

Module 3

About Water

Summary

This module consists of 3 parts:

A. Water Properties

B. Water Cycle

C. Ground and Drinking Water

Water is one of the most important and ubiquitous molecules on the surface of our planet and in living organisms. It has very specific properties which are responsible for its very broad utilisation in nature and our daily life. Life could not exist without water. A brief overview of some water properties (**A. Water Properties**) are presented to encourage observation of them in daily life. Associated experiments are also suggested. In lesson **B. Water Cycle**, local and global water cycles are generally distinguished. Regarding Groundwater, specific aspects of regional and local conditions recharge and climate characteristics are summarized. In lesson **C. Ground and Drinking Water**, the occurrence of different types of natural drinking water sources are presented. A few examples of springs in Bulgaria are given.

Objectives

The pupils achieve physical and chemical background of water and carry out related experiments. They can describe important aspects of the water cycle, link these aspects to their own local water sources and water supply. They become more aware of the influence (changing) climate and varying weather conditions have on the local water supply. The pupils can distinguish between different types of natural drinking water sources, do experiments to see how soil cleans water and do first water tests to identify the water quality.

Key words and terms

Density, freezing and melting point, specific heat capacity, polarity and solubility, pH, surface tension; water cycle, evaporation, condensation, precipitation, infiltration, storage, runoff, groundwater, surface water; soil structure, soil type, aquifer, groundwater, spring

Preparation/materials

Materials	Preparation
Little glass bottles (2), 2 plastic sticks	Pupils should bring several water samples.
Freezer, Thermometer, Bunsen burner (or hot water burner)	
Modell of water molecule	
Salt, sugar, oil, Soap, Glasses, Towels (or tissue)	
Paper clips, screws, cork, ice cubes	Ice cubes have to be prepared before.
Paper and pens for drawing, scissors	
Charcoal (cotton wool), silt, gravel	
Big plastic bottles with a cap	

About Water

3A. Water Properties

Introduction

Do the pupils know about any living organism which can exist without needing water at least every now and then? Is there any flower that does not fade, any animal that does not die without water? Every species on earth, whether it is a big animal like an elephant or a small insect like a bee or an ant, depends on water. Human Beings not only depend on water to survive but they consist of 60-70 % water. Water bodies are also important habitats for living creatures (e.g. sea, swamp, lakes and rivers). Water is a very important element in our daily life. We need water for the production of goods for (daily) consumption (clothes, food, etc.), transportation (rivers, sea, etc.) or recreation (swimming, skiing, ice-skating). Water is also essential for everyday activities like cooking, drinking and cleaning. Water is a very crucial element for life and especially for our well-being and prospering. To gain a deeper understanding of our drinking water's vulnerability, it is helpful to know some of its properties. These properties are sometimes very astonishing (and on a first glance more or less hidden) and show us an admirable, vibrant, and vivacious element.

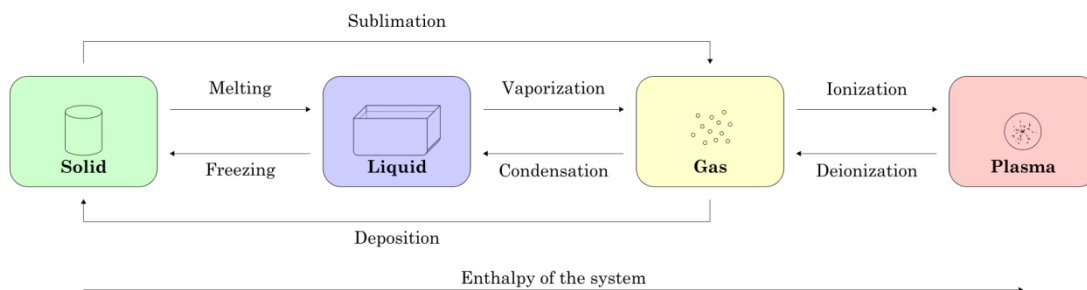
1. Water properties

Density

Water has an approximate density of 1 g/cm^3 in its liquid state. But this changes when water freezes. The volume expands during the phase transition from water to ice and so the density lowers to around $0,9 \text{ g/cm}^3$. Therefore, ice seems to be "lighter" than water because it floats on the water surface. As the volume of water increases when freezing, it develops a huge power as well. For example water pipes can burst during wintertime if not properly insulated.

