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Water – an important element not only of the soil environment

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Abstract

This general overview article presents water as a unique substance, which constantly accompanies people on our globe. The authors described the most important physical (density, boiling point, maximum density temperature, critical temperature, heat of fusion, evaporation heat, specific heat, surface tension, dynamic viscosity, electrolytic conductivity) and chemical properties (pH, solubility) of water. These properties are important for the functioning of soils and both living organisms (microorganisms, plants, animals, humans) as well as inanimate elements of the environment (lithosphere, waterbodies, watercourses, landscape, etc.). The authors presented the polygenetic origin of water (from the emission of volcanic gases, lava, comets, asteroids) and characterised the Earth's water resources, paying particular attention to the limited quantity and exponentially growing demand for fresh water. This situation was illustrated with the water footprint – an indicator of the amount of fresh water which is used directly or indirectly to produce any natural or artificial thing. The article also discusses the negative aspects of water (floods, tsunamis, water erosion), which have been intensified by ill-considered human activities (deforestation, limitation of soil water retention capacity, etc.) in recent centuries. The authors emphasised the therapeutic properties of water, which can be used to treat various ailments (water massages, steam baths, purifying parameters of mineral and spring waters). The article also mentions the scenic functions of water as a liquid (water scenic parks, geysers, hot springs, waterfalls), solid (glaciers) and gas (fog, clouds, rainbow, halo phenomenon). The authors also mentioned the need to save water both globally and locally. As the deficit of this valuable substance is constantly increasing, it may cause numerous conflicts in the near future, as they already occurred in the past at various intensity.

1. Introduction

Water is considered to be the most unusual natural substance in the universe. It is a basic ingredient of the biosphere and an element which has inseparably accompanied man. As early as antiquity mankind treated water as an important component of the Earth – the planet which was considered a flat shield of undefined dimensions more or less until Aristotle's times (385–323 BC). The first sentences in the Book of Genesis in the Bible confirm the fact that water has always surrounded man: '*In the beginning God created the heaven and the earth. And the earth was without form, and void; and darkness was upon the face of the deep. And the Spirit of God moved upon the face of the waters*' (Bible, 2005). According to the Bible, the presence of water preceded God's creation of light and all other things in the Garden of Eden.

Water owes its value to numerous physicochemical properties and the fact that it is the only substance on the Earth that naturally occurs in three states of matter, i.e. solid (ice), liquid (water) and gas (water vapour). Apart from that, it relatively easily transitions from one state to another. Thus, it can be found in the lithosphere, hydrosphere and atmosphere. The transitions between states of the matter (phases) are called as follows:

- freezing – from liquid into solid;
- melting – from solid into liquid;
- vaporisation – from liquid into gas;
- sublimation – from solid into gas;
- deposition – from gas into solid;
- condensation – from gaseous into liquid.

The presence of water on our planet results from the location of the Earth in the Solar System, i.e. at a specific distance from the Sun (150 million km). Water can occur in three states of matter only in a very narrow zone of our planetary system, i.e. within 2% of the solar radius (Kaniecki, 2018). In the distant past Mars and Venus were also highly hydrated. Mars lost water due to low gravity and the absence of a magnetic field, which are protective factors ensuring its maintenance. As a result of strong radiation, hydrogen evaporated from Martian water and oxygen

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was incorporated into rocks, which resulted in the red colour of the planet (iron oxides – hematite forms). Water lasted longer on Venus, which is a slightly larger planet, due to stronger gravity. However, it also evaporated due to the shorter distance from the Sun (about 100 million km), making Venus a very hot and dry planetary object. Currently Mars and Venus are located near the borders of this narrow zone of life, but on its outer sides. Many cosmologists and planetologists claim that even in the Milky Way we may have brothers and sisters, i.e. exoplanets rich in water, with different life forms.

2. Basic physicochemical properties of water

Chemically, water is a compound of hydrogen and oxygen, known under the molecular formula H_2O, i.e. dihydrogen oxide. In nature, it is very rarely found in its pure state, because in most cases it is an aqueous solution of inorganic substances (particles smaller than 1 nm). It may also contain colloids (particles sized 1–500 nm) and fine suspensions (particles larger than 500 nm) (Dojlido, 1995; Brini et al., 2017). Water in this sense will be presented in further sections of this article.

In order to understand various functions of aqueous solutions in the inanimate and animate world, it is necessary to mention several most important parameters of pure water. The hydrogen atoms in the water molecule are situated asymmetrically to the oxygen atom. The angle between the hydrogen and oxygen bonds is 104.5°. The hydrogen atoms are positively charged, whereas the oxygen atom is negatively charged. As a result, water is a polar molecule, i.e. its negative and positive charges are away from each other (Dojlido, 1995; Bandurska, 2007; Łubkowska, 2016).

Table 1
Basic physical properties of water (Dojlido, 1995)

Parameter	Value
Molecular mass	18.0153
Density ($g \cdot cm^{-3}$)	0.9982
Melting point (°C)	0.0
Boiling point (°C)	100.0
Maximum density temperature (°C)	+3.98
Critical temperature (°C)	374.65
Heat of fusion ($cal \cdot g^{-1} \cdot °C^{-1}$)	79.71
Heat of fusion ($J \cdot g^{-1} \cdot K^{-1}$)	333.75
Heat of evaporation ($cal \cdot g^{-1} \cdot °C^{-1}$)(0°C)	595.4
Specific heat ($cal \cdot g^{-1} \cdot °C^{-1}$)(15°C)	1.00
Specific heat ($J \cdot g^{-1} \cdot K^{-1}$)(15°C)	4.19
Surface tension ($mN \cdot m^{-1}$)(20°C)	72.75
Dynamic viscosity ($mN \cdot s \cdot m^{-2}$)(20°C)	1.000
Electrolytic conductivity ($S \cdot m^{-1}$)(25°C)	$5 \cdot 10^{-6}$

This polarity results in an electric dipole moment, which is equal to the product of the charge and the distance between the centres of positive and negative charges and amounts to 1.83D (D – debye). The water molecule has strong polar properties. Due to the forces of attraction the dipoles of water molecules often form larger structures through hydrogen bonds. Such associations are very large, because they may go up to 100 molecules at room temperature (Dojlido, 1995).

The weight of most water molecules is 18, which results from the atomic masses of hydrogen (1) and oxygen (16). However, due to the fact that oxygen and hydrogen atoms also have three isotopes each, there may be waters of different molecular weights. The basic physical properties of water are shown in Table 1.

Here are the characteristics of selected physicochemical parameters of water:

Density is the mass of cm^3 of water. This parameter changes slightly with temperature. The highest density of water is at a temperature of +3.98°C. This dependence is of high significance for nature, because ice is lighter than water (Majewski, 2019). It is so because polar water molecules in ice are combined by electrostatic interactions and form hydrogen bonds, where molecules are less tightly 'packed' than in liquid water, which causes this anomaly. Therefore, ice is present only on the surface of waterbodies and provides insulation to lower water layers. As a result, throughout the winter there is liquid water in deep waterbodies, thanks to which aquatic organisms can survive this period. When ice melts at 0°C, only some hydrogen bonds are broken and there are still groups of molecules in the liquid, which will be further broken down as temperature increases. The density of the water increases abnormally to reach its maximum level at +3.98°C. As temperature increases even more, this parameter will decrease slightly. This regularity can be observed in all liquids. If ice was heavier than water, lakes, rivers and other waterbodies would start freezing from the bottom. In persistent frosty weather, ice would fill entire waterbodies and thus many aquatic organisms would die.

