TYPES AND PROPERTIES OF WATER

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Summary

The total volume of the Earth's hydrosphere is about 1.39 billion km^3. The main types of water are atmospheric (0.001 percent of total volume), the oceans (96.4 percent), fresh surface water, saline lakes, and land-locked seas (0.013 percent), groundwater (1.68 percent), and glaciers (1.86 percent).

Earth's water can exist in three phases: liquid, solid, and gaseous. Hydrogen and oxygen atoms form water molecules, H_2O. Atomic nuclei in the molecule form an isosceles triangle with two protons at the base and an obtuse angle at an oxygen atom in its vertex. The angle H-O-H and inter-nuclear H-H, O-H intervals are a function of water phase state.

The chemical composition of surface water is created in the process of water circulation on Earth, which connects the hydrosphere with the atmosphere, lithosphere, and biosphere. Water, being a universal solvent, is enriched with a wide spectrum of various substances in a gaseous, solid, and liquid state, so it varies greatly in its chemical composition. The chemical composition of ocean water remains constant due to a complex dynamic equilibrium between the ocean water, atmospheric gases, and hard rock masses.

The biological properties of water systems are caused by the totality of flora and fauna. As the density of water is considerably higher than air, living organisms are able to exist both within the water column (pelagic) and on the bottom (demersal).

The most important water functions in the system are the following:

- supply of a self-renewable resource: fresh water, for industrial, agricultural, and municipal purposes
- production of organic matter, including fish
- maintenance of biodiversity in and around aquatic ecosystems
- cycling of materials in global biogeochemical cycles
- self-purification: a natural system of waste treatment.

1. Introduction

Natural water is one of the most important substances for the maintenance of life. It was called “a primary source of all that exists” by an ancient Greek philosopher Thales of Miletus 2,600 years ago. Water is one of the most astonishing compounds on Earth, and even now has not yet been fully deciphered. It is characterized by a complex of anomalous properties that make it very different from other substances (e.g. high melting, boiling, and evaporation points, and high dissolving ability).

The main part of the Earth’s water is concentrated in the hydrosphere. The hydrosphere (from the Greek *hydro*, water, and *sphaira*, sphere) is not a continuous water cover of the Earth. The hydrosphere is the totality of oceans, seas, and surface terrestrial waters, including oceans, lakes, streams, underground water, and all the snow and ice. This sphere covers 70.8 percent of the Earth’s surface (the total volume is about 1.39 billion km^3). Oceans and seas make up about 96.4 percent of the hydrosphere by volume, and underground waters form 1.68 percent. About 2 percent is composed of snow and ice (mainly the snow and ice of the Arctic, Antarctic, and Greenland), and 0.059 percent is surface fresh water, saline lakes, and inland seas. The atmosphere and living organisms also contain water, but in insignificant quantities.

All water masses are transformed from one form to another in the course of the *hydrological cycle*, a continual shift of water on the Earth (in the atmosphere, hydrosphere and the Earth’s crust) that occurs under the influence of solar radiation and gravity. This planetary process includes evaporation of water from the Earth’s surface, its transfer with the help of air currents from the place of evaporation, condensation of water vapor and precipitation (transfer of water masses in water bodies onto the Earth’s surface and inside its crust). The quantity of precipitation annually falling on the Earth’s surface is equal to the quantity of water evaporated from the surface of the landmasses and oceans.

2. Water Types

2.1. Atmospheric Water

Atmospheric water, transforming from one state to another, participates in water circulation in nature. Moisture is mainly in a gaseous state in the atmosphere. The average content of water vapor decreases with height and latitude and depends on the season and type of underlying surface. Although it has only a relatively small moisture content, the atmosphere is the only source of fresh water regeneration in nature (through evaporation) and the main means of replenishment of water reserves (through precipitation). The total evaporation from the ocean surface and continents amounts to

577,000 km^3 per year (a mean water layer of 1.13 m over the Earth); it consumes on average 88 W/m^2 of heat, which amounts to more than a third of the solar energy supply of the Earth. Through the operation of the water circulation on the Earth, the entire 577,000 km^3 falls to the Earth each year. Meridional water vapor transfer is a significant peculiarity of water circulation.

Water vapor (H_2O) is the most variable of the atmosphere components. Its volumetric content can change by a factor of 100,000, depending on the season and place. The lowest water values are observed either at a considerable height in the atmosphere or above the Antarctic plateau, and the maximum observed in subtropical and equatorial areas, where it often amounts to more than 3–4 percent. To determine water vapor content in a given air volume (the part of total atmospheric pressure caused by water vapor), a notional water vapor pressure (partial pressure) is used.

Alternatively, specific humidity can be used. This is the ratio of water vapor mass to the humid air mass. Absolute humidity is the ratio of water vapor mass to the humid air volume. The percentage ratio of water vapor partial pressure to the pressure of the water vapor saturated under the given temperature is called relative humidity.