States of matter

Our temperature scale of "degree centigrade" uses the freezing and boiling point of water for scaling. At both points water changes its state of matter. The graphic below names all the changes of water's states of matter. Water is the only molecule on earth which shows all three states of matter in a natural environment.



Graphic 1: Water – states of matter.

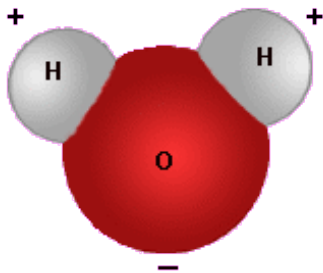
Source: http://en.wikipedia.org/wiki/State_of_matter

Specific heat capacity

Water has a very high specific heat capacity (4,186 kJ/ kg*K) in comparison to a lot of other materials like metals (e.g. steel 0,477 kJ/ kg*K) or other liquids (e.g. oil 1,67 kJ/ kg*K). Water needs – as it can store much more energy – a lot of energy to get heated. In return it keeps this energy and slowly cools down. Therefore, large water bodies can serve as a local energy reservoir and we can use water for heating (hot water bottle). The Black Sea works as a large heating source in winter (higher temperatures at the coast of the Black Sea than in the inland).

Polarity/Solubility

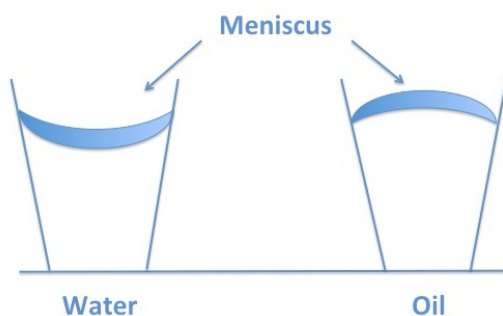
Water has a molecular structure which leads to the effect that water has a positive and a negative part (see graphic). This property is responsible for the solubility or insolubility of other substances in water. Polar molecules like sugar, salt and ethanol can easily be dissolved in water. Oil is nearly insoluble and floats as a thin layer on the water surface. However, if we use soap or a similar detergent we can “dissolve” substances like oil or fat.



*Model of a water molecule.
Source: www.uni-duesseldorf.de*

Surface tension

The above mentioned polarity of water molecules causes strong forces between them. The forces between molecules (surface tension) cause also the curve (meniscus) in the surface of a liquid close to the surface of a glass or other object. The meniscus of oil is different to the meniscus of water. The forces between the water molecules are lower than between water and the glass, and the forces between oil molecules are higher than between oil and the glass. In the illustration below, water and oil shows the effect of building respectively a concave and convex meniscus when filled into a glass. Intermolecular forces are also responsible for water building drops. In the nature and daily life we can see effects of the surface tension liquids. For example some animals can “walk” on the water surface (e.g. water strider). The addition of some drops of a detergent interrupts the strong connection between the water molecules and destroys the surface tension.



Surface tension of different liquids (water and oil)

pH

pH is a measure that describes how acid or alkaline the (watery) environment is. It ranges from 1 (very acid) to 7 (neutral) to 14 (very alkaline). For many biological and chemical processes, a specific pH is important. If it differs too much from the optimum for a specific reaction, the process will not work. For example our stomach needs a pH around 1 (which is provided by the stomach acid) to digest the food properly. See also module 5.

2. Exercises and activities

Let the pupils describe which results they expect from the following experiments, why they expect them and what they observed doing the experiments:

Density

- Different materials (screws, cork, wood, ice) show different behaviour when put into a container with water. They float or sink in water depending on their density.
- Freezing water in a small glass bottle. The bottle will be cracked when ice is formed and expands. Fill 2 glass bottles with water and close it with a cap. Put them into the freezer. Next time when taking the bottles out (after a few hours) they should be broken.

States of matter

- Where can we find the different states of matter (water, ice, steam) in our natural (or artificial) environment?

Polarity/Solubility

- Show with an electrostatic chargeable material like plastic sticks (e.g. 2 plastic pens, or wool) that flowing water (tap) can be deflected by electric voltage.
- Solubility of different materials: salt, sugar, oil. What happens if soap is used?

