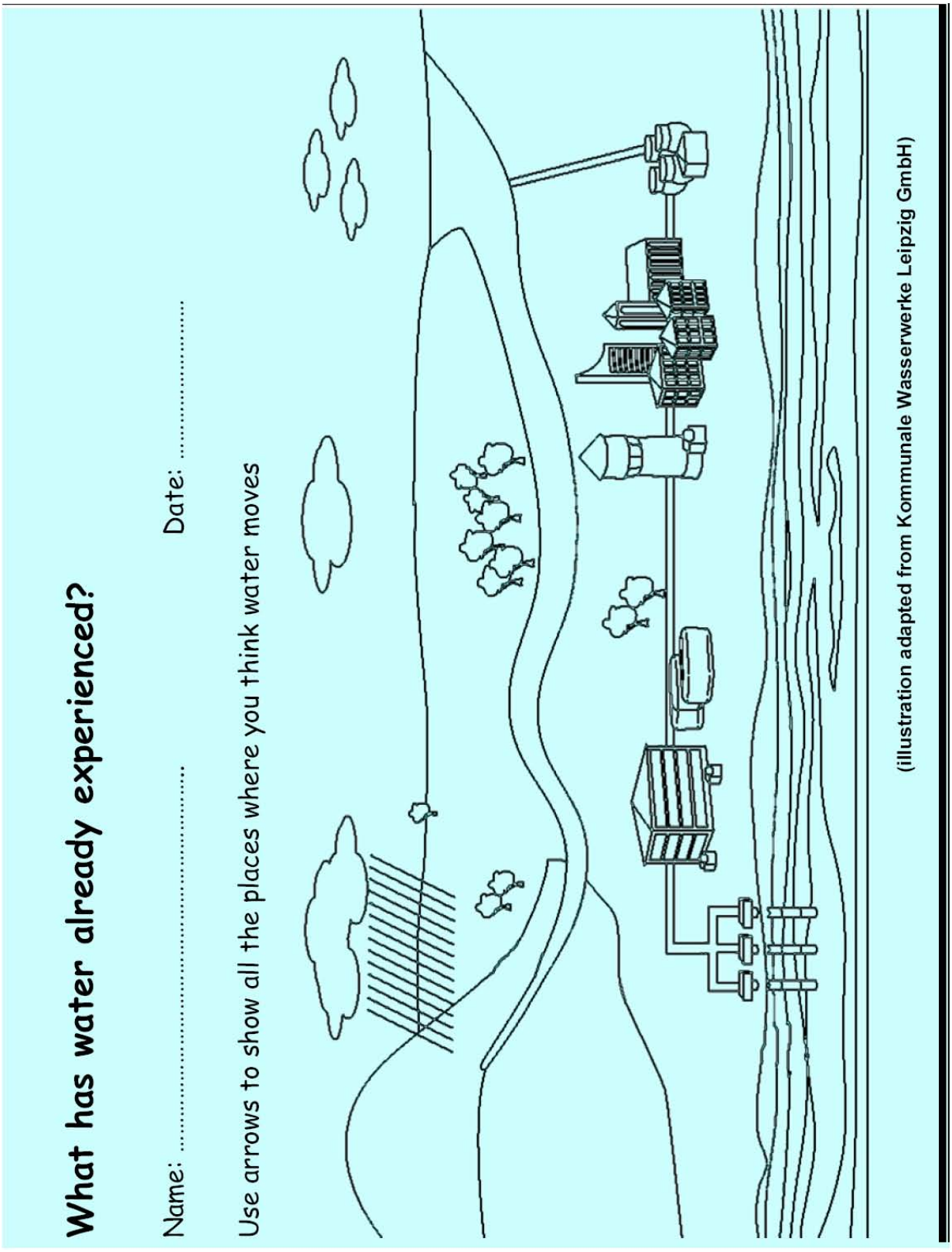


Figure 6 **Evaluation worksheet: Water cycle**

3 LESSON 2: WATER DISTRIBUTION AND USE

3.1 Grade level

Class 3-5

3.2 Duration

Preparation time	Part A: 15 min,	part B: 5 min
Activity time	Part A: 20 min,	part B: 25 min

3.3 Teaching goals

Students develop care and concern for water as a scarce resource and an awareness of the need to preserve and conserve water resources. They get a feeling for different water amounts.

3.4 Lead-in to lesson part A: The drop of potable fresh water

Pictures taken from space show the earth as a blue planet. Two thirds of the earth's surface is covered with water. The amount of water on our planet is estimated to be around 1,46 billion km^3. However, the greatest part of that (97%) is saltwater in the oceans.

The portion of fresh water, which can be used by humans, is only 3% of the total amount. Most of that fresh water is stored as ice at the poles and as glaciers and groundwater. Only a very small portion can be found in rivers, lakes and streams.

Northern Europe is rich in fresh water. It is situated in a temperate climate, where it rains or snows all year round.

There are areas in the world, where it rains almost every day, like in rain forests, but there are also very dry areas, for example, in Southern Europe, Asia and Africa. The fresh water is distributed very unevenly in the world. In many countries of Africa and Asia, water is very scarce. In some areas of Africa, people only have about 1-2 buckets of water at their disposal per day. In Europe, we use approximately 13 buckets per person.

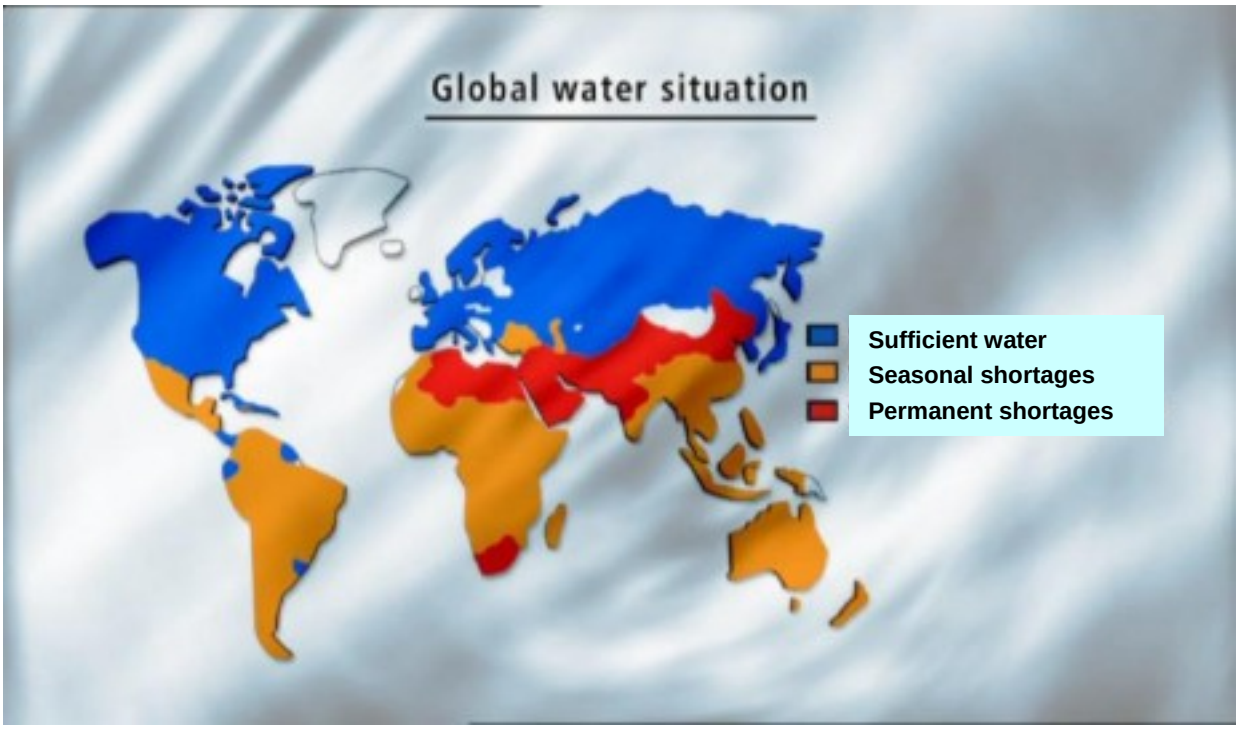


Figure 7 **Global water situation**

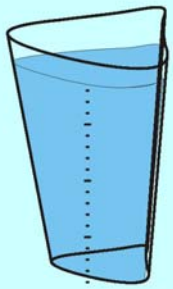
3.5 Activity A: The drop of potable fresh water