Water in the atmosphere mainly comes from evaporation, from the surface of both the ocean and the land. Transpiration and direct evaporation from the surfaces of green plant (evapotranspiration), and evaporation from ice (sublimation) also increase the water content of the atmosphere. Condensation occurs when air, being saturated with water vapor, becomes cooler, and relative humidity reaches 100 percent. Condensation can be in the form of dew or rime. Dew forms when the air temperature is equal to the temperature of condensation and is higher than the temperature of any surface. Rime occurs if the temperature of the air and the surface is less than zero.

Condensation in the atmosphere occurs on condensation nuclei: small particles of dust, salt crystals, smoke, and so on, and results in cloud formation. Clouds are classified into types, kinds, and varieties according to their form and state (water drops or ice crystals). Depending on the synoptical and thermodynamical conditions of precipitation, clouds are divided into the following main types: total, shower, and mixed. The occurence of total precipitation is connected to a large-scale vertical air motion caused by a frontal or orographic rise, or large-scale horizontal convergence. Shower precipitations are formed in cumulus-rainy clouds under conditions of mesoscale convection in the unstable air of the layer within 5–10 km. Clouds mixed as to their genesis are caused by the simultaneous effect of regulated and convection motion, whose input differs depending on the precipitation type.

Fog is an accumulation of the smallest water drops or ice crystals decreasing visibility in and near the surface air layer. There are fogs of cooling and evaporation. Radiation fog can be formed when there are no clouds and the land surface is cooled by long-wave heat radiation at night. Advective fog can be formed by the horizontal movement of a relatively warm air mass over a colder air mass lying over the land surface.

2.2. Oceans, inland seas, costal zones, and estuaries.

The seas are classified as interior (inland), marginal, or inter-insular according to their geographic position and degree of isolation. An inland sea is one almost completely surrounded by land and joining the ocean or adjacent seas only through relatively narrow channels. Interior seas are assumed to be subdivided into continental and inter-continental types. A continental sea is usually shallow, deeply intruding into the land within a continent (e.g. the Azov, the White and Black Seas, and Hudson Bay). An intercontinental sea is a part of the World Ocean located between continents and connected with the ocean or other seas by channels (e.g. the Mediterranean and the Red Sea). A marginal or adjacent sea is a part of the World Ocean adjoining the continent and partially separated from it by peninsulas or a group of islands, or simply by the ocean bottom uplifting. Marginal seas can be on the continental shelf (a shelf sea) or on the continental slope (e.g. the Barents, the Laptev, and the Norwegian Seas). An inter-insular sea (encircled by islands) is a part of the World Ocean surrounded by a more or less dense circle of islands, the straits between which prevent a free water exchange with an open ocean (e.g. the Japan, and Sulu Seas).

The chemical composition of seawater, particularly in marginal and continental seas, can differ considerably from that of ocean water. This is because it is affected by the run-off from the land. An abundant runoff of rivers and springs (surface and groundwater discharges) changes marine water content considerably. The salinity of water in oceans and marginal seas is also very much affected by evaporation. However the chemical composition of seawater is practically constant (the exception being in zones of river water entry).

Water in the coastal zone is very mixed, being affected by waves and accompanying currents. The marine boundary of this zone is determined by near bottom wave velocities and is limited by depths equal to ten times the wave height.

An estuary is a partially enclosed coastal water area freely connected with the ocean, within which the seawater is considerably diluted by freshwater flowing from a river catchment area. These are transient zones between the land and sea. They can be subdivided into coastal plain estuaries, fiords, flooded river valleys (Chesapeake Bay), estuaries with coastal barriers (Pamlico Sound), estuaries of tectonic origin (San Francisco Gulf), and deltas. All estuaries are subdivided into three classes: “positive” where seawater is diluted by freshwater (river runoff with precipitation exceeding water losses for evaporation); “reverse” estuaries with increased salinity, where losses from evaporation exceed discharge and precipitation; and “neutral” where evaporation is fully compensated by discharge and precipitation. Estuaries can also be subdivided in relation to the way in which mixing takes place. They are usually subdivided into three groups: those which are completely mixed and are vertically homogeneous; those which are partially vertically mixed and which are moderately stratified; and those with a salt wedge, which are highly stratified.

2.3. River, reservoirs, lakes, and wetland

Surface water is that water which occurs permanently or intermittently on the land surface in the form of different water bodies: rivers, streams and temporary watercourses, reservoirs, lakes, swamps, mires, glaciers, and snow cover. The process of transporting water of atmospheric origin over the land surface under the influence of gravity is called surface runoff. It is measured as a water discharge ($m^3 \cdot s^{-1}$), volume of water run-off (km^3), specific water discharge ($l \cdot s^{-1} km^{-2}$) or a layer of water run-off (mm) per year or some other period of time.

A river is a watercourse flowing in a self-developed bed augmented by surface and groundwater. With all its tributaries it forms a river system whose character and development is related to climate, relief, geologic structure, and the dimensions of the basin. Rivers can be subdivided into mountain rivers – usually flowing rapidly in narrow valleys – and plain ones, which flow more slowly in wide terracing valleys. The water regime depends mainly on the character of river augmentation and the climate conditions in the region. Total annual river runoff into the World Ocean is about 47,000 km^3.