Surface tension

- What does the surface look like when water is filled into a thin, flat bottomed flask?
- Children stand together and each child takes the hands of two other children (no row!) This should demonstrate the forces between the water molecules and that they tend to built “round” structures e.g. a meniscus (or drop). An object (e.g. book, glass) that each child should hold in one hand (in the other one still holding a hand of another child) demonstrates the effect of a detergent to lessen the surface tension.
- A paper clip can float on the water surface. If the children are not able to put the clip carefully on the water surface they can use some absorbent paper. The addition of some drops of detergents will destroy the surface tension and the clip will sink to the ground.

pH

Measurement of pH of different liquids:

- vinegar: 2,5
- Cola: 2-3
- orange, apple: 3-4
- rainwater: 5-6
- mineral water: 6
- drinking water: 6-8
- soap: 9-10

General questions

- A person weights 100kg. How much of him/her is water?
- In which states of matter does water exist?
- At which temperature does water freeze and boil?
- At which temperature does sea water freeze and boil?

WSP related activities

- If you think of your home environment, in which situations do you come into contact with different states of water matter?
- In which months of the year is the soil in your environment probably frozen?

3. Text sources and further reading

Water Science for Schools, U.S. Geological Survey (USGS), (2012). Available from <http://ga.water.usgs.gov/edu/>

Water Structure and Science, (2012). Available from <http://www.lsbu.ac.uk/water/>

About Water

3B. Water Cycle

1. Water cycle - global

The water cycle starts on the ocean because it is the largest water reservoir on earth. It covers 71% of the earth's surface. Solar energy heats the water, particularly in the tropics. Through evaporation, especially at the sea surface and to a lesser extent also on the mainland, humidity is created. Because this vaporised water is lighter than air, it rises into the atmosphere. In higher altitudes, the air cools down and the water vapour condenses. This creates clouds. The wind transports the moist air and clouds to the mainland.

When humid air meets cold air layers, it is lifted (warm front), as it is when it meets on mountain flanks (convection). When air rises, it cools down. Cold air can hold less moisture than warm. If the clouds are already saturated with condensed water to a certain extent, precipitation occurs and the water falls as rain, snow or hail to the ground. The form of precipitation depends on the local temperature. When the water falls to the ground, it can infiltrate the soil and seep into the groundwater layer, or it can flow on the surface directly into the next creek or river.

Via a spring or well, the groundwater reaches the surface again and flows through a river system back into the ocean. In the Polar Regions and high mountain ranges, a part of the precipitation is stored in solid form as ice or snow, where it could pass through as melted water into the ocean again (Figure 1).