Specific heat capacity is the coefficient which determines the tendency of a body (substance) to change its temperature as a result of supplying thermal energy. The specific heat capacity of water is very high (Tables 1 and 2). It was established as a standard and marked as 1 in the CGS system (Centimetre

Table 2
Specific heat of some substances (website 1)

Substance	Specific heat ($J \cdot g^{-1} \cdot K^{-1}$)
Water	4.190
Water vapour	1.970
Ice	2.100
Air	1.005
Copper	385
Iron	449

–Gram–Second), which was replaced by the SI system (French *Systčme international (d'unités)*) in 1960. It is the amount of heat expressed as $cal \cdot g^{-1}$, which is needed to raise the temperature of 1 gram of water from 14.5°C to 15.5°C. In the SI the unit of specific heat capacity is the joule per kilogram per Kelvin, where 1 $cal \cdot g^{-1} \cdot {}^{\circ}C^{-1} = 4{,}186\ J \cdot kg^{-1} \cdot K^{-1}$ (Table 1).

As results from the data in Table 2, the specific heat capacity of water varies, depending on the state of matter. The specific heat capacity of ice is almost two times smaller than that of liquid water, and that of water vapour is slightly smaller than that of ice. However, the specific heat capacity of air and two commonly known metals differs considerably from the specific heat capacity of water. Due to such a high value of the specific heat capacity of water global changes in the temperature of large masses water are mild and temperature fluctuations in the water environment are smaller than on land. Large waterbodies heat up and cool down slowly. In consequence, they make the climate of adjacent areas milder and positively influence the life of aquatic organisms.

Surface tension is the work that needs to be done to increase the surface area of the liquid. It is a physical phenomenon which occurs when the surface of a liquid meets a solid, gas or another liquid and causes this surface to act like a spring. If we assume that the surface of water resembles a flexible membrane, the surface tension will be a breaking force. Water exhibits the highest surface tension among liquids (Table 3) (Dojlido, 1995; Lack and Evans, 2001; Mitosek, 2007). The surface tension of water decreases as its temperature increases (Table 4). Due to the surface tension forces the shape of a water droplet is spherical, which may increase its erosive action.

Dissolving capacity is the ability of chemical substances, e.g. water, to dissolve other substances (solids, liquids and gases) in it. Water is the best natural solvent mostl-y due to its polarity. Water does not exist in nature in a pure form, but as a solution with a very diverse composition. This capacity of water usually positively affects the life of living organisms, but it may also have negative influence. Some environments may be depleted of valuable nutrients, it may cause the salinity of soils, destruction of valuable monuments made of poorly resistant limestone and gypsum or the formation of karst landscapes.

Although dissolving capacity is a physical phenomenon, this process results in numerous chemical parameters of water. Depending on the quality and quantity of dissolved substances, waters exhibit different biological productivity in waterbodies. Water bioproductivity depends on various natural (the composition and abundance of organisms) and anthropogenic factors (the quality and quantity of mineral fertilisers, etc.). Water bioproductivity most often concerns lakes. Depending on the fertility, the following types are distinguished: oligotrophic (poor), mesotrophic (moderately fertile), eutrophic (fertile), polytrophic aka hypertrophic (very fertile) and saprophytic (overfertile) lakes (Choiński, 2007). There are many indicators of lake water productivity, although the main ones are the content of total phosphorus and organic nitrogen (Table 5).

pH is a major chemical property of water. It expresses the concentration of hydrogen and hydroxide ions in moles per cubic decimetre ($mol \cdot dm^3$). The symbol *pH* as a measure was introduced by the Danish chemist Sřrensen in 1909. It is the negative decimal logarithm of the concentration (activity) of hydrogen ions expressed in moles per cubic decimetre (litre). It results from a very low degree of dissociation of water molecules ($2H_2O \rightleftarrows H_3O^+ + OH^-$), where H_3O^+ is the hydronium ion (hydrated H^+ ion) as a cation, and OH^- is the hydroxide ion (anion). The hydronium ion is often replaced by the symbol H^+ in records. In pure water at a temperature of 24°C the concentrations of H^+ and OH^- are equal and amount to 10^{-7}, i.e. pH = 7. This state is called neutral. The concentrations of H^+ and OH^- ions in this state are very low, because 1 dm^3 of water contains 55.4 moles of H_2O, so there are about 554 million water molecules per one H^+ ion and one OH^- anion (Dojlido, 1995). The pH scale in water solutions ranges from 0 to 14 (pH < 7 acidic solution, pH > 7 alkaline solution).

Table 3
The surface tension of the some liquids 20°C (website 2)

Liquid	Surface tension $m\ N \cdot m^{-1}$
Water	72.75
Benzene	28.90
Carbon tetrachloride	26.80
Acetone	23.70
Ethyl alcohol	22.30
Diethyl ether	17.00
Mercury	42.80

Table 4
The surface tension of water vs saturated air and temperature (Dojlido, 1995)

Temperature °C	Surface tension $m\ N \cdot m^{-1}$	Temperature °C	Surface tension $m\ N \cdot m^{-1}$
0	75.64	30	71.18
10	74.22	40	69.56
15	73.49	60	66.18
20	72.75	90	60.75

Table 5
The trophic classification of lakes (Chełmicki, 2001)

Trophic class	Total phosphorus $\mu g \cdot dm^{-3}$	Inorganic nitrogen
Ultraoligotrophic	< 5	< 200
Oligotrophic	5–10	200–400
Mesotrophic	10–30	300–650
Eutrophic	30–100	500–1,500
Hypertrophic	> 100	> 1,500

The pH of natural waters occurring in various environments mostly depends on:

- the carbonate system, i.e. the content of carbonates (Ca, Mg, Na) and carbon dioxide; in carbonate waters pH > 7, whereas in waters with low content of carbonates pH < 7;
- the type of substrate from which alkaline or acid compounds are washed out;
- the type and class of soils formed in the catchment area;
- incoming pollutants of anthropogenic origin (sewage, fertiliser components, acid rains, etc.) (Walna and Siepak, 1996; Pawlik-Dobrowolski and Łempicka, 2003; Łubkowska, 2016).

This chemical parameter of water is of particular significance both for all living organisms (microorganisms, plants, animals and humans) and for the economic use of water in its broad sense.

3. Polygenetic origin of water on the Earth

Hydrology (Greek: hydôr – water; logos – science) is the science that deals with all waters and aquatic phenomena occurring on the Earth. This applies to the entire hydrosphere, i.e. the sphere in which waters of the Earth occur as liquids, solids and gases.

Humans have always been intrigued by the problem of the birth of water in the Universe, especially on Earth. Although cosmologists, planetologists and hydrologists have been investigating this issue for many years, the origin of water on the Earth has not been clearly explained. There are several hypotheses and theories, not fully verified, which prove the polygenetic origin of water on the Blue Planet, which was formed in the solar system about 4.5 billion years ago. When the Earth was young and began its journey around the Sun, the temperature was too high for water to exist as a physical body. Water appeared as a liquid only when the temperature of the surface of the planet dropped below the critical value for water, i.e. 374.65°C (Kaniecki, 2018). This means that the first source of water on the Earth was water vapour contained in the emission of volcanic gases and lava, which condensed during its solidification. In consequence of intense volcanic activity the ejected gases and water vapour formed a dense atmospheric shell surrounding the surface of the cooling planet. As the surface of the Earth was solidifying, this coating reflected sunrays and caused water vapour to condense and fall in the form of heavy rains for many millions of years (Powstanie Ziemi – The genesis of the Earth, 2011).