This teacher demonstration shall help to illustrate how little of the total amount of water on earth can be used by humans:

Table 3 **Material: The drop of potable fresh water**

Material per group	Amount	Unit	Cost (EUR)
Graduated beaker	1	1 L	0.5 - 2
Water	1	L	0
Map or globe	1	Piece	1 - 2
Salt	5	Spoon	0
Graduated cylinder	1	100 mL	1 - 2
Graduated cylinder	1	10 mL	1 - 2
Glass or plastic pipette or eyedropper	1	10 mL	0.1 - 0.5
Small bucket or plate	1	-	0.1 - 0.5

A drop of potable freshwater



Salt water
975 mL

Glaciers and
icecaps 20 mL

Unavailable
fresh water
5 mL

Potable
fresh water
1 drop

1. Put one liter (1000 mL) of water on the front desk and ask the students to imagine this as the total amount of water on earth.

2. Ask the students to indicate on a globe or a map where most of the water on earth is located. Pour 25 mL of the water into a graduate cylinder. Explain that this represents the global freshwater resource. Put salt into the remaining 975 mL to simulate water found in oceans, unsuitable for human consumption.

3. Ask students if all the freshwater is available as drinking water. Explain that almost 80% of the fresh water is frozen in ice caps and glaciers.

4. Pour 5 mL of freshwater into a small graduated cylinder. This amount represents the freshwater resource on earth that is not frozen. Explain that not all of this water is available as drinking water (ground water, pollution, remote areas).

5. Using the pipette to placed only 1 drop of water into a small bucket or plate. This drop represents the clean fresh water on the planet that can be used as drinking water.

6. Discuss this demonstration with the pupils, considering pollution, personal use, population growth or climatic change.

Figure 8 **Worksheet: A drop of potable fresh water**

3.6 Lead-in to lesson part B: How much water do we use?

Water is essential for life. About 75% of the human body weight is water. You can survive for up to two weeks without food but you would die within three days without water to drink.

Water is needed for all aspects of life. Worldwide, most water (about 70%) is used in agriculture for irrigation.

Brainstorm how we use water. Have each pupil to find an example of when water is being used. Ask them to give the different examples categories. Here are some suggestions:

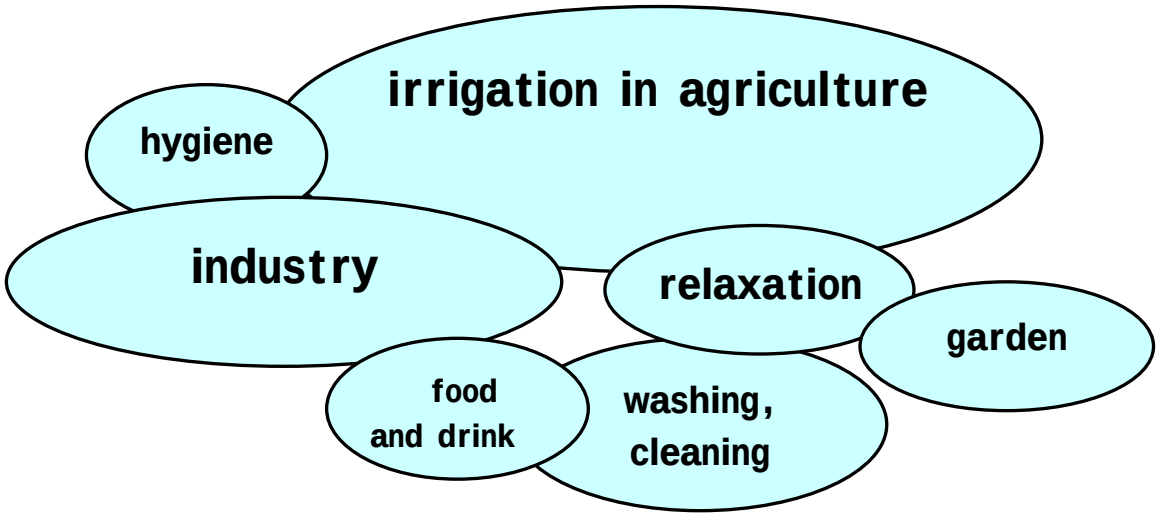


Figure 9 What do we use water for?

3.7 Activity B: How much water do we use?

In many areas in Europe, the average person uses about 120 to 130 L of water per day.

Divide the class into groups and ask to make lists, when they use water. They should also estimate how much water they use every time they use the toilet, wash their hands etc.

Food and Drink	3-6 L
Cleaning	3-10 L
Dishwashing	5-15 L
Shower	15 L per minute
Washing clothes	20-50 L
Toilet	20-50L
Bath	150 L

(illustration adapted from Kommunale Wasserwerke Leipzig GmbH)

Figure 10 Average amounts of water a person uses per day

3.8 Evaluation of lesson: Water distribution and use

Ask students to note down for one day every time they use water at home and let them calculate how much water that amounts to in total.

Ask the children to calculate: How much water will you use for flushing the toilet in your life?

Remember, for toilet flushing you use 20-50 L per day. One year has 365 days. Suppose you will grow about 80 years old.

4 LESSON 3: WHERE IS OUR WASTEWATER GOING?

4.1 Grade level

Class 3-5

4.2 Duration

Preparation time 2-4 h

Activity time 1/2 day

4.3 Teaching goals

Pupils learn that water becomes polluted from use and has to be cleaned. They should realise where water goes when it leaves our homes and understand the principles of wastewater treatment in a conventional sewage treatment plant.

4.4 Lead-in to lesson: Where is our wastewater going?

We seldom think about where the water we use in our home or school goes to, once it disappears down the drain. In most cities, wastewater normally passes on from the home into a network of sewer pipes, which lead to a wastewater treatment plant. Here, wastewater is cleaned by mechanical, biological, and chemical processes before it is discharged into surface water, generally into rivers. To prevent contamination of rivers and other water bodies, water that is discharged directly from wastewater treatment facilities must meet stringent federal and state standards.

The simplest form of wastewater treatment (preliminary treatment) involves filtration where the water passes through a bar screen. The bar screen retains large objects, such as paper, textiles, wood and plastic. Then the water flows into a grit chamber.