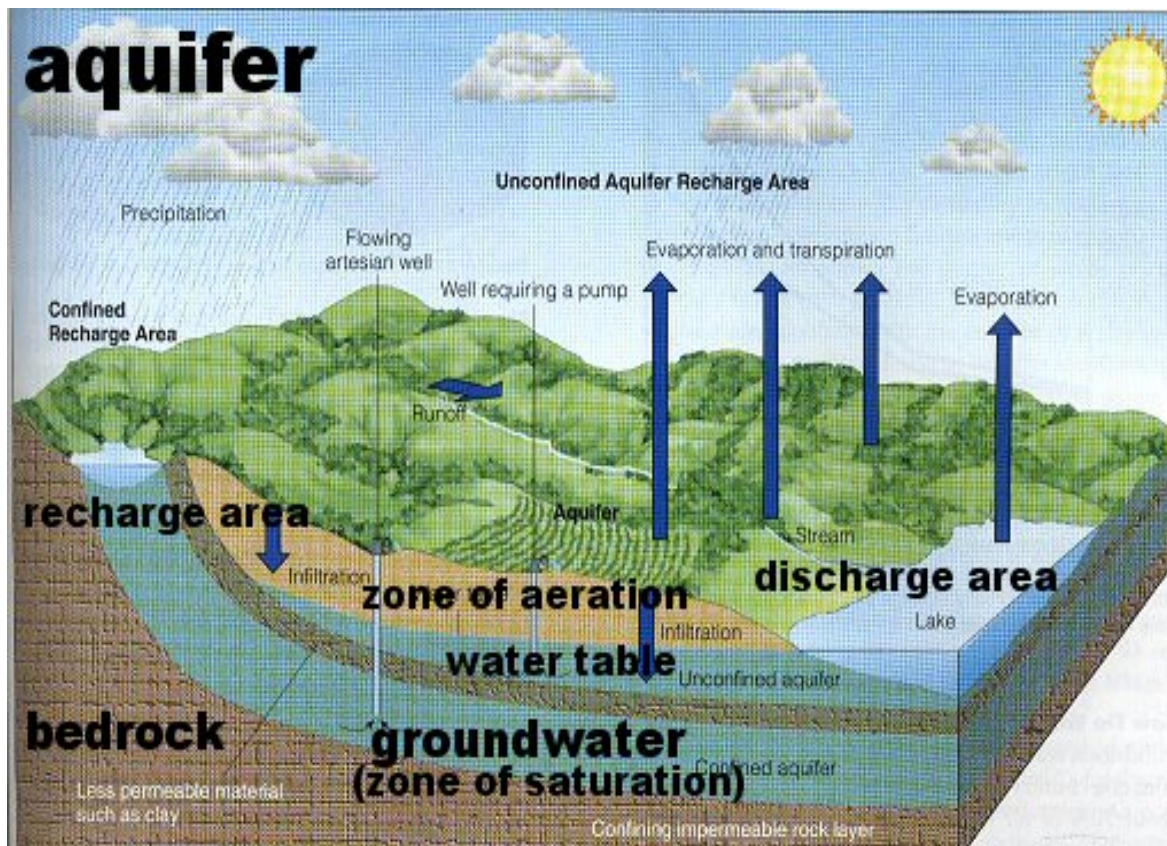


Figure 1: Water cycle

Source: <http://library.thinkquest.org>

2. Water cycle - local

The local water cycle depends on geographical aspects like latitude, distance to the sea, main wind direction, temperature profile (on a yearly base) and topography. Bulgaria has (as indicated by Table 1 and Figure 2) less precipitation in some of its parts than other countries in Europe and a slightly higher average temperature.

Town	Temperature [°C] (annual average)	Precipitation [mm] (annual average)
Sofia	9,7	563
Varna	12,1	471
Paris	10,6	639
Vienna	9,9	613
Moscow	5,0	688
Istanbul	14,1	698
London	9,7	753
Berlin	9,2	578
Munich	9,2	1009

Table 1: Temperature and Precipitation of different cities in Europe
Source: www.klimadiagramme.de

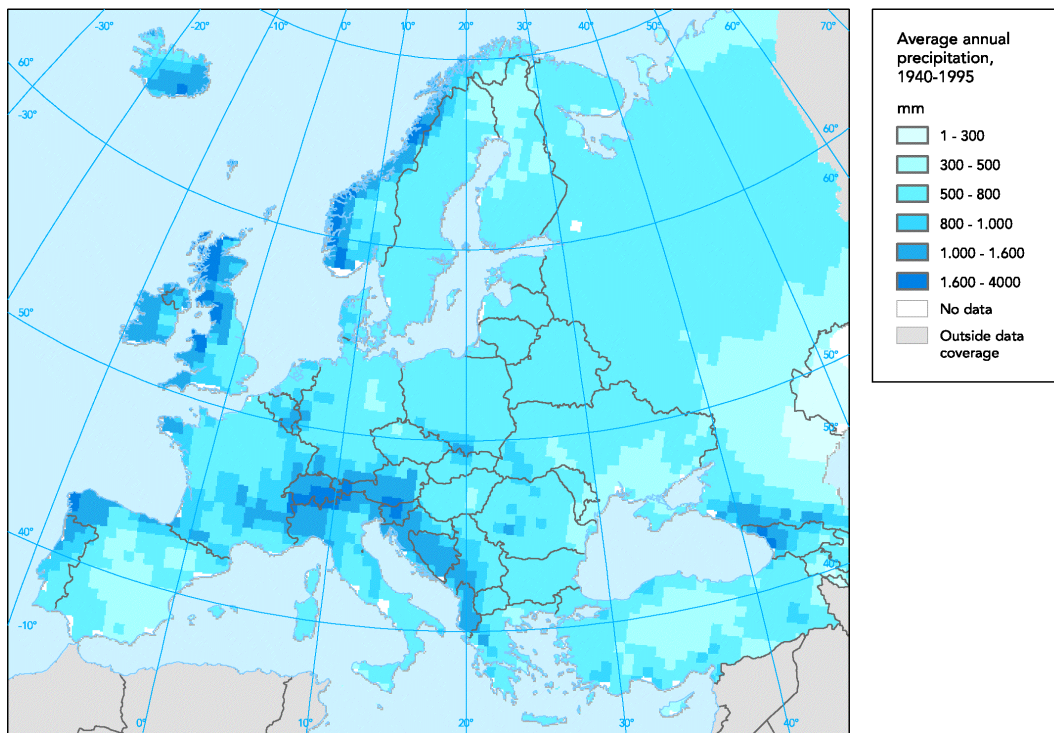


Figure 2: Average annual precipitation Europe

Source: <http://www.eea.europa.eu/data-and-maps/figures/average-annual-precipitation>