Comets and asteroids with high water content bombarded the Earth and thus became another source of water. These objects captured the water that formed on dust particles in interstellar space and delivered it to the Earth as a mixture of rock matter and huge masses of ice. Data from NASA satellites show that water may have been transported from space to the Earth. Louis Franke, an American physicist claims that currently smaller comets, consisting of ice and originating from the Kuiper belt, located behind Neptune's orbit, are heading towards our planet. Then they burst at an altitude of more than a thousand kilometres above the Earth's surface, and the heat emitted by the Sun turns the ice into water vapour. According to Franke, these chunks of ice hit the upper layers of the atmosphere every three seconds. Thus, there may be about 10 million of them every year. If this process had continued since the beginning of the existence of the Earth, enough water would have been supplied to fill the places where there are seas and oceans today (Kaniecki, 2018).

Recent studies have shown that part of the water formed from comet ice has a slightly different chemical composition. It contains heavy water, where the ^{2}H isotope, i.e. deuterium (its nucleus consists of a proton and a neutron – D_2O), constitutes a significant part of hydrogen atoms. Therefore, at present asteroids are ascribed a greater role in the transport of space water to the Earth.

There is also a theory of the solar origin of water on the Earth. It was announced in the mid– twentieth century by the English astronomer de Tourville (Balińska-Wuttke, 1973). In his opinion, during violent outbursts of the solar plasma into space (prominence) the nuclei of hydrogen atoms (protons) reach the Earth's atmosphere. Next, they capture electrons and transform into hydrogen atoms, which violently react with oxygen and form water, which falls to the Earth.

The water that accumulated on the surface of the Earth began to evaporate, which resulted in long–lasting heavy rains. Thus, the circulation of water in nature was initiated.

All the aforementioned hypotheses clearly prove the polygenetic origin of water on the Earth. Without analysing the share of juvenile waters from the emission of volcanic gases and solidifying magma and the share of waters of solar–cosmic origin, it is safe to say that they filled the Earth's concavities and currently occupy about 71% of its surface.

4. The Earth's water resources

The Earth's shell, which includes surface water, groundwater, glaciers, and water vapour in the atmosphere, is defined as the hydrosphere. The Earth's water resources are estimated at about 1.386 billion km^3 (Korzun, 1978; Żurek, 2008; Małecka and Staszewski, 2015; Florek et al., 2017). According to geologists, there is almost the same amount of water in the Earth's crust, which is the outer part of the lithosphere. However, the largest amounts of this unusual substance (about 13 billion km^3) can be found in the Earth's mantle, which reaches a depth of 2,900–300 km (Kaniecki, 2018). In most cases this water is built into the crystal lattice of rock–forming minerals, mainly igneous rocks. Thus, there is about 16 billion km^3 of water on and inside the Blue Planet. Water cannot be found in the Earth's nucleus, which is mainly composed of iron and nickel. Table 6 shows a detailed distribution of the Earth's water resources.

The data in Table 6 show that ocean waters amount to over 96% of these resources and occupy an area of 361.3 million km^2. There is only 50 million km^3 of water on the continents, 15 million km^3 of which is saltwater, and about 35 million km^3 is freshwater. The latter is particularly important for living organisms, because freshwater is necessary for their life functions. Table 7 shows freshwater resources in different parts of the hydrosphere.

Table 6
World water resources (Korzun, 1978)

Form of water	Area (10^3 km^2)	Volume (10^3 km^3)	Share in world resources (%)		
			Mean water layer (m)	Total water resources	Fresh water resources
World ocean	361,300	1,338,000	3,700	96.5	–
Groundwater, including	134,800	23,400*	174	1.7	–
fresh groundwater	134,800	10,530	78	0.76	30.1
Soil moisture	82,000	16.5	0.2	0.001	0.05
Glaciers and permanent snow	16,227.5	24,064.1	1,463	1.74	68.7
– Antarctica	13,980	21,600	1,546	1.56	61.7
– Greenland	1,802.4	2,340	1,298	0.17	6.68
– Arctic islands	226.1	83.5	369	0.006	0.24
– mountains	224	40.6	181	0.003	0.12
Ice in permafrost zone	21,000	300	14	0.022	0.86
Water resources in lakes	2,058.7	176.4	85.7	0.013	-
– Fresh water	1,236.4	91	72.6	0.007	0.26
– salt water	822.3	85.4	103.8	0.006	-
Wetland water	2,682.6	11.470	4.28	0.0008	0.03
Water in rivers	148,800	2.12	0.014	0.0002	0.006
Biological waters	510,000	1.12	0.002	0.0001	0.003
Atmospheric water	510,000	12.9	0.025	0.001	0.04
Total water resources	510,000	1,385,984.61	2,718	100	-
including fresh water	148,800	35,029.21	235	2.53	100

* Without groundwater resources in Antarctica, which are estimated at 2 million km^3 (including 1 million km^3 fresh water)

The total volume of freshwater (Tables 6 and 7) on our planet ranges from 28.2 to 35.0 million km^3, which is only 2.0–2.5% of the total volume of water in the entire hydrosphere. A considerable part of freshwater (about 85%) is contained in glaciers and only about 0.3% of the total volume of water accumulated in the hydrosphere can be used by humans. This may indicate the scarcity of freshwater on a global scale and the need to protect it for the current and future needs of humans.

Table 7
Fresh water hydrosphere (Lwowicz, 1979)

Part of hydrosphere	Fresh water volume (10^3 km^3)	Percentage of part of hydrosphere	Percentage of total volume of fresh water
Glaciers	24,000	100	85
Groundwater	4,000	6.7	14
Lakes and artificial reservoirs	155	55	0.6
Soil moisture	83	98	0.3
Water vapour in atmosphere	14	100	0.05
Water in rivers	1.2	100	0.004
Total	28,253.2	-	100

5. The role of water in the pedosphere

Soil should be treated as a three-phase system because it is composed of:

- the solid phase, i.e. mineral and organic parts;
- liquid phase, i.e. water with dissolved chemical elements and compounds;
- gaseous phase, i.e. soil air.

The content of solids in most mineral soils amounts to about 50% of their volume. The remaining 50% is filled by voids, known as soil porosity. According to the laws of physics, there is periodically a certain state of dynamic equilibrium between the aforementioned phases. However, water and air compete for the same space. Water exerts both direct and indirect influence on soil, and it is an important soil–forming factor. It takes part in all stages of numerous soil–forming processes, mostly in:

- the processing (decomposition and synthesis) of the mineral substrate(s) and organic residues;
- the transport of mineral and organic soil components, mainly contained in solutions and in suspensions carried by the liquid phase of soil.

Water is also important for the course of soil processes taking place in already formed pedons (belonging to the relevant taxonomic units). Water in soil is sustained by various forces. In soil science this value is known as the soil water potential and it is expressed in various units (Table 8).

