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# 1 ESSENTIAL FOR LIFE – WATER IN VIEW OF NATURAL SCIENCES

WITHOUT WATER NO LIFE – MANKIND KNEW THIS ALREADY SINCE PREHISTORIC TIMES. MANY RITES AND CUSTOMS, BUT ALSO TECHNICAL PLANTS FROM THE DIFFERENT CULTURES GIVE EVIDENCE FOR THE INDISPENSABILITY OF WATER, BUT ALSO FOR THE DANGERS CONNECTED WITH WATER IN ITS DIFFE-RENT FORMS OF APPEARANCE. THE DEVELOPMENT OF THE BRANCHES OF WATER RESEARCH CORRESPONDS TO THE IMPORTANCE OF WATER. TODAY IT IS WELL KNOWN THAT THE SUBSTANCE WATER IN ITS SOLID, LIQUID AND GASEOUS PHASE SHOWS PHYSICAL AND CHEMICAL PECULIARITIES. COMPARED WITH SIMILAR CHEMICAL COMPOUNDS ONLY WATER HAS SUCH ANOMALIES. WITHOUT THESE THE OCEANS, THE GLOBAL ENERGY AND MATERIAL CYCLES AS WELL AS THE CONTINENTS WITH THEIR VEGETATION, LAKES, RIVERS AND SO ON INCLUDING MANY ATMOSPHERIC PROCESSES COULD NOT EXIST AS WE KNOW THEM. WATER IS THE PREREQUISITE OF LIFE AND OUR CIVILIZATION. THE ORIGIN OF ANY WATER SUPPLY FOR MAN IS THE GLOBAL WATER CYCLE WITH ITS MANIFOLD COUPLINGS TO WEATHER AND CLIMATE AS WELL AS TO NATURE AS A WHOLE. THE FOLLOWING CONTRIBUTIONS GIVE IMPORTANT BASIC KNOWLEDGE AND A GOOD INSIGHT INTO MANY FEATURES OF THE WATER PROBLEM.

## 1.1 Water as the basis of life

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***SUMMARY:*** *Without water the Earth would be a dead desert. Water is a pre-requisite for life, is involved in almost all processes of life on our planet and has many functions in the climate system as well. All organisms contain 50–90% water, some aquatic organisms even 99%. If water becomes scarce or has poor quality, plants and animals die. Humans must drink about two litres of water per day. The function of water cannot be substituted by any other substance. 98% of the water on Earth is salty and unsuitable for drinking and irrigation. 1.8% is frozen in glaciers and snow. Only 0.77% occurs as liquid freshwater and its distribution is very inhomogeneous. Today, already about 20% of the world's population are suffering from scarcity of water. Water will be the most important substance during this century and therefore we need a global water policy guided by the United Nations.*

Without water our planet Earth would be a gigantic dead desert. According to present knowledge the Earth is the only planet of our solar system with water in all three phases: solid, liquid and gas. The Earth's surface is clearly dominated by water: 70.8% of it (361.2 million km²) is covered by the oceans, about 3.16% (more than 16.1 million km²) by ice on land. Lakes cover approx. 2 million km² (0.39%). Including rivers and wetlands, with approx. 2.7 million km² (0.53%), the total water-covered surface of our planet is above 75% (MARCINEK & ROSENKRANZ 1996). This is without considering the surface that are constantly covered with snow. In the troposphere water also occurs in liquid, gaseous and solid form, and very small amounts of water from the troposphere can even reach the stratosphere by means of turbulence.

Water has very important functions in the world. It plays a central role for the climate and for the co-evolution of the life on Earth. In this chapter the important facts about water as the basis for life and the evolution of the biosphere on Earth are summarised.

### Origin of life

Cooling of the Earth 4 billion years ago allowed water to establish its liquid form. There are several hypotheses regarding the origin of the water on our planet. Currently the prevailing assumption is that water might have arrived on Earth through comets. This is supported by observations scientists made in the year 2000 when investigating the comet LINEAR-S4. According to the analysis conducted by the space observatory SOHO (Solar and Heliospherical Observatory), the water discovered after the comet broke up had an isotope-composition identical with the water of our seas. Further investigations by the probes Stardust (NASA) and Rosetta (ESA) are expected to deepen our knowledge on this subject.