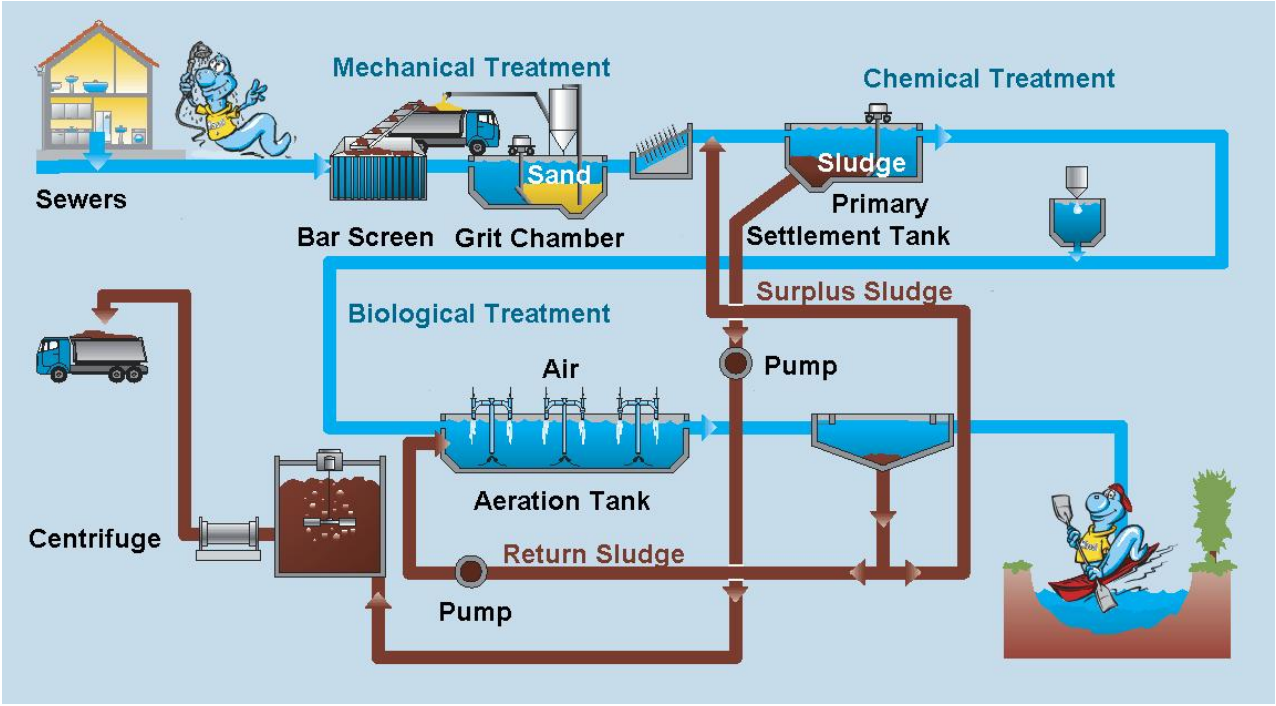
In the grit chamber the velocity of the flow is decreased to allow the heavier materials, such as sand and gravel, to settle to the bottom of the tank. In the primary settling tank, floatable solids, such as grease and oil are skimmed from the top of the tank. The sludge that settles to the bottom of the tank is pumped out and treated further.

Primary treatment removes about 50% of the pollutants. The material that was not removed by primary treatment goes to secondary treatment

In secondary treatment, the water flows into aeration tanks, where organic compounds are removed from the water. In most cases, air is pumped into the water to create an environment in

which bacteria can live. Bacteria eat the pollutants in the water which could not be removed in the first step. In the final sedimentation or settling tank they sink to the bottom and are pumped out. Some substances, such as phosphates, are eliminated from the water by chemicals. The cleaned water flows back into a river.

Explain the concept of centralised wastewater treatment and the principals of wastewater treatment using photos or videos. To prepare the treatment plant visit give additional information on the site, schedule of the excursion and site-specific rules.



(illustration provided by Kommunale Wasserwerke Leipzig GmbH)

Figure 11 Schematic drawing of a conventional sewage treatment plan

4.5 Activity: Where is our wastewater going?

Tell students their mission is to identify the path of their wastewater starting in the toilet and ending at the riverside where treated wastewater is discharged.

The field trip starts with a visit to the toilet, where pupils flush down a colored sheet of paper. Depending on local conditions, students should identify the drain and follow it to the first maintenance hole where students should pay attention to the manhole cover to identify the flow of the drained water. (Caution: choose a manhole where no problem with traffic exists).

The trip should continue following the sewer pipelines to the local treatment plant where students should identify the different treatment processes. This visit may be combined with some stops on

the way giving students the opportunity to identify typical wastewater related installations (manhole covers, inside views of sewers, open canals etc.) and get an impression of the journey of the paper flushed down the toilet. Sensitize students for the big technical and financial efforts necessary to construct and maintain an underground sewer system.

At the treatment plant pupils will meet the site operator and he will explain the installation and treatment procedure. Encourage students to ask for functionalities and structural elements of the plant. The operator might demonstrate how to take a sample of the inflow and outlet of the plant to demonstrate the treatment result of the plant. He even may explain some facts about the chemical analysis of the real wastewater before and after the treatment.

4.6 Evaluation of lesson: Where is our wastewater going?

Using a street map, let students calculate the total length of sewer lines of their town quarter or municipality.

5 LESSON 4: WATER A RARE GOOD

5.1 Grade level

Class 3-5

5.2 Duration

Preparation time	Part A: 25 min,	part B: 15 min
Activity time	Part A: 25 min,	part B: 20 min

5.3 Teaching goals

The pupils become aware that there are areas in the world with water shortage and of the consequences of insufficient water supply and sanitation. Students will learn the basics of environmental decision making related to water reuse.
The lesson should improve pupils' sociopolitical knowledge and the awareness of economic, social, political and ecological interdependence.

5.4 Lead-in to lesson part A: Make your life healthy and comfortable

More than every third human on earth does not have enough clean water to drink and many have no sanitation at all. Dirty water can contain bacteria and viruses, which cause diseases. Diarrhoea is a symptom of many diseases. Diarrhoeal diseases are the most deadly of the water and sanitation diseases. Over two million people die every year – mostly children under the age of five. Bacteria or viruses are spread through poor water, contaminated food, the unsanitary disposal of human waste and poor hygiene. The three most deadly diarrhoeal diseases are cholera, bacillary dysentery and typhoid. All of these diseases can be prevented by improving access to clean water and sanitation so that bacteria cannot re-enter water supplies and through hygiene education so that communities practice safe hygiene.
Some general hygiene rules are:

- using latrines,
- keeping food and water clean,
- cooking food thoroughly,
- washing and peeling fruit and vegetables,
- washing hands with soap before touching food

However, often these rules are not easy to be followed up. In poor countries, people have to collect water from the nearest stream or well, that already might be dirty. Another problem is the

amount of available water. In some regions in the world, people do not have more than 10L per day.

The living conditions in arid zones might be illustrated by showing some pictures or a short video clip.

5.5 Activity A: Make your life healthy and comfortable

Have pupil work in small groups. Provide each group with a bucket of water, jars and the working sheet.

Tell the pupils to remember how much water we use in Europe every day (12 buckets). Ask the pupils to imagine life with only one bucket of water per day. Have groups making a decision on what they would use the water for. Explain that humans need 3-4 L of water per day only as drinking water and food. Remember the sanitary aspects and tell them they should distribute the water to make their life healthy and comfortable. Explain that each jar represents one of the uses given in the work sheet. Tell them that they should use the measuring cup to distribute the water. Ask students to imagine the main differences of living with little or much water. Ask the representatives of each group to present their results.

Discuss the results, compare conditions in dry regions with pupils' actual life, and discuss the health aspects. One outcome of the discussion may be that the amount of water is not sufficient to live in a healthy way. Ask if students have ideas where to get more water from.

Table 4 Material: Make your life healthy and comfortable

Material per group	Cost (EUR)
1 Plastic bucket (10 L)	0.5 – 2.5
10 L Water	0
5 Jars (5 L)	3 - 8
Measuring cup (500 mL)	0.5 - 1
Marker (water resistant)	1 - 2
Cleaning equipment (sponge, towel or paper, etc.)	0
Worksheet	0.1

How to make your life healthy and comfortable with only

10 L

of water per day?

Group name: ……

Imagine each member of your family can use only 10 litres (one bucket) of water per day.
You have to decide how to use your bucket of water.