There are various classifications of soil water. From the physical point of view and the degree of retention, the following three forms of soil water are usually distinguished: free (gravitational) water, capillary water and hygroscopic water (Brady, 1990; Owczarzak et al., 2015). They have the following properties:

Gravitational water:

- occurs in soils saturated with water above field capacity;
- is kept in soil with low forces (less than 0.5 or even 0.1 atm.);
- needs to be drained from soil because it occupies pores intended for soil air;
- moves due to capillary and gravitational forces;
- leaches soil of its components.

Capillary water:

- is held in capillary spaces;
- the tension on the surface of water shells ranges from 0.1 to 31 atm;
- is partly accessible to plants;
- occurs as a solution.

Hygroscopic water:

- is maintained at a humidity corresponding to the hygroscopic coefficient;
- is maintained in soil (mainly by colloids) by forces ranging from 31 to 10,000 atm;
- does not have liquid properties (water vapour).

As far as the biological point of view and production are concerned, it is absorbable water that plays the most important role for plants. It is the soil water content ranging from the field water capacity and the so–called wilting point. Most of capillary water belongs to this range. The amount of available water in soil mainly depends on the size of its grains (Fig. 1). As the content of colloidal particles increases, so does the capacity to store larger amounts of available water, although clay forms have slightly lower content of available water than structured dust forms (Brogowski and Kwasowski, 2015; Kaczmarek et al., 2015).

Apart from the soil water content and suction force, the movement of water in soil also plays an essential role in supplying it to plants. There are three processes involved in the movement of soil water: infiltration, percolation and filtration. Infiltration is the process in which water, mainly rainwater, soaks into the soil surface and into deeper soil layers. This process is best reflected by fixed infiltration. It is a relatively constant value used as the basis of seven soil infiltration classes. It refers to the constant rate of water soaking into soil. It is assumed that fixed infiltration takes place when the difference between the infiltration rate in the next hour and the previous hour is lower than 0.1 of the infiltration in the previous hour. The measurement is made in the field by means of the double–ring method (Mocek and Drzymała, 2010). When the topsoil layers are saturated with water above the field water capacity level, water begins to seep (percolate) into deeper parts of the profile, which results in the leaching of nutrients. Some water (gravitational water) moves through macropores vertically into deeper layers of the profile (endopercolation) under the influence of gravity. Waters available to plants, or solutions of these waters (percolates), may also move towards the surface (percolation) or they may alternately move upwards and downwards (amplification). According to Pallmann, these types of water circulation occur mainly in the water–unsaturated zone profile in soil (Prusinkiewicz, 1999). In

Table 8
Soil water potential (Bednarek et al., 2004)

Soil moisture	Units of measure				
	pF	hPa	J	an H_2O	bar
Full saturated	0	0.981	0.0981	1.0	0.000981
Field capacity	2.0	98.1	9.8	100	0.098
Wilting coefficient (point)	4.2	15,547.9	1,554.8	15,849	15.5
Higroscopic ciefficient	4.7	49,166.7	4,916.7	50,119	49.2
Air dry soil	5.4	246,416.4	24,641.6	251,189	246.4

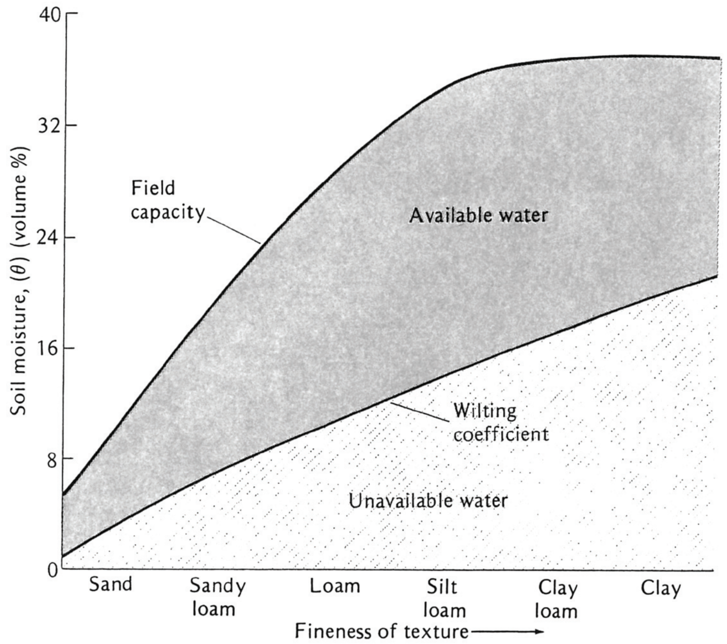

Fig. 1. Upward movement of moisture from a water table through soils of different textures and structures (based on: Brady, 1990)

the zone near the water saturation zone (saturation), soil solutions may move in all directions (periperculation). The movement of water in the saturation zone is called filtration.

As far as plant production is concerned, the most important element is the amount of available water retained in the surface horizons (accumulation and humus horizons) and in the zone reaching up to a depth of 50 cm, i.e. the place where the main mass of plants' roots can be found. It depends on the amount and distribution of precipitation (lithogenic and autogenic soils) and the depth of the groundwater table (hydrogenic soils) (Kędziora, 2008; Komisarek, 2008; Kozłowski and Komisarek, 2017). If these waters are not too deep underground, some of them may be available in the rhizosphere as a result of capillary infiltration. However, it is important to note that the heights (cm) of effective groundwater infiltration are limited and depend mainly on the size and distribution of soil grains (Mückenhausen and Zakosek, 1961 after Bednarek et al., 2004; Kaczmarek et al., 2015). They amount to 10–50 cm for sands, 30–60 cm for clay and 5 cm for loams. The soaking values are low in very fine-grained formations due to a considerable increase in resistance, which makes them almost impermeable. This characteristic is illustrated in Fig. 2 (Brady, 1990; Witkowska-Walczak et al., 2003).

Water plays a very important role in semi-hydrogenic soils, especially in hydrogenic soils, which until recently were an important hierarchical unit in earlier editions of the Polish Soil Classification (PSC, 1989). This applies to both the genesis and current functioning of these soils. They are formed from bedrocks, usually organic, which originated or underwent far-reaching transformations under the influence of water conditions in wetland habitats. This favoured the occurrence of hydrophilic

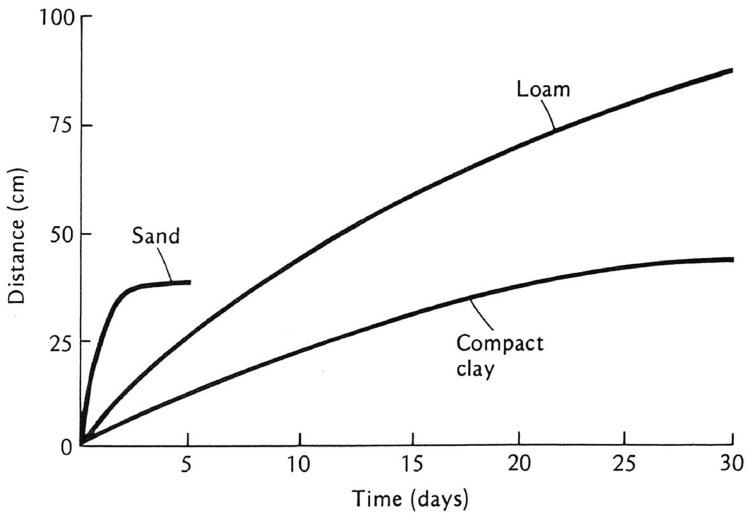

Fig. 2. General relationship beetwen soil moisture characteristics and soil texture (based on: Brady, 1990)

vegetation and progressive accumulation of soil organic matter. These soils are characterised by constant supersaturation of the soil mass with water, so they do not have almost any air–filled voids. In consequence, there are edaphic conditions suitable only for marsh plants and few woody plants (alders, willows, poplars). In the past some of these soils were taken over by agriculture in its broad sense. It was necessary to regulate the air and water relations by drainage. Unfortunately, in most cases these treatments caused excessive drying of these soils and their hydrological degradation (Parry et al., 2012; Baran-Gurgul and Bodziony, 2015). The progressing decession of organic matter in these soils is sometimes exacerbated by the warming climate and worsens the precipitation/evaporation ratio (Owczarzak et al., 2003; Gajewski et al., 2008; Kundzewicz, 2012). This causes further rapid mineralisation of organic matter with high content of nutrients.