It has been agreed upon by the scientific community that life on Earth had its origin in the sea, most likely in depths protected from the dangerous UV-radiation reaching the surface. The communities that exist in the deep ocean today, and which have as their energetic basis volcanism at temperatures between 80 and 120 °C (chemosynthesis) show that sunlight is not absolutely necessary for the development of life. So it is assumed that the first basic

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components of life possibly formed more than 3.5 billion years ago in clouds containing sulphur and hot lava from volcanic eruptions at the sea bottom (Prilipp 2001). These first primitive beings had to exist under anaerobic conditions, because free oxygen was first available many million years later after the first photosynthetic organisms evolved (cyanobacteria). These prokaryotic micro-organisms can use water ($H_2O$) instead of hydrogen sulphide ($H_2S$) as H-donor which results in the release of oxygen ($O_2$) instead of sulphur ($S_2$).

Cyanobacteria have existed for at least 2.7 billion years, thus belonging to the oldest organisms on Earth. They were the first to perform photosynthesis. This was during the Precambrium – the time between 3.8 billion and 540 million years before present (Arp & Böker 2001). Enrichment of the sea water with oxygen was an important step in evolution. Aerobic processes yield – as described later – a much larger output of energy than anaerobic processes, a fact surely advantageous for the aerobic organisms. Furthermore, the increase of oxygen in the water had a toxic effect on the older anaerobic creatures. These »anaerobes« probably were displaced gradually into the sediments. The largest part of the oxygen ($O_2$) produced by photosynthesis was bound first of all as insoluble ferric oxide ($Fe_2O_3$) and as sulphate ($SO_4^{2+}$). Only 4% of the world's oxygen is estimated to be free $O_2$ in the atmosphere and hydrosphere and the major part to be bound to the lithosphere.

Much later, the development of an enriched oxygen atmosphere and the formation of a stratospheric ozone layer allowed marine organisms to conquer land. Without this ozone layer terrestrial life would not have been possible because of the dangerous UV-radiation.

From the very beginning of life on our planet, water was of great importance. Almost all biochemical processes presuppose the presence of water (more details below), i.e. without water the formation of the basic components for the primeval organisms' origin would not have been possible. This is also the reason why the extraterrestrial search for life is coupled with the search for the presence of liquid water.

## Settlement of the continents

Life spread from its origin in the oceans over the entire Earth. Even in regions where water is very scarce like the deserts, plants and animals succeeded in adapting to these extreme conditions and can be found there today. Other extreme environments such as the polar regions with average temperatures between -10 °C and -40 °C, also harbour a variety of life forms ranging from penguins and mammals, e.g. polar beers and arctic foxes, to algae, fungi, and bacteria. The largest diversity developed in the wetlands like rainforests, river pastures, lakes and swamps.

The colonisation of freshwater habitats and landmasses by plants is thought to have begun about 380–310 million years ago. The first animals were possibly amphibious living organisms. The largest physiological barrier for the marine organisms conquering the terrestrial and freshwater habitats was the lack of salt in water. Over the course of evolution plants and animals had to adapt to these new conditions by developing different strategies. Freshwater environments are characterised by a low salinity. This results in an ionic concentration-gradient between the internal environment of life form and its surroundings, leading to a constant stream of water into the body. As a consequence the organism is forced to pump out this osmotically penetrating water at the cost of energy.

Furthermore, the organism has to actively take in salts (hypertonic regulation). The intake of salt is not generally specific however. With increasing pollution of the environment this may lead to harm for the organisms when essential salt ions like potassium and sodium are mixed up with contaminants like heavy metals.