You have 5 options:

1. Drinking and food ……..**Liters**

2. Toilet ……..**Liters**

3. Washing clothes ……..**Liters**

4. Cleaning, Shower ……..**Liters**

5. Dishwashing ……..**Liters**

Write the 5 uses on the 5 small buckets and distribute the water with the measuring cup. Then fill out this form together.

What do you think makes life different having only 10 L of water available?

……

……

……

……

Figure 12 Worksheet: Make your life healthy and comfortable

5.6 Lead-in to lesson part B: How to get out more from one drop of water

The domestic (household) water consumption only makes a small proportion of overall water need of rural populations in developing countries. The average human drinks about four liters a day. But producing the same person's daily food can take more than 500 liters of water. To produce wheat, it takes between 715 and 750 litres of water for 1 kilogram of dry grain. For maize, the figure is between 540 and 630 L/kg. For soybean, 1650 to 2200 L/kg and for 1 kg dry rice, 1550 litres of water is required. That is why the production of food and fiber crops claims the biggest share of freshwater withdrawn from natural sources for human use. In some areas of the world, water consumption for tourism has even exceeded the use of water in agriculture during the last years.

Consumption of freshwater for crop production (irrigation) and tourism therefore drastically reduces the available amount of drinking water for the population.

The reuse of wastewater can partly solve the problem. Small-scale solutions, possible to arrange on very limited area are known e.g. in Botswana where they are called "Sanitas wall". The system is based on application of washing water from households for growing crops for consumption.

Reuse of wastewater has the additional advantage that the content of nutrients in excreta of one person is sufficient to produce enough grain necessary to maintain life of just one person. The main problem using wastewater for food production is the hygienic aspect. Therefore wastewater has to be treated before reusing it for irrigation.

5.7 Activity B: How to get out more from one drop of water?

Have students to read the short story about the girl Palesa in Africa. Tell them to watch for ways how she and her family use water. Ask to underline each way they find. Ask for identifying ways of having more drinking water in the house. Make them see that reuse of wastewater reduces the water needed for the garden and thereby more clean water is left for the family. Discuss if it is also possible to use the wastewater from the toilet. Ask for ideas how to reuse the water.

5.8 Evaluation of lesson: Water a rare good

Have students to calculate the minimum amount of water they need for leading a comfortable life. Ask what type of wastewater that they produce could easily be reused within their homes.

How to get out more from on drop of water

This is a story about a girl named Palesa (pah-LAY-sah), whose name means "flower." Palesa lives in a rural village in Lesotho, Africa. Read about a day in her life.

Using Water Every Day

Early in the morning, Palesa wakes up and goes to fetch water at the water tank in her village. There her family is allowed to pick up 5 buckets of water per day. She drinks a cup and returns carrying the heavy water on her head. When she returns fifteen minutes later, her mother has already started a fire in the hearth. Mapalesa, her mother, heats up some water so Palesa can take a sponge bath before going to school. She boils water in another pot so she can stir in maize meal and make “papa” for breakfast. Palesa eats fast so she won't be late for school. She hands her empty bowl to her mother and runs down the hill to catch up with her friends.

Now Mapalesa begins her morning chores. First, she goes to the water tank again. She has to make two trips, to fetch enough water for the small garden and washing. Then she waters the plants and washes the dishes. She pours also the used water on the spinach in her garden since she does not want to waste anything. After this, she prepares a soup with some meat and sweeps the house. In the meantime, Palesa comes home from school.

Quickly Palesa changes out of her school uniform and washes it in a small plastic basin: it must be dry by tomorrow! The water she used for washing she now uses to water her tomatoes in the garden. Then she goes to fetch 2 more buckets of water, one for the toilet and one for the cattle. At sundown, her brother comes home from tending the cattle all day in the fields. Palesa helps Thabo (TAH-boh), whose name means "happiness." She brings water for the two cows now safe in the stone kraal by their home.

After dinner, Mapalesa gives her children a special treat: a steaming mug of tea with lots of sugar in it. They drink the tea while sitting around the fire in the center of the one room house. They are glad to be warm on this chilly fall evening. Palesa wishes her father were there to tell them stories, but he is far away in South Africa, working in the mines. Like many fathers in Lesotho, he won't be home until Christmas, and that is a long time away.

Modified from Coverdell 2006

Figure 13 Worksheet: How to get out more from one drop of water

6 LESSON: CONSTRUCTING A WETLAND

A constructed wetland is a nature-orientated technology to treat wastewater. The following construction manual allows pupils to build their own treatment plant. Pupils get an understanding of the set-up of a constructed wetland and the way it works. They realize that constructed wetlands are a modern ecological technology, where principles of nature are used to clean wastewater. They conduct experiments to follow up the "cleaning capacity" of their treatment plant.

6.1 Grade level

Class 3-5

6.2 Duration

Preparation time: 3-5 hours (incl. shopping)

Activity time: 45 min

6.3 Teaching goals

- The pupils learn that constructed wetlands are a simple technology, where principles of nature are used to clean wastewater (soil filter, degradation, plant take-up)
- The pupils will get an understanding of the set-up of a constructed wetland and the way it works.
- The pupils will build the model themselves and handle technical equipment. Thus, they will get an insight into the practical work of engineers and scientists.

6.4 Lead-in to lesson: Constructing a wetland

Wetlands are found in a variety of places along rivers and lakes, in low-lying woods or fields and in man-made low spots where water is collected. Wetlands have qualities of both, aquatic and terrestrial ecosystems or in other words: wetlands are neither lakes nor rivers but also not solid ground.

Wetlands are defined as areas where soil is saturated with water for all parts of the year. The sources of this water may be surface or ground water, rainfall or even melting ice.

The ability of wetlands to store water makes them valuable as water source and habitat for a variety of plants and animals. Wetlands are biologically very active, an important factor for the self-purification capacity of the water cycle. Constructed wetlands are a modern and nature-orientated technology to treat wastewater that uses the natural potential of soil and natural water

bodies to clean water. The processes occurring in soil and rivers and streams are called “self-purification”. They are mainly due to tiny organisms (mostly bacteria and other unicellular organisms) that live in the soil or the water and have the ability to degrade pollutants and turn them into harmless substances. The soil matrix also functions as filter and the plants growing in the soil provide perfect growing conditions for bacteria, which remove dirt particles and pathogens in the water. The bacteria need oxygen to survive, which they receive directly from the atmosphere and via the roots of the plants.

These natural processes in wetlands are the same as those used in conventional wastewater treatment plants as presented in the lesson “Where is our wastewater going?”.

Constructed wetlands are the result of ecological engineering and represent an alternative technology to conventional sewage works. The technology is able to eliminate a variety of wastewater components (excess nutrients, toxic substances, and pathogens) and generate treated water, which can be reused. Because of their relatively low construction and operation costs, these eco-technology systems have a broad application spectrum covering even rural regions with low infrastructure and countries with low economic resources.

Show pupils pictures, slides or a short video clip of wetlands and constructed wetland. Ask students to describe why these areas are called wetlands and what differences exist between wetlands and traditional wastewater treatment systems.