6. The significance of water for living organisms

Water is extremely important for all living creatures. It is essential for the function of these organisms, because it is involved in most biological reactions, and it is part of the environment in which they live. Water is either a substrate or a product in various metabolic reactions. The degree of hydration of organisms determines their life activity and the intensity of their growth and development (Solomon et al., 1996; Bandurska, 2007).

There are interrelations between living organisms. What deserves special attention is the way they are supplied with available nutrients, transported by aqueous solutions.

Microorganisms can be found in all ecosystems of the environment. Prokaryotes are a particularly numerous domain. Their number in the biosphere is estimated at 10^{30} cells, which accumulate $350–550 \cdot 10^{15}$ g of carbon (Whitman et al., 1998). This corresponds to 60–100% of the total carbon accumulated in all plants. It is easier to imagine this enormous number of 10^{30} cells as the length of the line they would create. If we assume that one prokaryotic cell is about 1 μm long, the total length of these cells would be $5.3 \cdot 10^{10}$ light years (about $9.5 \cdot 10^{12}$ km). This is a billion times more than the number of stars in the visible universe. This article discusses only water and soil microorganisms, whose physiological functions are inextricably linked with higher plants. The activity of microorganisms is closely correlated with the humidity of the environment, especially with the amount of water available to their cells. Water is necessary for life, and its lack stops metabolism. If there is considerable drying, these bacteria use bound and hydration water. They are poikilohydric organisms, i.e. organisms in which the relative hydration of the protoplasm (hydrature) adjusts to the current water potential in the environment (Walter and Kreeb, 1970 after Bednarek et al., 2004). The following three groups of poikilohydric organisms were distinguished in a laboratory, on artificial media:

- hygrophilous organisms, which can grow at high water potential, but not exceeding pF 4.85. This group includes most bacteria, yeasts and some other fungi;
- mesohygrophilous organisms – their activity disappears only at a pF potential of 4.85–5.48. This group includes the vast majority of fungi and some bacteria;
- xerophilous organisms – their life processes continue even at water potentials above pF 5.48. This group includes only some moulds, e.g. *Aspergillus niger*, *Aspergillus glaucus*, *Penicillium glaucum*.

Thus, it is evident that most soil microorganisms die only when pF values are much higher than those for plants (pF 4.2).

Substances dissolved in water reduce water activity to different extent, depending on their concentration, degree of dissociation and hydration. Most microbes require water activity within 0.95–0.99 to develop (Kwaśna, 2007). Fungi and yeasts exhibit greater tolerance to dehydration of the environment than bacteria. The only exception is halophilic bacteria, which can grow at a water activity of 0.75. Most microorganisms do not tolerate solid substrates with lower moisture than 30%. Fungi cannot develop when humidity drops below 15%. Reduced amount of water immediately inhibits the growth and development of some bacteria. Small and spherical cells, e.g. cocci, are more resistant to the lack of water due to their surface to volume ratio. Due to the cell wall structure of Gram–positive bacteria, bacteria producing mucous shells, e.g. *Azotobacter* sp., or survivable forms – endospores, they are also more resistant to water deficit. Spores produced by *Bacillus anthracis* retain germination capacity even after 40 years of drought (Kwaśna, 2007). Soil moisture indirectly determines the soil air content and temperature (thermal properties), i.e. it stimulates or limits the intensity of microbiological processes. The soil water content significantly influences the processes of ammonification, denitrification and nitrification, which reach their maximum at the so–called field water capacity. Therefore, they are the most intensive in spring and autumn, and the least intensive in summer and winter.

Unlike air, water is the natural environment of microorganisms, where they can grow and reproduce. The water microbiota is less numerous and diversified than the soil environment. The key determinants of the development of aquatic microorganisms are the content of nourishment, oxygen, temperature, pH and the presence of light. In clean waters with low amounts of organic substrate oligotrophic microorganisms are predominant because they do not need large amounts of organic compounds (Wargin and Marchelek, 2015). Water also contains organotrophic and lithotrophic microorganisms, whose main task is to oxidise NH_3 to NO_3 and the mineral compounds of iron and sulphur. Psychrophilic and mesophilic species predominate in waterbodies. Thermophilic microorganisms are present only in the surface waters of shallow inland waterbodies, hot springs and tropical waters. Water is the natural habitat of autochthonous (indigenous) microorganisms, e.g. sulphur bacteria of the *Beggiatoa*, *Thiobacillus*, *Thiothrix* and *Chlorobium* genera and iron bacteria of the *Crenothrix*, *Gallionella* and *Leptothrix* genera. There are also colonies of allochthonous microorganisms brought from other environments (air, soil, sewage, the digestive tract of humans and animals). These microorganisms can survive several weeks in surface waters or several days in tap water. Examples of allochthonous microbiota include *Shigella*, *Escherichia coli* and *Salmonella*. It must be remembered that water may also be the habitat of various pathogens, especially when it is contaminated with faeces. They may cause various human and animal diseases. The most common genera of pathogenic bacteria include: *Salmonella*, *Campylobacter*, *Vibrio cholerae*, *Escherichia coli* and *Mycobacterium*. They cause gastric disorders, such as typhoid, pulmonary tuberculosis, cholera, etc. (Łubkowska, 2016; Księżopolska, 2019). Fresh waters contain ciliated and mobile bacteria of the *Pseudomonas*, *Vibrio*, *Spirillum*, *Spirochaeta* genera, as well as *Azotobacter vinelandii* – the bacteria which fix free nitrogen from the air dissolved in water, *Caulobacter* – bacteria with holdfasts, thanks to which they can adhere to underwater objects, sulphur and ferrous bacteria. If there is access to light and oxygen in inland waters, numerous algae develop and produce antibiotic substances eliminating bacteria. Bacteria of the *Pseudomonas*, *Cytophaga* and *Caulobacter* genera coexist with algae, which supply oxygen to them. At greater depths, where access to oxygen and light is limited, purple and green bacteria develop. They oxidise hydrogen sulphide, which is toxic to algae, and is released as a result of the sulphate respiration of *Desulfovibrio*, *Clostridium* and methanogenic bacteria. There are few bacteria in seas and oceans due to high salinity and osmotic pressure as well as low content of nutrients. At great depths in seas, where there is no access to light, bioluminescent bacteria live in symbiosis with fish (Kwaśna, 2007).