The greatest challenge for plants and animals are the habitat conditions in the tidal regions and estuaries. This is because they need to be able to tolerate the relatively great fluctuations in salinity characteristic for these environments. The physiological adaptations to these ever-changing conditions require a high-energy effort to maintain osmotic homeostasis through excretion or uptake of ions and water or other mechanisms. Similarly, terrestrial organisms must actively maintain their water and electrolyte budget.

Some organisms like fish, birds and mammals have resettled the sea secondarily (secondary sea animals). As the former adaptations of life to the osmotic environment in the sea were irrevocably lost, they had to develop new strategies and/or organs, to exclude salt and to take in water periodically. For this purpose sea-gulls (*Larus*) e.g. developed salt glands that help to excrete surplus salt. These new adaptations have energetic costs, a disadvantage in comparison to the primary sea organisms. The additional energy plants and animals needed for the colonisation of new habitats had to be compensated at least partially by new mechanisms to render this step advantageous.

## Distribution of micro-organisms, plants and animals

The organisms most important for the primary production in the sea and the turnover of organic matter are the members of the bacterio- and phytoplankton communities. With respect to the total biomass, these pro- and eukaryotic micro-organisms are of much greater importance than the macro-algae (including the brown algae in the Sargasso Sea) and all representatives of the kingdom of animalia.

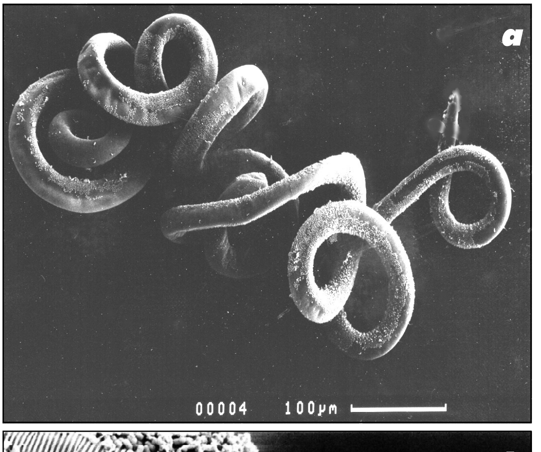
Microbiologists estimate that micro-organisms constitute more than half of the biomass on Earth. At maximum only 1% of all the omnipresent and important bacteria and archaea species have been recorded up to now. The turnover of organic materials would not be possible without micro-organisms. There is no natural substance, which could not be utilised or transformed by microbes. Numbers of bacteria per millilitre water are reported in a range of $0.1\times10^6$ to $0.7\times10^6$ in oligotrophic lakes and $1.8\times10^6$ to $40\times10^6$ in eutrophic ponds, lakes and reservoirs (WETZEL 1983). In the marine habitats prokaryote numbers vary in a similar way depending on the concentration of organic material. Bacterial numbers reported from oceanic euphotic surface layers are comparable to those in oligotrophic lakes but much higher when newly discovered ultramicrobacteria are taken into account. Because the majority of organic matter is deposited at the bottom as sediments, approx. 95% of all micro-organisms live in these benthic habitats (PRILIPP 2001).

Thus, diversity of the marine environment is dominated by the two groups of bacteria (archaea and bacteria *senso stricto* including cyanobacteria) and various eukaryotic heterokontobiont, rhodobiont and chlorobiont algae (diatoms, green-, brown- and red-algae and others) as well as various mycobionts (fungi). Bryophyta (moss), pteridophyta (fern), and spermatophyta (seed), which dominate on the land, are almost completely missing in the sea. Seagrass, which forms extensive meadows in coastal ground, belongs to the few exceptions. This kind of plant, however, has settled in the sea secondarily. In freshwater brown algae are missing. In contrast to the marine flora and fauna of the upper water layers, which are easily accessible and consequently have been recorded systematically very well, less is known about animals and micro-organisms living in the deep-sea habitats.