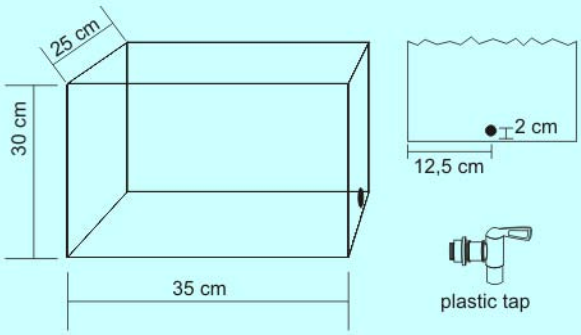
6.5 Activity: Constructing a wetland

Table 5 Material: Constructing a wetland

Material for 1 model	Cost (EUR)
Wetland model	
1 transparent plastic box 35*23*31cm	2 - 5
15 kg Gravel 4-16mm	2 - 10
25 litre expanded clay (LECA) 1-4 mm	2 - 10
2 plastic buckets 10 litre	1 - 5
25 cm transparent plastic hose, diameter 20mm	0.5 - 1
1 plastic water tap (with screw and nut)	3 - 5
1 measuring cup 1 litre	1 - 2
Wooden slat	0.5 - 1
1 measuring tape (tailor)	0.5 - 1
1 roll adhesive tape	1 - 2
Plants: e.g. indoor plants, Umbrella Papyrus (*Cyperus alternifolius), rush (Juncus spec.)*	0 - 10
additional equipment (scissors, pen, sponge, towel, paper, etc)	0

Most materials are available in pet markets and markets for home improvement and construction products.

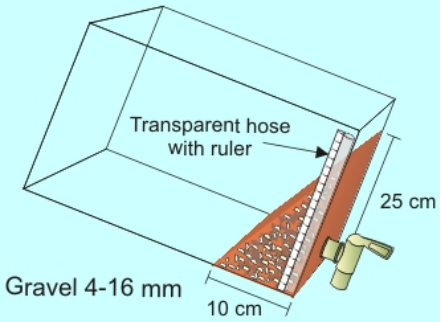
Wetland model



1) Pierce 1 hole of the size of the tap into the narrow side of the box. The hole should be located centrally and 2 cm above the bottom. (should be done by the teacher).

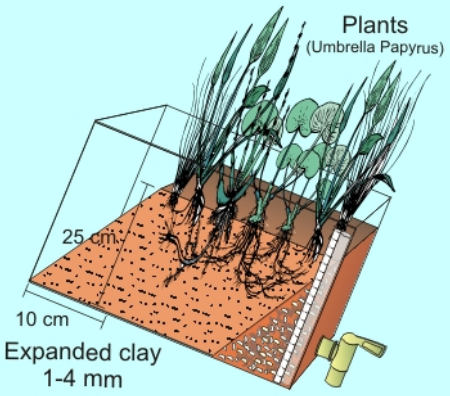
2) Install the plastic tap and tightly fix the plastic nut. Make sure that the connection is waterproof.

3) Fix the transparent plastic hose in a corner of the box and the measuring tape (ruler) next to the plastic hose at the outside of the box.

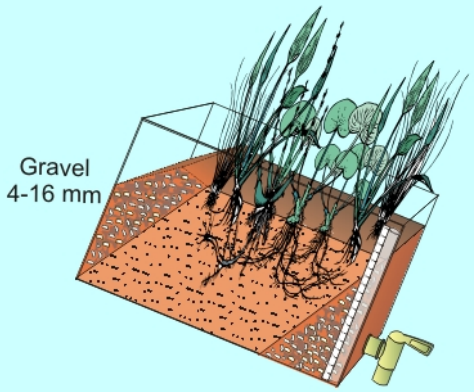


4) Lift one end of the box as shown in the figure above and fill in first gravel, then the expanded clay.

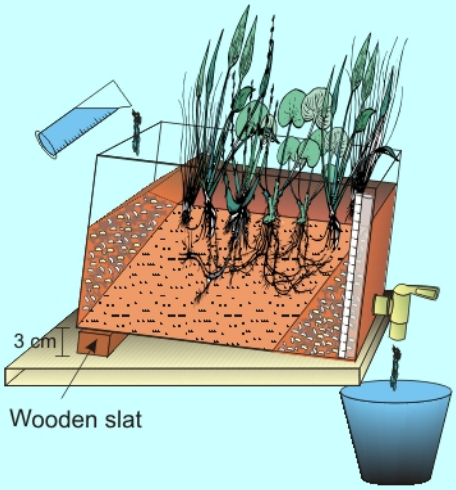
5) Remove the pots from the plants and carefully take away most of the soil from the roots. Implant the indoor plants (pupils brought along) or the Umbrella Papyrus in the expanded clay (be careful with roots).



6) Finally fill in gravel and form the inlet (inflow filter) of the treatment plant



7) Place the wetland at a safe place, put the bucket below the outlet and use the measuring cup to slowly pour approximately 5 L of water to the inlet of the system. If the outlet water is turbid, repeat the procedure until the out-flowing water is clear.



8) Pour 1 L of artificial wastewater into the system and fill up with clean water to a water level of 10 cm.

9) Take a water sample once a week and "analyze" the water quality as described in the experiment "WATER ANALYSIS"

10) After taking the water sample, pour once a week 1 L of artificial wastewater into the system and fill up with clean water to a water level of 10 cm.

Figure 14 Worksheet: Students instruction sheet "Constructing a wetland"

6.6 Evaluation of lesson: Constructing a wetland

Have students maintain the constructed models by defining a maintenance plan with responsibilities that makes each student feel responsible for the well-being of plants and preserve technical equipment (Preparation of wastewater, application of wastewater).

6.7 Photo documentation “Constructing a wetland”

Fixing the water tap and the transparent plastic hose


Filling the box


Planting the plants in the plant


Washing the system

Pouring wastewater and taking the first sample

7 LESSON 6: WASTEWATER ANALYSIS

The experiments demonstrated here can either be conducted as an individual lesson or, once established, as routine analysis for measuring the performance of the constructed wetland model or filter systems (see: Constructing a Wetland), which has to be maintained and periodically feed with "artificial wastewater". This lesson aims to explain the concepts of "clean water" and "water quality guidelines" and supports to understand the principles of water analysis.

7.1 Grade level

Class 3-5

7.2 Duration

Preparation time 1-2 hours (incl. shopping), 15 min (routine analysis)

Activity time Part A: 55 min (lesson) or 15 min (routine analysis), Part B: 35 min

7.3 Teaching goals

- Students learn how to define the term “clean water” and “quality guidelines”.
- They should understand the principles of water analysis to measure different substances in water.

7.4 Lead-in to lesson: Wastewater analysis

Ask pupils to remember the lesson "Water distribution and use" and ask how and what makes water dirty?
Explain which substances are found in household (domestic) wastewater.

- Easily degradable organic substances, such as human and animal faeces and food scraps.
- Nutrients, such as phosphate, nitrate, ammonium.
- Pathogens, like bacteria, viruses, protozoa.
- Long lasting organic chemicals, such as artificially produced substances, from disinfectants, paints, solvents etc..
- Heavy metals, salts

Discuss who defines if water is clean or not. Ask how they can trust that tap water or bottled drinking water is really clean?

Mention, that water discharged from wastewater treatment facilities, must meet stringent federal and state standards.

In order to decide if the treatment of wastewater was successful it is necessary to measure the concentration of pollutants before and after treatment. For this purpose many sets of analytical methods exist that normally are carried out in specialized water analysis laboratories. Each country has defined water quality guidelines that give clear limit concentrations (how much can be tolerated) for more than a hundred different substances. Theses limits vary with different uses of the water. For example, the limits for drinking water are much lower than for water used in agriculture.

7.5 Activity: Wastewater analysis

Divide the class into groups and hand out the set of material to each group.