Water is a basic component of microbial cells. It is also the place of existence of numerous microorganisms, especially cyanobacteria and prokaryotes, which belong to Gram–negative bacteria (formerly to algae). These bacteria are commonly found in ponds, lakes, swimming pools, seas and moist soil. They can also be found in oceans, and some species inhabit even hot springs. The first cyanobacteria appeared more than 3 billion years ago. This fact is evidenced by stromatolites – conical rock formations (calcium carbonate), which consist of a large number of very thin layers of prokaryotic cells, mainly cyanobacteria. Stromatolites can be found in various places around the world, e.g. around Great Slave Lake in Canada and Lake Superior in the United States. Apart from these extremely old traces of cyanobacteria, now these organisms also form stromatolites with colonies of living cells in the hot and shallow waters of Yellowstone National Park and in Shark Bay, Australia (Solomon et al., 1996). Cyanobacteria were the first photosynthetic autotrophs to break down water to obtain a hydrogen proton, which combined with its NADP+ acceptor and formed NADPH (nicotinamide adenine dinucleotide phosphate – reduced form), a high–energy compound that is necessary for the formation of energy–rich carbohydrates. During the photolytic decomposition of water, oxygen was also released. Initially it was used to oxidise inorganic substances in oceans. After some time its excessive amounts passed into the atmosphere and initiated a change in its composition (Solomon et al., 1996; Błaszczyk, 2007).

Plants primarily use edaphic nutrients dissolved in soil water as products of the microbial activity. Plant roots take up this water and then transport it to the aerial tissues thanks to the processes of diffusion, imbibition and osmosis (Solomon et al., 1996; Lack and Evans, 2001; Bandurska, 2007; Kochhar and Gujral, 2020). The driving force that enables the flow of water from the soil through the conductive tissues to the atmosphere is the gradient of its chemical potential, which is a function of pressure, temperature and the amount of molecules of the substances dissolved in it (Bandurska, 2007; Taiz et al., 2018). The course of these processes is determined by the structural characteristics of cells and environmental factors (Saccon, 2018). Precipitation is a direct source of soil water, which is mainly used by plants. They can absorb small amounts of this valuable substance directly from rainfall or dew. The pathway of water transport in plants can be divided into three segments of different length. The first, which is very short, comprises the conduction of water in the root from the hair cells to the xylem (Kim et al., 2014). The second, which is very long and often reaches up to 100–150 m, comprises water transport in the root and stem, mainly through dead cells, i.e. tubules in gymnosperms or xylem vessels in angiosperms. It also comprises the transport of water in the leaves through branches of the vascular tissue network. The third segment of water transport is the shortest. It comprises the movement of water in the cells of the foliar parenchyma and its evaporation as water vapour into the atmosphere. Capillary forces, adhesion, cohesion, transpiration and root pressure enable massive flow of water in the xylem over long distances. The rate of water flow in the plant depends on the anatomical structure of the conductive elements and their diameter. It may range from about 1.0–1.4 $m \cdot h^{-1}$ in coniferous trees to 16.0–45.0 $m \cdot h^{-1}$ in deciduous trees (Bandurska, 2007).

The vast majority of the water taken up by plants is lost in the process of transpiration, i.e. it is evaporated from their surface. Leaves are the main transpiring organs – water vapour escapes from them mainly through the stomata (stomatal transpiration) or through the epidermis and cuticle (cuticular transpiration), which is much less intense. Transpiration enables not only the flow of water and mineral salts from the root through the conductive vessels to the leaves, but it also lowers the temperature of various organs and protects them from overheating. The transpiration processes in plants exposed to frequent water deficits are limited by the reduction of the leaf surface (conifers) or their disappearance (cactus plants), as well as by hairs or wax on their leaves.

In order to produce organic matter plants use only about 0.05% of the considerable amounts of water they take up (Bandurska, 2007). The amount (g or dm^3) of transpired water that is necessary to produce a specific (g or kg) dry biomass is defined as the transpiration coefficient. Its values vary considerably for different plants and fluctuate within very wide ranges, from about 200 to about 1,000 dm^3 of water per kg of plant biomass (Bandurska, 2007; Mocek and Drzymała, 2010). They are not a constant value, because they depend on a large number of external factors (soil moisture, temperature, fertility, pH, as well as plant species and air temperature, etc.).

Water is not only a carrier of nutrients and cooling medium in herbaceous plants, but also a substrate in photosynthetic reactions and a product of plant respiration. Water molecules also stabilise the structures of proteins, nucleic acids and saccharides. Apart from that, they enable plants to survive under thermal or biotic stress (Bandurska, 2007; Kozłowska, 2007; Filipović, 2020).

As a result of evolution, plants adapted to variable content of water in soil. There are two types of plants: poikilohydric and homoiohydric (Bandurska, 2007). The former are characterised by variable hydration, which adapts to the environment. If there is a high water deficit, they can dry up completely, but this does not damage their structure. Examples of poikilohydric plants include some mosses, liverworts, and ferns. Homeohydric plants are characterised by relatively constant tissue hydration, regardless of the degree of soil moisture. This group includes most higher plants and all crops. Four ecological types can be distinguished among homeohydric plants with respect to their water management: xerophytes, mesophytes, hygrophytes and hydrophytes (Bandurska, 2007).

Animals. Water is a basic component not only of plant but also animal organisms. It is the habitat of some animals, too. It makes up about 70% of their bodies (Dojlido, 1997). It also has various functions as a basic component of body fluids transporting nutrients and eliminating toxins from organisms. It is the main ingredient of blood plasma, a factor distributing various substances in animals' bodies. The excess of water evaporates from the body surface or it is excreted by specialised organs. Therefore, animals should have constant access to good-quality, fresh water. This particularly applies to farm animals, because their products are consumed by humans. It is estimated that beef cattle need to drink 20–33 l of water daily, porkers – 8–14 l, sheep – 6–7.6 l, and broilers – 0.18 l. The amount of water for handling these animals ranges from 5 to 11 l for beef cattle, 25–50 l for porkers, 1.3–5 l for sheep and 0.10 l for broilers. The total share of water for drinking and handling animals amounts to only 1.1% and 0.8%, respectively (Florek et al., 2017).

As a result of long-term evolution, animals living in various environments have developed a wide range of self-regulating mechanisms. For example, the concentration of salt in the body fluids of freshwater animals is much higher than in the surrounding water. Therefore, they are often referred to as hypertonic or hyperosmotic animals. The bodies of freshwater fish are covered with scales and mucus in order to prevent excessive penetration of water from the external environment. The excess of water which usually enters their bodies through the gills is excreted by the kidneys in the form of highly diluted urine. On the other hand, marine animals living in saline waters have to replace the loss of body fluids. Many marine bony fish (osteichthyes) drink seawater, which contains large amounts of salt, which is then removed through their gills. Their kidneys excrete very small amounts of urine. Other aquatic marine animals, such as cartilaginous fish (e.g. sharks and rays), have developed special osmoregulatory mechanisms, thanks to which they can tolerate high concentrations of salt, which they store in the form of urea in body fluids (Solomon et al., 1996).