Therefore, Bulgaria is vulnerable to severe droughts in some parts of the country, as they have already occurred in the past (Figure 4). Drought in Bulgaria was most severe in the years 1945 and 2000 with a precipitation of less than 30% of the current climatic values (1961-1990). The last drought period (1982-1994) affected groundwater considerably in Bulgaria (Figure 3). There was a reduction of discharge in most of the springs and the wells showed lower water levels. The reduction of spring discharge was determined to be up to 20-30%.

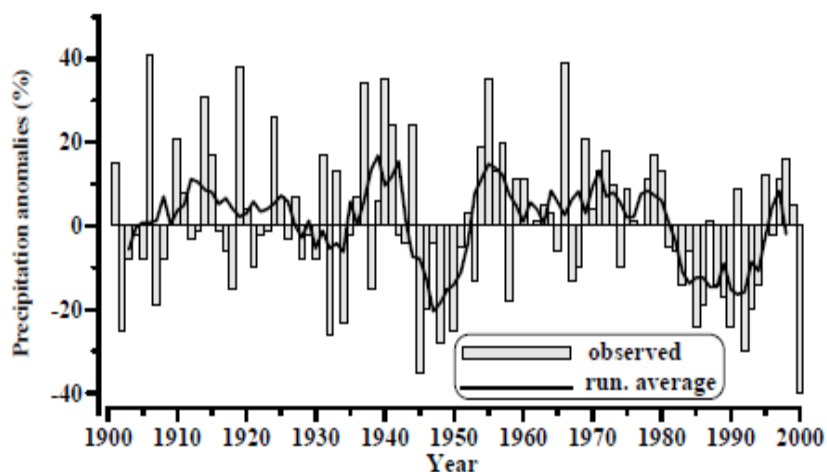


Figure 3. Long-term anomalies of annual precipitation, relative to 1961-1990

Source: European Water 1/2: 25-30, 2003; V. Alexandrov & M. Genev

The following graphic shows the parts vulnerable to severe droughts in colour which might be most affected by the climate change hence drought.