Tell students their mission is to “measure” wastewater quality. Show students the materials needed and explain them the general measuring procedures and necessary safety rules. As reference, also provide a sample of drinking water for each group and 2 data sheets (one for wastewater, the other for drinking water)

Table 6 Material: Wastewater analysis

Material per group	**Cost (EUR)**
Wastewater ingredients (2L)	
1 Transparent water jug with tap (2 L)	1 - 2
1 Spoon	0.5
Water (approx. 10L)	0
Toilet paper (6 sheets)	0
Milk (4 spoons)	0
Liquid soap (shampoo) (1 spoon)	0
Vinegar (1 spoon)	0
Vegetable oil (1 spoon)	0
Coffee ground (4 spoons)	0
Testing material	
2 Transparent plastic beakers (200 mL)	0.5 - 1
1 Discharge sieve	0.5 - 1
2 stripes of brown packing paper (3x15cm)	0
1 Straw	0
2 pH-strips (pH 2-10) and color table	0.5
2 data sheets	0
1 Pen	
Set of cleaning equipment (sponge, towel, paper, etc)	

Materials are available in supermarkets and pet markets.

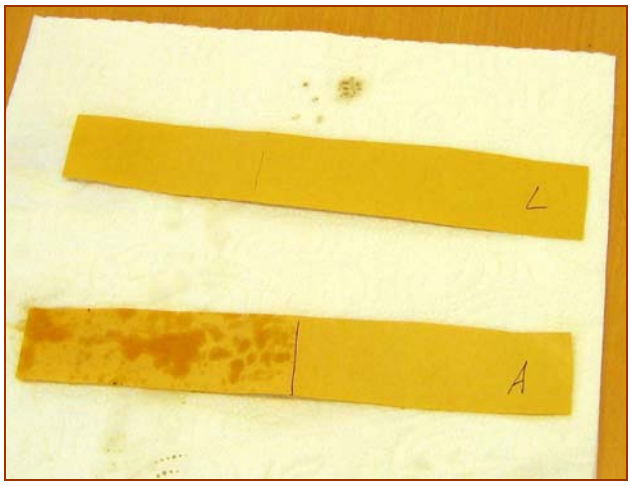
- Preparation of artificial wastewater: Fill the water jug with 2 L of tap water. Rip the toilet paper into small pieces and put them together with the other ingredients (liquid soap, vinegar, vegetable oil, coffee ground and milk) in the jug. Close the jug tightly and shake the water well. The artificial wastewater is now ready. Ask pupils if they consider the mixture as wastewater and why. Discuss their criteria.

(Caution: Be aware that pupils should never taste the water and ingredients!)

- **Big particles:** Gently shake the jug with wastewater. Have a look and decide if you see big particles (paper) or not, if so, mark the "Yes". Now put the sieve on the plastic beaker and fill it half with wastewater. How many big particles are retained? (No big particles = 0 points, Bottom nearly full = 1 point, Sieve nearly full = 2 points.)

- **Oil:** Take a strip of brown packing paper (3 cm x 15 cm) put the name of the sample (tap water, wastewater or treated water) on top and dip it into the water sample. Wait for 1 minute and take it out. Place it on a sheet of cleaning paper. After the paper is dry (10-20 min) decide if there are oil marks (darker than the paper colour) remaining on the paper, if so, mark the "Yes".

Estimate the area of the oil marks. (No oil marks= 0 point, Less than half the size of the paper= 1 point, More than half the size of the paper = 2 points)



- **Smell:** Decide if the water sample smells different from tap water. If yes, mark the "Yes" and write down the type of smell and intensity. Distinguish between light, medium and intensive smell. (Light=0 points. Medium=1 point. Intensive=2 points)

- **Colour:** This is a visibility test. Decide if the water is coloured. If yes, mark the "Yes" and write down the colour and intensity. Distinguish between lightly coloured, medium and intensively coloured. (Light=0 points. Medium=1 point. Intensive=2 points)

- **Small particles:** Gently mix your water sample with a spoon. Have a look and decide if you see particles or not, if so, mark the "Yes". Take out a spoon full of water and estimate the number of particles you see in the spoon. (Less than 10 = 0 points. More than 10 = 1 point. More than 100 = 2 points)

- **Turbidity:** Take the beaker with the water sample, look through the beaker and decide if the water is turbid or not. If so, mark the "Yes". Take a spoon, put the spoon behind the beaker and try to perceive it, looking only through the beaker. If you see the spoon the water sample is clear or slightly turbid, in case you don't see it the water is medium turbid. Take the spoon and put it into the centre of the beaker. If you still don t see the spoon through the beaker, the wastewater sample is very turbid. (Clear = 0 points, Medium turbid = 1 point, Very turbid = 2 points.)

- **Detergent:** One pupil deeply takes in breath and very gently breathes out into the water sample using the straw. Do this only once, it shouldn't be repeated. Observe if there is foam, if so, mark the "Yes". Decide if there is little, medium or much foam. If the wastewater already has foam, only consider the newly formed foam. (Little foam= 0 points. Medium foam = 1 point. A lot of foam = 2 points)

- **Acid (pH):** Use test strip and dip it into the wastewater sample. Immediately return it and compare the colour with the reference. Write down the value of pH. If pH is below 5, the water contains acids and you can mark the "Yes". (pH 5 to 8 = 0 points, pH 4 to 5 = 1 point, pH 4 or below = 2 points)

- Ask groups to count how often they marked the "Yes" and sum the “pollution points” of the wastewater and the drinking water reference sample. Compare the quality of different water samples (tap water, wastewater or treated wastewater).

Water analysis: Test results

Group name: ……. **Date:** …….

Type of water: …….

Parameter	Quality	Quantity	Pollution Points
Big particles	Yes No	Amount of big particles: No big particles = 0 points, Bottom nearly full = 1 point, Sieve nearly full = 2 points	
Oil	Yes No	Surface area of oil marks: No oil marks= 0 point, Less than half the size of the paper= 1 point, More than half the size of the paper = 2 points	
Smell	Yes No	Smell: Light=0 points Medium=1 point, Intensive=2 points	
Colour	Yes No	Colour: Light=0 points Medium=1 point, Intensive=2 points	
Small particles	Yes No	No. of small particles: Less than 10 = 0 points. More than 10 = 1 point. More than 100 = 2 points	
Turbidity	Yes No	Clear = 0 points, Medium turbid = 1 point, Very turbid = 2 points.	
Detergents (Foam forming)	Yes No	Little foam= 0 points Medium foam = 1 point A lot of foam = 2 points	
Acids (pH)	Yes No	pH 5 to 8 = 0 points, pH 4 to 5 = 1 point, pH 4 or below = 2 points	
Number of X for Yes:		**Number of points:**	

Figure 15 **Worksheet: Wastewater analysis: Test results**

7.6 Alternative Activity B: Constructing a Filter

Additionally to the wetland or as continuation of the lesson “Wastewater analysis”, a filter system can be easily constructed by using plastic bottles and different filling materials.

Table 7 Material: Constructing a filter system

Material per group	Cost (EUR)
1 Plastic bottle (1.5 L)	0
1Measuring cup (1 L)	0.5 - 1
1 Plastic bucket (10 L)	0.5 - 2.5
1 Transparent plastic beaker (200 mL)	0.5
Gravel (2 – 5 cm) (0,5 kg)	0.5 - 1
Gravel (0.2 – 1 cm) (0,5 kg)	0.5 - 1
Straw (1 L)	0 - 1
Sand (0 – 1 mm) (0,5 kg)	0 - 1
Woodchips (1L)	0 - 1
Loamy soil (0.5 kg)	0
Cleaning equipment (sponge, towel, paper, etc)	0

Divide the class into groups and hand out the set of material to each group and tell them that this will be a competence between the groups and their mission is to:

Construct the best filter for cleaning wastewater!

Show students the materials and a sample of the “artificial wastewater” that should be cleaned. Explain that they can build layers from different materials, compact them or that they even can mix materials to create new filtration properties.

The general requirements for the filter are:

- The materials should not be washed out
- The water should flow through the filter
- The particles and other substances in the wastewater should be removed

After washing the filter with clear water (approx. 2 L), let pupils pour very slowly 0.5 L of the artificial wastewater on top of the filter. Collect the filtrates of each bottle in the transparent beaker marked with the name of the group.