The world species inventories are dominated by the terrestrial fauna. 70% of all species described to date belong to the class of insects, while approx. 20% are aquatic, and only 0.2% of the described aquatic species live in the seas. This is in contrast to the fact that more than 75% of the Earth's surface is covered with water. At least 19 of the 22 metazoan phyla are represented in the sea, 15 phyla have their main distribution area in the marine environment, reflecting the role of marine habitats in evolution. The insects' and also the vertebrates' explosion on land are most likely connected with the structural diversity of terrestrial habitats resulting in regional isolation, which has a strong influence on evolution. Many marine species groups have survived over millions of years in nearly unchanged form, bearing evidence of the conservative character of the marine biosphere.

## Survival by »co-operation«

In unfavourable conditions a kind of inter-specific partnership (symbiosis) is very often observed between two or three partners, with host and symbionts mutually profiting. Without this co-operation survival in unfavourable conditions would be very difficult and the evolution of the present diversity on Earth in the plant and animal kingdom would not have been possible (*Fig. 1.1-1*).



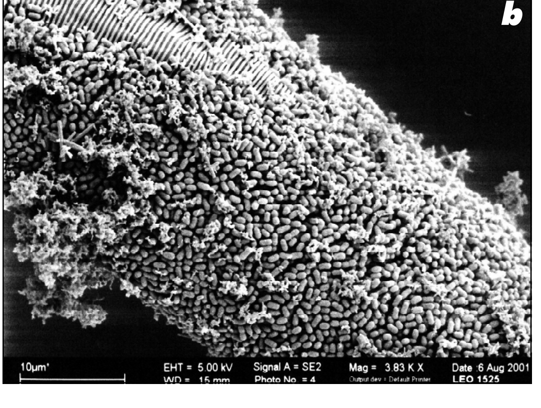




***Fig. 1.1-1:*** Another example of partnership is formed by the intestineless oligochaet *Olavius algarvensis* (***a:*** host) with ***b:*** sulphur bacteria (primary symbionts) and sulphate bacteria (secondary symbionts). The foto shows the bacteria on the surface of the host. The sulphur bacteria use $H_2S$ as H-donator. The energy won serves to form carbohydrate from $CO_2$ and $H_2O$. By reducing sulphate ($SO_4^{-2}$) the sulphate bacteria make sure that sufficient $H_2S$ is constantly available to the sulphur bacteria (DUBILIER et al. 2001). Multitude of symbioses in the plant and animal kingdom have been discovered recently thanks to molecular biological and biochemical methods.

For these organisms the only way to survive under extreme conditions was co-operation. As a consequence of climate change the water scarcity in arid regions will become the problem number 1 in the 21st century. The successful survival in evolution shows us that the neighbouring countries in regions with extreme water scarcity have to co-operate as the only possibility to solve this problem (Foto: O. Giere - from RIEMANN et al. 2003).

A classical example is the co-operation of heterotrophic arbuscular mycorrhizal (AM) fungi and autotrophic algae, when 400 to 500 million years ago the first probably bryophyte-like plants colonised terrestrial habitats. According to the hypothesis of Pirozynsky & Malloch (1975) an AM was helpful, because without this co-operation, in the new environment the algae would have major problems to take up water and nutrients like phosphorus. Even now, the majority (more than 80%) of terrestrial plants is fed with support of AM symbionts. Correspondingly MA fungi play an important role in sustainable maintenance of plant health and soil fertility and have to be taken into account in the management of disturbed ecosystems including areas threatened by desertification. A proposed approach to combat desertification includes inoculation of symbiontic micro-organisms (Jeffries et al. 2003)

## Dissolved gases and solid substances

Water is the universal solvent for biological processes. It dissolves salts and organic solids from the soil, gases from the atmosphere, and organic as well as inorganic biogenic compounds and transports them via the rivers into the lakes and/or into the sea. Thus all waters found in nature (including the subsurface waters) contain dissolved inorganic materials (ions and trace elements), organic compounds (amino acids, humic substances, etc.) and gases (nitrogen, oxygen and carbon dioxide among others). As the water evaporates it leaves most of the dissolved substances behind. With the exception of aerosol particles, mainly pure water is transported through the atmospheric water circulation. As a consequence, water is a natural renewable resource. Substances emitted into the atmosphere can dissolve in rainwater and pollute it secondarily.