Human**.** The first civilisations appeared and developed in areas that were abundant in water. As early as several thousand years before Christ the foundations of modern agriculture, based on the use of water for various irrigation systems, were born in the fertile river valleys of the Nile, Huang He, Ganges, Euphrates and Tigris. However, people did not predict that excessive concentration of salt in the waters of these rivers in the subtropical zone, especially in Mesopotamia, would cause high salinity of soils and result in the collapse of these civilisations (Hillel, 1995, 2012). Water is both the first and the last natural liquid that humans encounter when newborns are washed immediately after birth and corpses are washed before passage to eternity. Water performs the same metabolic functions in the human body as in animal bodies. It constitutes about 70% of the human body mass and as much as about 90% of blood plasma. The water content in human tissues ranges from 20% in bones to as much as 85% in brain cells. Embryonic and young cells are characterised by the highest content of water (Małecka and Staszewski, 2015). Its amount in the body decreases with age. It may decrease even to 50%. The female body contains about 10% less water than the male body because of a slightly higher fat content (Łubkowska, 2016). Water is present in the nervous, digestive, muscular, skeletal, excretory and circulatory systems. The daily demand for water strictly depends on the body weight, sex, working conditions, season of the year, etc. However, it should not be less than two litres (Tsindos, 2012). The human body absorbs considerable amounts of water along with food of plant and animal origin (Table 9).

Marshlands have always been inhabited by some ethnic groups, e.g. the Ma'dân, also referred to as the Marsh Arabs. They live in the marshlands of the lower Mesopotamian Plain in the forks of the Tigris and Euphrates Rivers. They are considered descendants of the Sumerians, and like them, they have been building reed houses without nails on hundreds of small islands since the fourth millennium BC. In the late twentieth century the then – President Saddam Hussein, the former Iraqi dictator, ordered to drain and destroy large parts of these swampy areas for the political disobedience of the Ma'dân. Currently this so-called Mesopotamian Venice is the first national park in Iraq, with an area of about 3,500 km^2. Being one of the largest marshlands in the world, these Iraqi areas were inscribed on the UNESCO World Heritage List. Thanks to this organisation and the allocation of financial resources, the rich history of these unique Mesopotamian marshlands is gradually being restored.

Table 9
The water content in foods (%) (website 3)

Food item	Water content (%)	Food item	Water content (%)
Chocolate	3	Beef	71
Walnuts	5	Bananas	75
Salo	9	Fish	80
Butter	16	Apples	84
Honey	20	Carrots	89
Cheese	36	Strawberries	90
Bread	42	Mushrooms	93
Chips	57	Tomatoes	94
Ketchup	65	Cucumbers	96

7. Water as an element of the inanimate environment

There has been continuous rivalry between two types of natural forces throughout the history of the Earth. One type causes the development of terrain and convex forms (orogenesis – geological processes resulting in the formation of mountains; epeirogenesis – upheaval of land), whereas the other type levels the terrain (water and wind).

Erosive processes, which mainly involve water and wind as factors transporting rock materials over long distances, often cause considerable degradation of the subsurface layers of the Earth's crust. Water erosion is a natural and inevitable process, which constantly occurs in specific natural ecosystems. It also referred to as geological or natural erosion (Prochal et al., 2005).

There are much worse consequences of accelerated erosion, intensified by ill–considered human activity, i.e. the anthropogenic factor (tree logging or burning, which causes deforestation, overgrazing, river regulation, etc.) (Kędziora, 2011). The removal of vegetation from the areas where the soil is composed of loess or other materials that are highly susceptible to erosive processes, triggered the destructive activity of water from rivers, which transported large amounts of clastic material. For example, the Huang He River (Yellow River) transports even as much as 1,900 million Mg (tonnes) of loess suspension in its waters. Other rivers in southeast Asia, such as the Ganges, transport about 1,500 million Mg, whereas the Brahmaputra and the Yangtze carry over 1,000 million Mg (Karczewska et al., 2015).

Water may not also damage the soil surface, but also be disastrous to humans when floods, tsunamis, and other phenomena resulting from either intense rainfall or subduction processes caused by tectonic movements of the continental and oceanic plates in the top part of the lithosphere lead to enormous destruction. Climate change, which has been observed for many decades, also contributes to these processes (Climate Change, 2007; Kędziora, 2011; Kundzewicz, 2011, 2012). Deeper underground waters often also have negative influence, because they flood mines with various mineral resources.

Short but heavy rainfall increasingly often causes mini–floods (inundations) in city centres. They are caused not only by the forces of nature, but also by strong human impact on the environment, which constantly limits the number of open soil surfaces in urbanised areas. Humans cover almost every free space with asphalt and concrete. Thus, the natural soil cover is transformed into technogenic soils, most of which belong to the *Ekranic Technosols* subtype (French *écran* – screen, cover) (PSC, 2019). In the past these were natural soils, but now they are covered by a solid technogenic layer. These soils can be found in the urban environment under old roads, pavements, car parks, company yards, etc., where they limit the natural infiltration of rainwater into the soil. In consequence, water from a 300–500 mm rainfall cannot be retained in the one–meter zone of the pedosphere. This causes huge amounts of rainfall enter rainwater sewage systems in a short time. As these systems are not prepared to collect such large amounts of water, there are floods in streets and local land depressions.

Water is also an important mineral, which is used directly or indirectly in almost all sectors of the economy. The demand for water is particularly high in the heavy industry, especially the mining and energy industries. Although the mining industry uses deep groundwater water and moves it to the surface, it cannot be further used for economic purposes due to its quality. Open–pit lignite mining has greater possibilities to use groundwater (Palaeogenic–Neogenic groundwater) (Gajewski et al., 2015; Owczarzak et al., 2017). Huge amounts of water – several dozen million cubic meters per year – are taken and discharged through the drainage barrier of open–pit mines into local lakes and rivers, from where they flow to the Baltic Sea (Rząsa et al., 1999; GUS, 2019). These waters are characterised by good physicochemical parameters and could be used by agriculture, especially during periods of rainwater deficit in the growing season. However, large amounts of money needs to be invested to develop appropriate infrastructure. The Konin and Adamów Lignite Mines pumped out over 7.5 billion m^3 of groundwater during their operation (Kasztelewicz and Szwed, 2010).

The energy industry consumes enormous amounts of water. Every three minutes, coal power stations need the amount of water that could fill up an Olympic–size swimming pool (Marciniak, 2020). Huge amounts of water (steam) are necessary to drive steam turbines in classic, thermal power stations as well as nuclear and heliothermal stations (Łubkowska, 2016). These power plants differ in the electricity production technology – they use different thermal energy carriers (coal, fission of heavy nuclei, solar energy) to convert liquid water into steam and drive turbines (mechanical energy) activating electricity generators. These power stations also use large quantities of water to cool steam turbines in cooling towers. These turbines are usually cooled with water taken from lakes located in the vicinity of power plants. Although power stations use relatively closed circuits, they are certainly leaders in water consumption.

Almost no product can be manufactured without water. According to the Water Footprint Network, the indicator which specifies the amount of freshwater used directly or indirectly to produce any natural thing is referred to as the water footprint (Allan, 1998; Hoekstra and Chapagain, 2007; Hoekstra et al., 2011; Mekonnen and Hoekstra, 2012; ISO 14046, 2014; Stępniewska, 2014, 2015; Lovarelli et al., 2016; Florek et al., 2017; Wróbel-Jędrzejewska et al., 2019). Each citizen in Poland leaves a water footprint of about 3.9 m^3 per day, which exceeds 54 million litres per annum, so 1,423.5 m^3/yr (Marciniak, 2020). The average consumer in Poland had a water footprint of 1,400.5 m^3/yr in periode from 2006 to 2011 (Stępniewska, 2015). This value is close to the world average. We are usually unaware of the fact that the values of this indicator for various products seem incredibly high (Table 10). As results from the data presented in Table 10, agricultural products are characterised by high water footprint. This fact was also stressed in studies conducted by other authors (Burszta-Adamiak and Fiałkowicz, 2018). It is particularly important to take this into consideration in view of increasingly frequent droughts (IPCC, 2013, 2014).