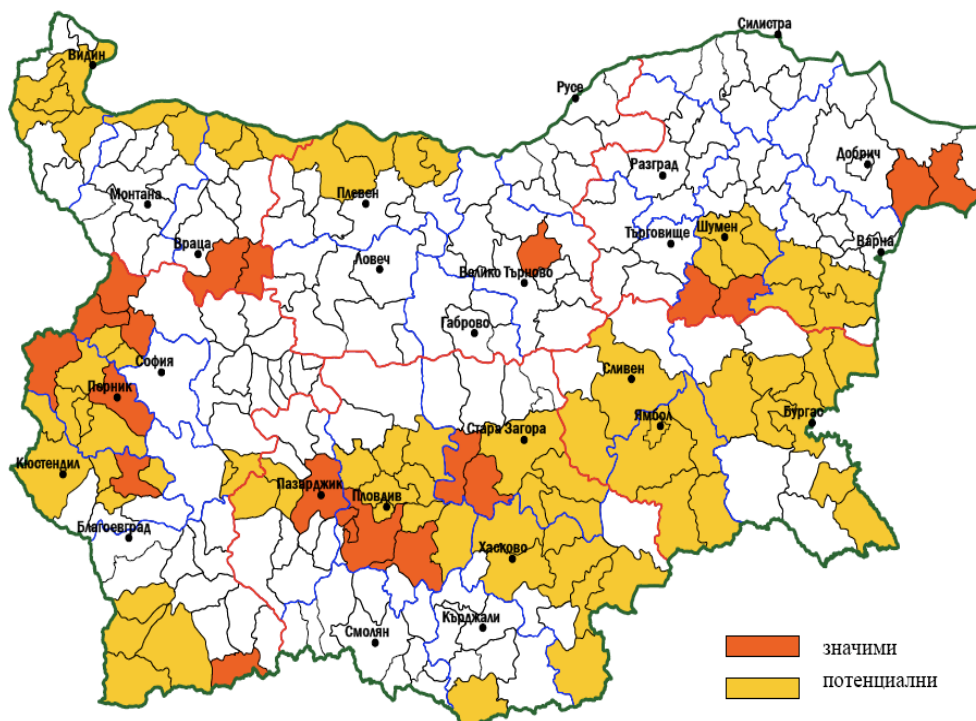


Figure 4: Regions threatened by droughts

orange: serious risk; yellow: moderate risk

Source: chm.moew.government.bg/SLM/files/spatial%20soil%20drought_part%201.pdf

3. Exercises and Questions

- Which forces generate the water cycle?
- How much of the earth's surface is covered by water?
- Draw a simplified picture of the water cycle. Name and describe all important stations of the water cycle.
- Quote different types of precipitation.
- What happens to your water sources (springs, wells or water supply) if there is less precipitation?
- Have the pupils already experienced drought?
- What could drought mean to their daily life?

WSP related activities

- How does the precipitation of the local area occur throughout the year?
- Is the local area considered as an area prone to droughts, hence leading to water scarcity?
If yes, is there a programme for implementing water saving measures?

4. Text sources and further reading

European Water 1 / 2: 25-30, (2003). Climate Variability and Change Impact on Water Resources in Bulgaria. Available from http://www.ewra.net/ew/pdf/EW_2003_1-2_04.pdf

Water Science for Schools, U.S. Geological Survey (USGS), (2012). Available from <http://ga.water.usgs.gov/edu/>

About Water

3C. Ground and Drinking Water

1. Groundwater

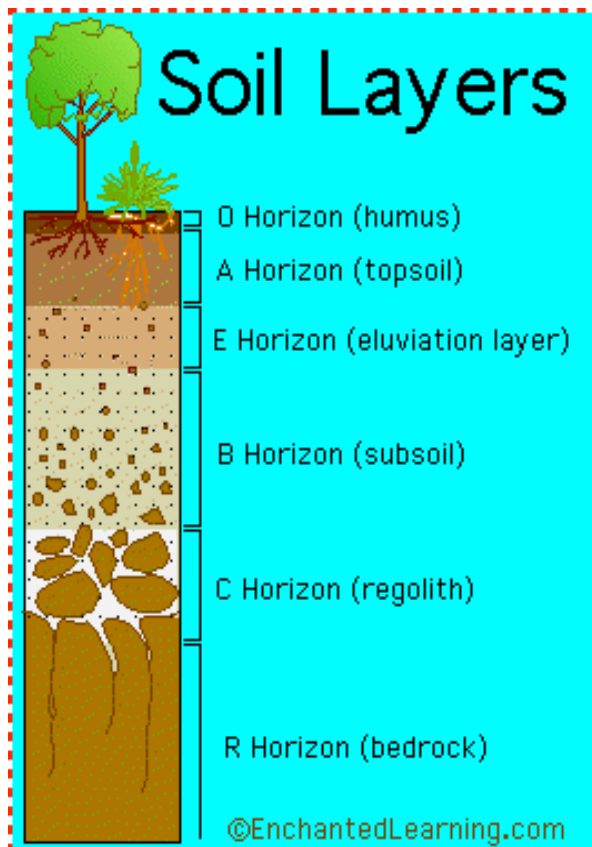


Figure 1: soil layers

The following text describes the flow of water, starting from the point where it soaks into the soil to the point where it appears on the earth's surface; e.g. a spring or in a well. Groundwater, as mentioned in module 3B (water cycle), is generated by precipitation infiltrating (rainfall, snow) into the soil. Gravity forces water to seep deeper and deeper through the soil and water move through the groundwater system where it eventually makes its way back to the surface.

Soil is – put simply – a mixture of bedrock, clay, silt, organic material, air, water and many different organisms. It also has many different layers (Figure 1). There is a large variety of different soil types and each one has unique characteristics, like in colour, texture, structure, depth and minerals. The composition and depth of the soil influences the compounds of the groundwater. There is an intense exchange of substances between water and soil components resulting in, for example, mineral-rich or mineral-poor water and with different hardness. Soil can act as a filter and can absorb substances like minerals (fertiliser), pesticides or acids. As water passes through the soil it can uptake wished substances, like minerals but also unwished substances such as arsenic, nitrate or pesticides.