*Table 1.1-1* shows the great difference in the ionic composition of the dissolved solids in seawater and river water. Because of the ocean currents, seawater world-wide shows a very similar salt composition. In contrast, water of rivers and lakes varies in its composition depending on regional differences in the geochemical conditions. The values indicated in the table are thus average numbers.

***Table 1.1-1:*** The most important substances dissolved in sea and river water (%) (from Schwoerbel 1987).

| | *Sea water* | *River water* |
|---|---|---|
| $CO_3^{-2}$ | 0.41 ($HCO_3^-$) | ($CO_3^{-2}$) 35.15 |
| $SO_4^{-2}$ | 7.68 | 12.14 |
| $Cl^-$ | 55.04 | 5.68 |
| $NO_3^-$ | – | 0.90 |
| $Ca^{+2}$ | 1.15 | 20.39 |
| $Mg^{+2}$ | 3.69 | 3.41 |
| $Na^+$ | 30.62 | 5.79 |
| $K^+$ | 1.10 | 2.12 |
| $(Fe,Al)_2O_3$ | – | 2.75 |
| $SiO_2$ | – | 11.67 |
| $Sr^{+2}$, $HBO_3$, $Br^-$ | 0.31 | – |

Freshwater can typically be classified as carbonate water with $CaHCO_3$ being the prevailing compound. In contrast, sea water is a chloride type water, in which NaCl dominates. The ion composition of several inland waters like the salt lakes varies widely. For example, the Dead Sea has a salt concentration that is about 7.5 times higher than that of oceanic seawater with magnesium being the primary ion. Other salt lakes show different geochemical properties, which are of importance for the composition of flora and fauna.

## Water in life processes

Water is essential for all processes associated with life on Earth, outside as well as inside of organisms. The high water content of all life forms indicates the relevance of this element to all organisms. Bacteria, plants and animals including humans, consist of 50 to 80% water. Some aquatic plants and animals like gelatinous seaweeds and jellyfish can contain even up to 99% water. In insects the water content varies from 45 to 85%. Even the water content of different organs in terrestrial organisms can vary widely. Fruits like tomato and cucumbers contain 93–95% water, berries and leaves of many plants 80–90%, fresh wood 50%, crops 10–13%, walnuts and hazelnuts 7% (Tischler 1984).

An ensured water balance and ion budget is of central importance for the nutrition of all known organisms. Without water, plants would not be able to take up nutrients, since these must be in solution to be available for the plant. Furthermore, the water quantity and/or the moisture of the environment must be within optimal ranges. Too little or too much moisture has a life-limiting effect on many plant species. Unfavourable conditions for plants first result in failures in the functioning of certain organs, and then death of the whole plant. Death of animals occurs even more rapidly if they do not take in the minimum quantity of water in a certain period of time.

As indicated above, water has many functions within an organism. Physically, water serves as the transportation medium for nutrient salts and other vital materials such as enzymes and hormones to their target organs. Furthermore, it serves as the solvent for most metabolic reactions and for renal elimination of endogenous waste- and other toxic materials. Besides this, water is decisively involved in a great number of biochemical processes.

During oxygenic photosynthesis, which is performed by higher plants, algae and the photoautotrophic bacteria, water is oxidised in the presence of sunlight, releasing oxygen, protons and electrons ( $2\,H_2O \rightarrow O_2 + 4H^+ + 4e^-$). In this so called »Light Reaction« the electrons are transferred via the photosystem II and I coupling electron transport chains toward an acceptor protein. They are subsequently used in the so called »Dark Reaction« to drive the biosynthesis of reduced carbohydrates from $CO_2$ via the Calvin Cycle.