The examples given above clearly show that enormous amounts of water are consumed to make a large number of basic products. These facts should encourage reflection upon un-

Table 10
The water footprint in some popular products (website 4)

Product	Litres of water	Product	Litres of water
Sheet of paper	10	T-shirt	2,495
Cup of coffee	132	Kilo of rice	2,497
Pint of beer	170	Kilo of cheese	4,325
Chicken egg	196	Kilo of chicken	5,553
Glass of milk	255	Kilo of butter	3,118
Kilo of potatoes	287	Pair of jeans	11,000
Kilo of cucumbers	353	Kilo of chocolate	17,190

necessary purchases and food waste. According to statistics, the amount of food wasted (thrown away) in Poland is high, i.e. 235 kg per capita per annum, as compared with the European average, i.e. 179 kg per capita per annum (Marciniak, 2020). Apart from saving water, it is also necessary to maximise its retention in soil and reservoirs. Unfortunately, there are too few reservoirs, not only in Poland. It is also necessary to store water in small reservoirs such as garden ponds and in rainwater tanks so that it can be used to water lawns and gardens (Kędziora, 2008; Kundzewicz, 2012).

Water is also credited with healing properties as it can be used to combat all ailments by means of hydro massages, steam baths in saunas, or mineral and spring waters, which have healing and purifying parameters (Łubkowska, 2016). Each year SPA centres (*sanus per aquam* – healthy by water) are becoming increasingly popular with patients.

Apart from recreational and sports properties, water also plays an important role in landscape. Various types of landscapes are distinguished, depending on the type of surface waters, e.g. river, lake, sea, glacier, etc. (Wiśniewski and Gwiazdowicz, 2009). In many countries there are geysers and hot springs in the places where volcanic activity is disappearing. There are national parks where waterbodies are the main element, e.g. Plitvice Lakes National Park (Croatia). It has amazing views of waterfalls with turquoise and green cascades of water flowing into the lakes. The colour effect is caused by various chemical compounds from local rocks dissolved in the water. It is also noteworthy that in the mountains of various countries all over the world there are numerous waterfalls, which differ in height, width and the amount of flowing and falling water per unit of time.

Not only liquid water is an admirable element of landscape. Snowy and icy landscapes as well as clouds, fog, rime, rainbows, and the halo (a rainbow around the Sun or Moon), made of water vapour, look charming and provide unforgettable optical impressions.

Hydropolis Wrocław is the only water knowledge centre in Poland and an interesting educational facility. The multimedia exhibition, which opened at the end of 2015, is dedicated to the most precious treasure – water. It is very popular among people of all ages. The exhibition is divided into nine thematic zones (Planet of Water, Depths, Ocean of Life, Relaxation Zone, Man and Water, History of Water Engineering, City and Water, Stages, and Temporary Exhibitions) with 64 interactive devices, which make the museum an attractive and modern educational centre (website 5).

8. Summary

This article discusses the specific properties of water as a chemical compound which has always been inextricably linked with living organisms. It describes the numerous important roles of water in metabolism and indicates its significance for the soil environment and as a factor satisfying the human demand for food as well as a vital element of recreation, sports, landscape and economy. Research has proved that at the current stage of development life can only exist on a planet with abundant resources of this natural and irreplaceable substance.

In the futuristic opinion of planetary scientists, water will still be present on our globe for about a billion years. This prediction is based on the fact that the Sun increases its radiant energy by about 10% after each billion years of its existence. This means that in the distant future the temperature on the Earth will rise and all waterbodies will evaporate, putting an end to inhabitants of the planet. The Earth will become a dry and hot planet similar to Venus. However, before this happens, it is necessary to fully protect water resources, both globally and locally. Poland has some of the smallest water resources in Europe, despite a relatively large number of rivers and glacial lakes. It is assumed that there is 1,600–1,800 m^3 of water per capita per annum in Poland, i.e. the amount of water flowing to the sea per one inhabitant (Żurek, 2008). Although it is still a safe level (1,000 m^3 is considered critical), it is almost 2.5 times less than the European average (Kędziora, 2008; Małecka and Staszewski, 2015; Mancosu et al., 2015). The disruption of the global water balance may lead to numerous international conflicts, as was the case many times in the past. Currently this is the cause of tension on the border between Israel, Syria and Palestine. Although in 1994 the United Nations established World Water Day on 22 March each year, it will certainly not save our planet from the increasing water deficit.

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Woda – ważny element nie tylko środowiska glebowego

Słowa kluczowe

Woda
Właściwości fizyczno-chemiczne
Gleba
Organizmy żywe
Ślad wodny

Streszczenie

W artykule przeglądowym przedstawiono wodę na naszym globie jako substancję niezwykłą, stale towarzyszącą człowiekowi. Zasygnalizowano najważniejsze właściwości fizyczne (gęstość, temperaturę wrzenia, temperaturę maksymalnej gęstości, temperaturę krytyczną, ciepło topnienia, ciepło parowania, ciepło właściwe, napięcie powierzchniowe, lepkość dynamiczną, przewodność elektrolityczną) oraz chemiczne (odczyn, rozpuszczalność) tej substancji. Są one istotne dla funkcjonowania zarówno organizmów żywych (mikroorganizmów, roślin, zwierząt, człowieka), jak i elementów nieożywionych środowiska (litosfery, zbiorników, cieków wodnych, krajobrazu itp.). Zaprezentowano poligenetyczne pochodzenie wody (z emisji gazów wulkanicznych, lawy, komet, asteroidów). Scharakteryzowano zasoby wodne globu, ze szczególnym zwróceniem uwagi na wody słodkie, występujące w ograniczonych ilościach, a na które zapotrzebowanie rośnie w sposób eksponencjalny. Zobrazowano to tzw. śladem wodnym, wskaźnikiem ilości wody słodkiej użytej bezpośrednio lub pośrednio do wyprodukowania jakiejkolwiek rzeczy naturalnej lub sztucznej. Wskazano także na negatywne strony wody (powodzie, tsunami, erozja wodna), które w ostatnich wiekach zostały spotęgowane nieprzemyślanymi działaniami człowieka (wycinka lasów, ograniczenie zdolności retencjonowania wody przez glebę itp.). Podkreślono właściwości lecznicze wody, służące do zwalczania wielu typów dolegliwości (masaże wodne, kąpiele parowe, oczyszczające parametry wód mineralnych i źródlanych). Wspomniano o krajobrazowej funkcji wody zarówno w stanie ciekłym (wodne parki krajobrazowe, gejzery, termy, wodospady), jak i w stanie stałym: lodowce bądź gazowym (mgły, chmury, tęcza, zjawisko halo). Zwrócono uwagę na konieczność oszczędzania wody tak w ujęciu globalnym, jak i lokalnym. Zaakcentowano, że stale zwiększający się deficyt tej cenniejszej od złota substancji, może w niedalekiej przyszłości stać się przyczyną wielu konfliktów, które już w różnym nasileniu występowały w przeszłości.