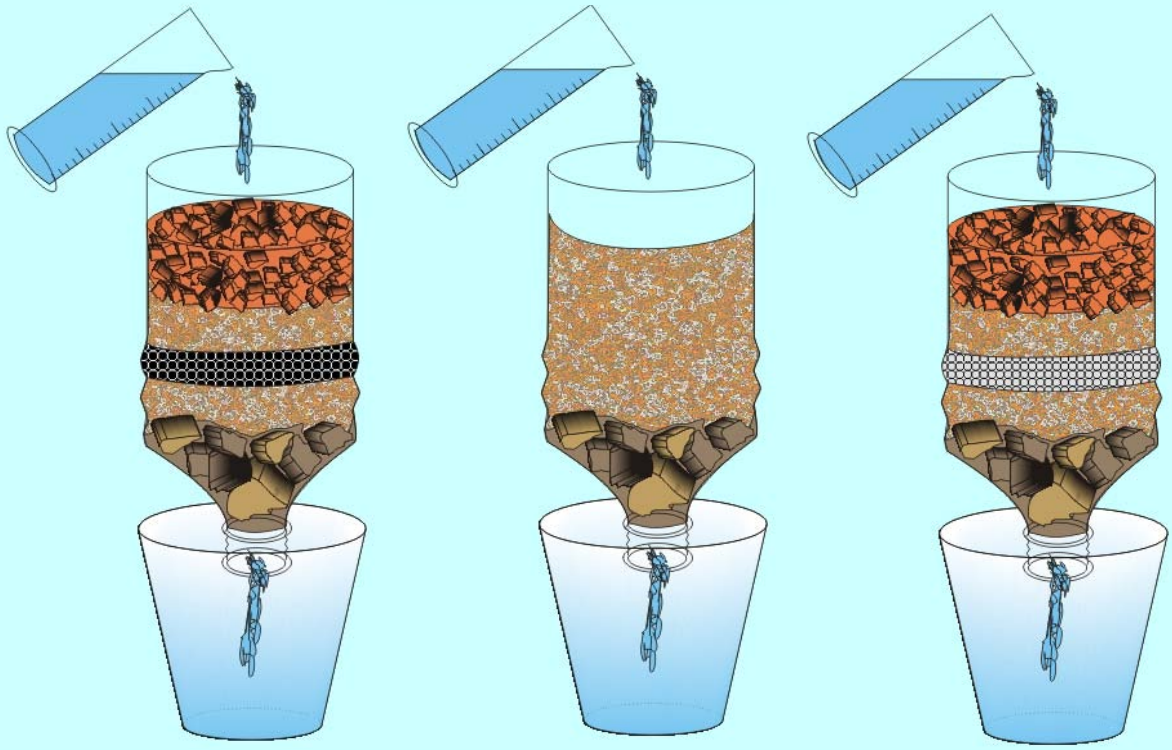
Have students analyse the filtered wastewater samples using the tests described above.

Make each group representative demonstrating the results. Discuss what filter system functioned best. Discuss functionalities of each filter and compare with the wetland model. Ask students which filter material or mechanism is best suitable for what kind of wastewater component.

Filter system

1) Carefully cut out the bottom of the plastic bottle (perhaps teacher's task).

2) Prepare your soil filter, using different filling materials.



3) Wash the filters with clear water until the outlet is clear.

4) Pour 200 mL of artificial wastewater onto the filter and collect the out flowing water.

5) "Analyze" the water quality as described in the lesson "WATER ANALYSIS"

Figure 16 Worksheet: Constructing a filter system

7.7 Evaluation of lesson: Wastewater analysis

Ask students to find out what the main parameters are, that define drinking water quality in their country and if in the past years, any of these substances presented a problem.

This task needs certain teacher input such as local information hotlines or internet pages.

8 "WASTE WATER RALLY"

The "wastewater rally" consists of a competition between different students groups that collect points by solving individual tasks and get the opportunity to win a price. It is favourable to apply the rally with more than one class and to have at least 2 supervisors per class on hand. The activities can be realized outdoor or inside of the school building. The principal elements of this activity also may easily be transfered to other related teaching units.

8.1 Grade level

Class 3-5

8.2 Duration

Preparation time 2-3 days

The schedule of the rally for one run (1/2 day) is given in the following table:

Table 8 Schedule of the „Wastewater Rally"

Exercise	Time (min)
Introduction	15
Closing the water cycle	25
Distribution of water on earth	30
Break	20
Water a rare good	20
Wastewater treatment	35
Awards ceremony	20

Table 9 Material: "Wastewater Rally"

General	Cost (EUR)		3. Water a rare good	Cost (EUR)
2 Scibers	5.00		10 plastic buckets 5L	10.00
1 Package adhesive pads	4.00		6 cloth hoops	0.00
1 Roll adhesive tape	1.50		50 m rope	3.00
2 Marker (water resistant)	3.00		50 Water filled ballons	2.50
2 Scissors	0.00		2 Plastic tubs	10.00
2 Flipcharts	0.00			
2 Exhibition walls	0.00		**4. Wastewater treatment**	
10 Tables	0.00		2 Posters of the soil profile (A0)	30.00
1 Cutter	2.00		20 Plastic bottles (1.5 L)	5.00
50 L Water	0.00		60 Plastic buckets (5 L)	60.00
			10 Plastic scoops	5.00
1. Quiz			10 Measuring cups	7.50
2 Posters of the water cycle (A0)	30.00		1 Tank (10L)	5.00
2 Posters of the quiz (A0)	30.00		15 kg Gravel (2-3 cm)	6.00
20 Print outs of the quiz	10.00		15 kg Gravel (0.1-1 cm)	6.00
			15 kg Sand (0-2 mm)	6.00
2. Water distribution on earth			20 L Straw. wood Chips	5.00
2 Measuring cups 1 liter	2.00		15 kg Silty soil	0.00
2 Graduated cylinder (100 mL)	3.00		10 L Artificial wastewater	0.00
2 Graduated cylinder (10 mL)	3.00		4 Pairs rubber gloves	2.00
2 Glass or plastic pipette or eyedropper	1.00			
2 Small buckets or plates	0.00		**Awards**	
1 kg Salt	1.00		10 Outdoor-water bottles	20.00
2 Styrofoam boards (A0)	20.00		80 Buttons	40.00
2 Posters of the worldmap (A0)	30.00		80 Bags	40.00
50 Water filled ballons	2.50		Sweets	20.00
120 Ballons filled with air	5.00			
1 Drill	0.00			
100 Clothespins	2.00			
12 Darts	40.00			
10 m2 Plastic film	3.00			
2 Floor rags	2.00			

8.3 Teaching goals

In order to deepen the students' knowledge. a "wastewater rally" can be performed as the final highlight of the teaching unit. The concept is based on the previous classroom activities and includes elements such as a short story. a quiz. an action game. a role play and experimental construction work.

8.4 Beforehand-preparation at school

One day before the rally. the classes should be divided into groups of 4 to 5 pupils. Each group can choose a name that reflects an element of the water cycle such as rain. cloud. river. spring or water drop. ice etc. As homework each pupil may design his individual name badge with group and personal name.

8.5 Introduction (15 min)

To get in the mood for the “Wastewater Rally” a background music related to water may by chosen. Have pupils form a circle and a teacher (instructor) tells a short story such as „The long journey of AGUA. the rain water drop“. The story is related to the water cycle and the pupils’ task is to listen carefully and to jump up in the case their group’s name was mentioned in the story.

Figure 17 **Introduction of the “Wastewater Rally” by telling the short story of “AGUA. the rain water drop”**

8.6 Closing the water cycle (25 Min)

Teaching goal: Pupils will deepen their knowledge on the global water cycle as a closed system.