Even in the absence of light, chemolithoautotrophic bacteria are able to produce carbohydrates by a similar process. However, the necessary energy to drive this biosynthesis stems from the oxidation of externally available reduced chemical compounds such as $H_2S$, $NH_3$ or $H_2$. Photosynthesis and chemosynthesis are the most important biochemical processes on Earth, since they enable plant and animal life.

Water is involved in almost all processes of life. It is even involved in many biochemical reactions as an essential reaction partner such as in the enzyme catalysed hydrolysis used to split complex nutrient compounds.

Water of bad quality is neither suitable for drinking nor for plant irrigation. Seawater and brackish water, which represents approx. 94% of the water on Earth, cannot be used in agriculture and as drinking water because of its high salt content. About 6% of the Earth's water is freshwater, with the major part being groundwater (3.8%) or frozen as glaciers, sea ice, snow and permafrost (1.9%). Only a minor part (less than 0.2%), which is rather unevenly distributed across the planet, is directly accessible to mankind (Chart 4).

## Adaptation of terrestrial plants and animals to limited water availability

Over the course of plant and animal evolution various traits have been developed to adapt to regional and seasonal differences in the availability of water, to regulate the water flux and to maintain the water balance (ACKERLY et al. 2000). Water flux refers to the amount of water passing through a plant or an animal per day. Water balance refers to the physiological condition of an organism where the intake of water is equal to its net consumption by metabolic processes and the loss through cutaneous and transpiratory evaporation, and the excretion of water bound with the elimination of metabolic products.

**Plants**: Adaptations of the higher plants include morphological adaptations like longer roots to reach deeper water sources, horizontally more extended finer root systems to maximise water absorption, and changes in the size, shape and structure of leaves to reduce evaporation. Of specific interest are physiological and biochemical adaptations mainly designed to reduce the transpiration stream and to promote water retention.

One ecophysiological adaptive trait is to have the stomata more or less closed and to cope with the resulting low intracellular $CO_2$ concentrations by using an additional very effective $CO_2$ pump. This is realised by the C4 plants, so called because a C4 (and not a C3) compound is formed as the first stable intermediate of the photosynthesis of these plants. The C4 pathway is common in monocotyledon plants, including a number of warm season grasses typical for semi-arid environments, and a limited number of agricultural plants like corn, sorghum, and sugar cane.

Another strategy common in crassulaceans, and other succulent plants including pineapple and cacti is to use the so called CAM pathway (Crassulacean Acid Metabolism), opening the stomata during night, performing C4 activity, accumulate the C4 acids, and completing the photosynthetic process during daytime in the light.

Field studies in semi-arid regions show adaptive differentiations among plant populations with increases in the relative abundance of C4 and CAM plants as a response to climate change and changes in the global water system. In dry grounds, C4 plants can produce twice as much biomass as C3 plants. This has to be taken into account when managing the agricultural food and biomass production in such regions of the world.

**Animals:** Like plants, animals developed traits to survive under conditions where water availability is limited. They maintain the required water balance through a number of morphological, physiological, and (most important) behavioural adaptations (actual review by CAIN et al. 2005).

Morphological adaptations include body size and shape, type of skin and pelages, as well as distribution pattern of fat deposits, which all are of relevance for thermoregulation and control of evaporative water losses. Physiological adaptations include adjustments of the basic metabolism, reduction of water losses through faeces and urine, as well as alterations in sweating behaviour (temperature when sweating starts) and the pulmonary activity (slow and deep breathing).

Behavioural adaptations include the use of cooler and shaded microhabitats to reduce the need for evaporative cooling, timing of activities such as nocturnal feeding of forage plants containing more water during night, timing of reproduction, as well as migration to select food and water sources.

There are great inter-specific differences in the water turnover rate, capability and flexibility of different species to adapt their physiological functions to the individual hydration status. There are also great differences in the degree of dehydration the individual animals can tolerate. A camel may survive water losses up to 40% of its body mass, whereas in other species, such as the waterbuck, a 15% water loss may result in mortality (TAYLOR et al. 1969, LOUW 1984). In humans, water losses as low as 1 to 2% are known to lead to disturbances in the electrolyte balance of the body fluids, resulting in impacts on the cardiac/circulatory system, a reduced physical fitness and deficiencies in mental, including cognitive, performance (SAWKA 1992, ARMSTRONG & EPSTEIN 1999).