As water seeps deeper, it sometime encounters an impermeable layer. It flows horizontally along this layer filling all the cracks, crevices and pores above like a sponge. This water filled layer is called an aquifer. When the aquifer water returns back to the surface, the groundwater forms a spring.

Depending on the local geographical conditions, there are different types of springs and aquifers which require different technical devices to extract water from the ground. An interesting type of spring or well is the artesian well. It is a well in geographical depression where the groundwater is exposed to a certain pressure. This pressure is high enough, that the water comes to the surface without pumping (Figure 2).

The depth of groundwater can vary and can reach hundreds of metres deep into the earth. Another term for groundwater is *aquifer*, however, this term is usually used to describe water-bearing formations capable of providing enough water for peoples' needs (industry). Often the different layers of aquifers structure the ground deep in the earth. Usually, the deeper the groundwater reaches, the more protected the water is. The different layers in the ground enhance the filter effect by purifying the water, as mentioned above by soil. Aquifers near the surface are prone to pollution. Severe pollution of groundwater is mostly caused by man. Thus the protection of water is essential (see module 11 for information on water protection).

Springs in Bulgaria

Bulgaria has many hot springs where the spring water has higher temperatures and varying mineral content. Some examples are Velingrad, Narechen, Kyustendil, Separeva banya, Sandanski, Pomorie, Pavel Banya and Hissarya. Depending on the mineral content, the water can be used for healing purposes or as mineral water for drinking. Other important (warm) water reservoirs are geothermal water resources. You can find them throughout Bulgaria in depths between 100m and 5000m by drilling. They can be used as an energy resource and theoretically as a drinking water resource.

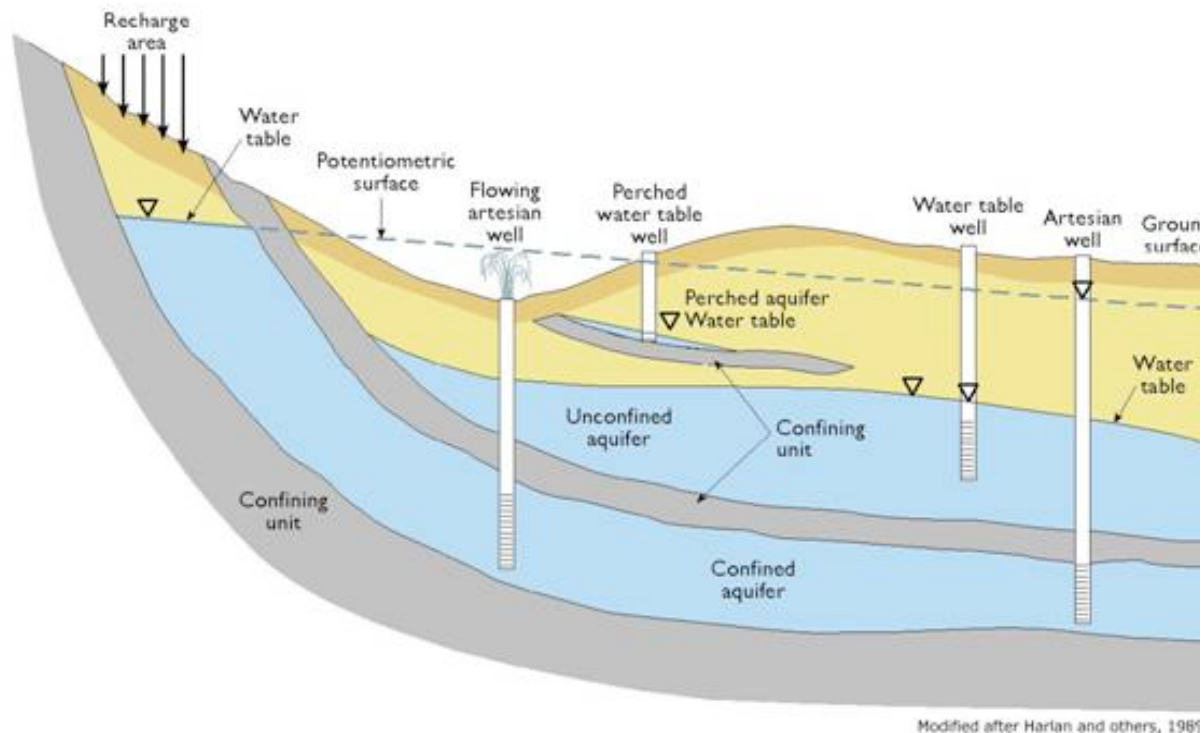


Figure 2: Aquifers and wells

Source: [http://www.douglas.co.us/water/What_is_an_Aquifer\\$.html](http://www.douglas.co.us/water/What_is_an_Aquifer$.html)