After the introduction the water cycle is repeated using the poster demonstrated lesson 1. Questions were asked such as „How do you think the water drop will come from one point to the other?“ or „What stations the water drop has to pass for reaching a specific location?” (approx. 10 Min)

Following the quiz should be explained by means of a poster such as that shown below. The quiz consists in several drawings that form three incomplete water cycles. The missing link of each cycle has to be selected from several symbols given in the corners of the working sheet. The correct symbols put into the spaces. result in AGUA as solution word. The time considered for this exercise is 15 min. The points each group can obtain by solving the task. are: 1 point for each fitting symbol (total of 3 points).

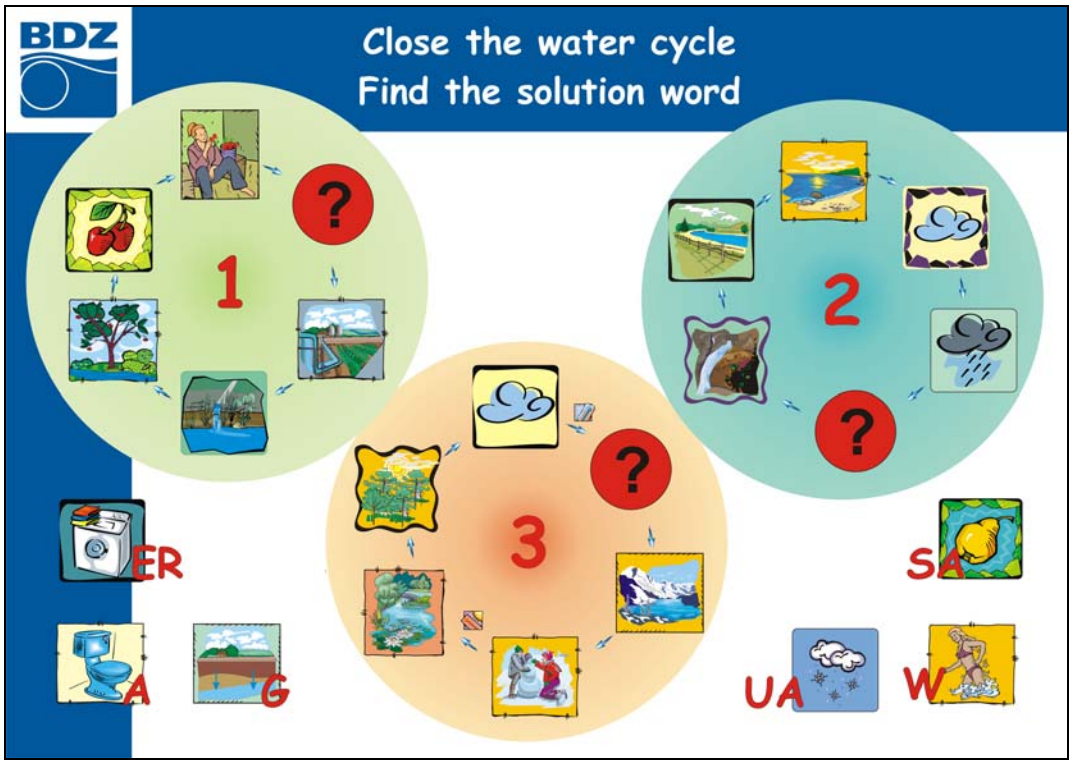


Figure 18 **Quiz: Closing the water cycle**

Figure 19 **Assistance in resolving the quiz**

8.7 Water distribution on earth (30 Min)

Teaching goal: Develop care and concern for water as a scarce resource and an awareness of the need to preserve and conserve water resources. The pupils get a feeling for different water amounts.

As lead-in. the demonstration „A drop of potable fresh water“ (Lesson: Water distribution and use) should be used to illustrate the small available amount of fresh water on the planet that can be used as drinking water and how little of the total amount of water can be used by humans.

Additionally the distribution of the drinking water on the planet was discussed by asking questions and demonstrating a world map that showed the global water distribution. (10 min)

Figure 20 Material needed for the demonstration “A drop of potable freshwater”

The next station of the rally is an action game (see illustration). The global water distribution is represented by multi color balloons (about 40 balloons) fixed on a large world map. The balloons in areas where drinking water is abundant are filled with water; those in dry regions or oceans only contain air.

The task for each pupil is to identify the balloons filled with water and to hit as many water-filled balloons as possible with darts. Each water-filled balloon that burst counts for one point and the successful pupil receives a glass marble as prize.

The pupils of each group alternated three times. Then the points (glass marbles) of each group were added and registered. (20 min)

Figure 21 Throwing darts to "Find the Drinking Water"

Because this game is quite exciting the supervisors should pay attention that observing pupils strictly respect a minimum distance of 3 m to the map.

8.8 Water a rare good (20 Min)

Teaching goal: Pupils should become aware of areas in the world with water shortage and the consequences of insufficient water supply and sanitation.

As introduction to the role play and competition African music may be chosen as back ground and a short story such as "Palesa. an African girl" can be told. One of the girls daily tasks consists of fetching water at the water tank in her village and carrying the heavy water home on her head. In her home the family reuses the washing water for irrigation of a small home garden. (5 min. see lesson: "Water a rare good")

The exercise consists of a footrace carrying a plastic bucket with 3 water-filled balloons on the head. The bucket is stabilized on the head by a cloth hoop and it is allowed to stop and adjust the bucket in the case of being in danger to slide down.

The distance of the race is about 40 m going 20 m back and forth. The bucket is passed to the next member of the group (relay) and that group wins whose last pupil passes the finish line first. Each pupil who transports the bucket without loosing a balloon receives one point and the winning group gets two additional points. In the case of a fallen bucket the pupil has to refill the bucket and return to the starting line.

Figure 22 Footrace of carrying a bucket filled with water balloons

(Tip: It might be exciting to include a race between the school teachers).

Figure 23 Teacher race

8.9 Wastewater treatment (35 Min)

Teaching goal: The pupils will repeat the set up of a filter system and get the chance to optimize the construction they already know from the lesson before.

In a short introduction the composition of a soil body should be repeated and that the pore structure cause a filter effect that remains particles from surface water that infiltrates to the ground water level.

First. a sample of the artificial wastewater should be shown and the ingredients explained. The pupils should have the possibility to take a smell and to clarify some doubts concerning handling. safeness and understanding (if not already known).

Then. each group receives a filter column (cut plastic bottle) and different filter materials such as gravel. fine sand. straw. soil. A time of 15 min should be set to construct the filter. Then two representatives of each group should wash the filter with clear water to remove fine particles and to allow the filter material to consolidate.

The filter is tested by passing 0.5 L of artificial wastewater. A representative of the group collects approximately 50-100 mL of the filtrate in a glass jug labeled with the group name.

For evaluating the results. the different percolates should be grouped according to the turbidity of the filtrate. The group(s) with the most transparent filtrate received 5 points. the second two and the most turbid one point.

In a short debriefing the questions should be discussed why some filters functioned better than others and how the optimal filter should be constructed. The total time needed of this exercise is approximately 30 min.

Figure 24 **Pupils constructing an testing a wastewater filter**

8.10 Awards ceremony (20 Min)

As already mentioned the groups receive points for each exercise. The points should be marked down on a flip-chart in a table were group names and exercise number are indicated. The resulting sum defines the winning group. In the case that the rally ends in a tie. a play-off for the affected groups should be organized. e.g. repeating the task to hit most water filled balloon with darts.

The members of the winning team should receive a bag filled with small toys and/or sweets and all children may receive an acknowledgment such as a “Water Day” button.

Figure 25 **The winning group and the acknowledgment for participating in the “Wastewater Rally”**

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