## Role of water in the climate system

The role water plays in the Earth's climate system is essential for the existence of life on our planet. Water vapour is the most important greenhouse gas in the atmosphere. Without greenhouse gases the mean temperature at the Earth's surface would be around -18 °C (254 K), and not 15 °C (288 K) as it is today. Thus, the natural greenhouse effect contributes approx. 33 K to the current temperature, of which 20.6 K can be attributed to the water vapour in the troposphere. As a result, water ensures that the Earth will not become an ice ball. The remaining greenhouse effect is due to atmospheric carbon dioxide (7.2 K), ozone (2.4 K), dinitrogen oxide (1.4 K), methane (0.8 K), and other gases (0.6 K) (LOZÁN et al. 2001).

Regarding the role of the oceans in the climate system, dependencies between temperature, salinity and the density, which are the driving forces of the thermohaline component in the ocean currents, must be considered (s. Chapter 1.4). The interaction between these factors is e.g. the regulating factor for the north directed currents in the North Atlantic. In the area of the GIN–Sea (Greenland – Iceland – Norway – Seas) and the Irminger Sea the warm water coming from the south gets cooled down by loss of heat to the cold air. As a consequence the density of the surface water increases such that it becomes heavier than the less salty water in Northeast Atlantic. Large quantities of this cold, salty water sink deep into the ocean before it can freeze, where it is pulled southward toward the equator. More warm water from the equator flows north to replace the sinking water, setting up a global oceanic »conveyor belt«. This »conveyer belt«, which extends with an orbiting speed on the order of 1,000 years over the three oceans, has a substantial influence on the climate of the continents.

The oceans absorb three times more solar energy than the land-surface, and through their enormous thermal capacity and their slow cooling they damp climate variability in many regions of our planet. For example, the pattern described above for the Northeast Atlantic helps keep Northern Europe far warmer than other locations at the same latitude, and smoothes the relatively large diurnal and annual temperature amplitudes typically observed in more continental climates.

With the evaporation of the water latent heat is transferred into the atmosphere (s. Chapter 1.5) and the atmospheric circulation helps to distribute this heat in form of water vapour over long ranges. Thus the atmospheric transport contributes – like the ocean currents – to the reduction of temperature gradients.

## Water as living space

The part of the Earth's surface covered by water is divided into two very different habitats: that of the sea and that of the lakes and rivers. The oceans can be considered as a temporal and spatial continuum, even with their outlines having changed over the course of the tectonic evolution. Consequently, the development of life in the sea has also proceeded mostly undisturbed. In contrast, freshwater habitats, whose share of the Earth´s surface is less than 1%, are measured on geological time scales, and can be classified as ephemeral (short-lived) water bodies. The lakes´ limited lifespan can be explained by erosion processes in the surroundings and sedimentation of the allochthonus matter transported into the lake basin. The origin of only few large lakes such as the Baikal and the Tanganyika Lake goes back to the tertiary period. However, most of the lakes of our planet emerged after the last ice age.

The density anomaly of water (Chapter 1.2) is of particular importance for life in freshwater habitats. Because of this anomaly water bodies with a certain depth cannot freeze down to their bottom, even at very low temperatures during the cold months of the year. Water cooling down at the surface sinks because of its increasing density into deeper layers (thermal convection). This process is continued up to the maximum density at 4 °C. If the temperature cools down below 4 °C the density of water begins to decrease again. Consequently, freezing of water bodies starts at the surface. After a surface ice layer has formed it isolates the water beneath and protects it from further cooling. In deep lakes of the temperate zones the water temperature of the lower layers will not sink below 4 °C. This characteristic of water is especially important for the hibernation of the plants and animals in lakes and rivers. Problems can occur only during extremely cold winters that are of a long duration, since the icecaps prevent the entrance of atmospheric oxygen into the lake, river or wetland, because biological processes continue also at this temperature, and this may result in oxygen deficiencies.