The recharge of local springs depends largely on the local geology and climate. As aquifers store only a certain amount of water, the local water supply depends largely on the precipitation received in past weeks or months. If there is less precipitation and/or higher temperatures, the wells and springs could dry up.

2. Drinking water

According to the Protocol on Water and Health of UNECE and WHO “*Drinking water means water which is used, or intended to be available for use, by humans for drinking, cooking, food preparation, personal hygiene or similar purposes,*” drinking water or potable water is water of sufficiently high quality that can be consumed or used especially for drinking and cooking with low risk of immediate or long term harm. It has to be very pure.

There can be various sources depending on local conditions. Drinking water can originate from groundwater (springs, wells), surface water (rivers, lakes, reservoirs, sea), rainwater or even mist. The usage of surface water can be necessary if local groundwater is scarce or non-explorable. Surface water is much more vulnerable to contamination by anthropogenic and natural activities and should be analysed and always treated adequately.

Though our planet is covered by 71% of water, only a fraction can be used as drinking water (Table 1).

		Water volume [km ³]	Percentage [%]	
Total		1 384 120 000	100,00	
Saltwater (sea)		1 348 000 000	97,39	
Freshwater (total)		36 020 000	100	2,60
Freshwater	Water in polar ice, sea ice, glaciers	27 820 000	77,23	2,01
	Groundwater, soil moisture	8 062 000	22,38	0,58
	Water in rivers and lakes	127 000	0,35	0,01
	water in the atmosphere	13 000	0,04	0,001

Table 1: Water volume of the earth

Source: Marcinek & Rosenkranz 1996, Data according to Baumgartner und Reichel 1975; bfw.ac.at/300/pdf/globaler_wasserkreislauf.pdf

Only 1% of all freshwater can be used as drinking water! This is an equivalent of 0,0026% of the total water volume!

To make this a little bit more quantifiable here is a comparison:

If a bath tub is full of water (150l) and this stands for the whole water reservoir of our world than roughly 4,2l (½ bucket) are freshwater and of these

- 3,2l are ice (poles and glaciers)
- 1l is groundwater and only
- 0,02l (a brandy glass) are surface water bodies (lakes, rivers)
- 0,004l (a thimble!!) are theoretically usable as drinking water

3. Experiments and questions

Build your own water filter

- Cut the bottom of the plastic bottle. Turn it around (the cap is now at the bottom), put charcoal in first, then silt and add some gravel at the top.
- Create some "dirty water" (soil + water and stir it)
- Remove the cap of the bottle and place the bottle on a glass. Fill some of the dirty water into the bottle which is now the filter and see what happens. How does the dropping water look like?
- Fill one bottle with pure garden soil and one with clay as explained above. Put some water on the top of the soils and observe what happens. Try to explain why.

WSP related activities

- Which types of water sources are found in the local environment?
- In which geographical situation is the local area situated?
- Which soil layers are found and how do they protect the water?
- Which source is the drinking water taken from? How deep is the source?

4. Text sources and further reading

Bundesanstalt fuer Geowissenschaften und Rohstoffe (BGR), (2004). Groundwater bodies in Bulgaria, Identifikation and delineation. Available from http://www.bgr.bund.de/EN/Themen/Wasser/Veranstaltungen/workshop_gwbodies/Presentation_04_spasov_pdf.pdf?__blob=publicationFile&v=2

UNECE, WHO (2000). Protocol on Water and Health. Available from <http://www.unece.org/fileadmin/DAM/env/documents/2000/wat/mp.wat.2000.1.e.pdf>

UN-Statistics Water Resources, (2012). Available from http://www.unwater.org/statistics_res.html

Nelson, Stephen A., Tulane University, (2011). Groundwater. Available from <http://www.tulane.edu/~sanelson/geol111/groundwater.htm>