Water shapes the landscape of the continents and determines the character of the flora and fauna, which depend on water resources. It creates different habitats and forms them continuously. Along the rivers especially productive areas have emerged with an abundant biodiversity - such as in the river pastures.

## Implications for society

Water shapes not only the landscape and enables an abundant flora and fauna, but also creates favourable areas for settling of human communities, and the development of cities. Rivers transport nutrients, which sediment in flat areas. In this way, nutrient rich plains have emerged that can be used for agriculture. Based on such favourable conditions early civilisations developed and thrived, e.g. on the banks of the Nile (Egypt) and in the Two-Streamland between Tigris and Euphrates (Mesopotamia). The big cities of the world are often located in close proximity to important stretches of water, which are also used as transport ways.

Water is an essential food resource for man, since humans must drink at least 2 litres of water daily. People's health also depends on the quality of the water. Drinking water should be free of pathogenic germs and the contamination by toxic compounds like pesticides and industrial chemicals. Biogenic toxins from harmful algae and cyanobacteria should also not exceed certain levels.

Six percent of the global water consumption is by households. An average global share of 9% serves the production of cement, paper, and various products of the chemical industry (in industrialised countries this share can be much greater, e.g. 23% in Germany). In order not to affect surface and groundwater sources, a sufficient treatment of communal sewage and industrial wastes must be insured before their release into the environment. A major part of water is used for cooling processes in power plants (10% and much more at a local scale). The water discharged from the cooling stations may pose a risk to its surroundings due to its unnaturally high temperature and the occasional occurrence of contaminants (antifouling pesticides). The by far largest water consumption of 75% is by agricultural food production (less in highly industrial countries like Germany because of other consumption patterns). For instance, over 1,000 litres of water are typically required to produce 1 kg of bread. Water in sufficient quantity and a profitable food production are thus associated very closely with each other.

Due to the uneven distribution of the water in the world, shortages of water required for food production are a common phenomenon in some regions of the Earth. Numerous irrigation projects to expand the agricultural plains are necessary. The UN assumes a lower boundary of 1,000 $m^3$ per person and year as minimum need for all activities (agriculture, industry and household). Accordingly, today 500 million people already suffer from water shortage. In the year 2025 this number will probably increase to 3,000 million, intensifying the threat of hunger in the world.

For human beings, proteins from aquatic sources are of major importance. The nutrients contained in the oceans, as well as in the rivers and lakes are the basis for a considerable production of plants and animals, which represent major sources of food. In 2002 fisheries landed world-wide 94.6 million tons of fish, crab, shellfish, and algae. Furthermore, 51.4 million tons of plants and animals were raised and harvested from aquacultures both in the sea and freshwater (FAO 2004).

## Concluding comments

Water is the basis of the great biodiversity on our planet. Without water in sufficient quantity and quality the future of both humans and wildlife is threatened. Water is part of all vital processes on Earth and has a central function for life as we know it. Water is thus the largest treasure mankind has inherited from nature. For these reasons water should be placed under the protection of the UN by a Water Convention – like the climate by the Climate Convention and biodiversity by the Biodiversity Convention. It is our opinion that without of such a convention the loss of biodiversity can not be stopped, because it is based on water.

Preserving the aquatic resources requires the restoration of lakes and rivers as well as the rehabilitation of dried wetlands. The social and economic problems resulting from the unequal distribution of water on Earth must be solved in solidarity by the world community. New advantageous techniques should help to use the water more efficiently in irrigated agriculture, which will allow to increase the food production without increasing water consumption to meet the threatening hunger problem. Degradation of the soils by mismanagement like those resulting in **salinisation** should be avoided.

As the »right to enough water is a Human Right«, a Water Convention should improve the future world-wide availability of water, in terms of both quantity and quality (see Chapter 4.17)♦