A lake is a natural reservoir filled with water within a lake basin not directly linked with the sea. Basins are subdivided according to their origin into tectonic, glacial, fluvial, coastal, sinkhole (in karst and thermokarst), volcanic, and dammed (artificial reservoirs and ponds). Depending on the nature of the lake bed, three main lake types can be distinguished:

- dammed lakes: fluvial, valley, and coastal (including reservoirs)
- hollow lakes: moraine, karst, thermokarst, deflation, volcanic, tectonic
- lakes of mixed origin.

There are also other classifications. According to the water regime, lakes may be subdivided into lakes with an outlet (exorheic) and lakes without an outlet (endorheic). Exorheic lakes are those from which rivers flow, for example Lake Ontario (Canada/USA), and the Baikal, Onega, and Ladoga lakes in Russia. A particular case of such lakes is comprised of flowing lakes (drainage lakes). Rivers run into such lakes, and then flow out from them. The best-known flowing lakes, are Lakes Boden and Geneva, which allow the passage of the Rhine and Rhone rivers. From endorheic lakes no rivers flow. All the water that enters such a lake is taken up by evaporation or infiltration, or used for economic purposes. The largest endorheic lakes are the Caspian and Aral Seas, Issyk-Kul Lake, Lake Eyrie and Salt Lake.

A water reservoir is an artificial water basin, usually formed in a river valley by water supply lines that regulate its use for purposes of the natural economy. According to the form of the basin, reservoirs may be subdivided into fluvial, lacustrine, and mixed. Water reservoirs can be split into permanent or temporary (a day, a week, a season, or a year).

Vertical temperature stratification, caused by the fact that water reaches its maximum density at a temperature of 4 ^oC, is characteristic of weakly flowing and deep lakes and reservoirs. In the warm period of the year, a uniform layer (the epilimnion) develops near the surface of lakes and reservoirs, and the oxygen regime is favorable to development of aquatic life. There is a layer below the epilimnion where the water temperature falls abruptly, and below which the density increases with depth. This layer is the thermocline. Deeper layers, in the hypolimnion, interact poorly with atmosphere, and the dissolved oxygen content decreases considerably, so that anaerobic processes occur with the liberation of hydrogen sulfide and methane. This phenomenon is particularly characteristic of many water reservoirs in arid and tropical zones.

A wetland is an area of land characterized by constant or excess moistening, favoring hydrophilic vegetation and the development of specific soil processes. Soil formation alternates with short periods of peat formation, followed by its washout. In some cases siltation with organic-mineral muds occurs, and sometimes it is only gleying.

Bogs (marshes and wetland) are formed through the excess moistening of area or eutrophication of a reservoir. The former is the most common. Bogs occur as a result of flooding of territories. Flooding may be observed in the coastal zone of rivers, lakes, reservoirs, and seas as a result of long-term rise in water levels. Under-flooding is also a consequence of this process. Bogs can also form when there is a change in the ratio between deposition and evaporation of atmospheric precipitation, and a natural or anthropogenic increase of subsoil waters. Eutrophication of reservoirs and their transformation into bogs is observed in zones of temperate and warm climates. It reflects a natural stage in the evolution of a reservoir.

The general area of bogs on the Earth equals 2.7×10^6 km^2, which amounts to about 2 percent of land area. They hold 0.03 percent of the freshwater on the planet. Eurasia and North America contain the greatest areas of bog.

Peat bogs are distributed in tundra, and the forest and forest-steppe zone. They differ among themselves in a series of attributes. Low-lying bogs have a concave or flat surface. They are formed on the shores of rivers, lakes and reservoirs, and in river mouths. Low-lying bogs are directly connected to the rivers and underground waters that provide them with mineral substances and good conditions of nutrient supply for aquatic communities. High-lying bogs generally have a convex surface, typically with a thick layer of peat. Such bogs are formed on drainage divides (watersheds), and also as a result of the growth of low-lying bogs. On watersheds, the water balance of bogs is basically determined by atmospheric precipitation and evaporation. Receipt of mineral substances is low, and this has a fundamental effect on the aquatic ecosystem. The intermediate type of peat bogs has a weakly convex surface and relatively better conditions of nutrient supply in comparison with high-lying bogs.

Depending on conditions of rainfall, water-temperature, and inflow, mires can be subdivided into oligotrophic (nutrient-poor) bogs, with low pH and low levels of nutrients available for vegetation, and eutrophic fens and marshes. Oligotrophic bogs receive most of their water from precipitation, and so tend to be located near river basin watersheds. Rainfall is high, so nutrients are constantly removed. Eutrophic mires, on the other hand, tend to be lowland in character, and the vegetation is not severely limited by lack of nutrients. They receive mineral nutrition from surface drainage and groundwater. They tend to be located in depressions, so minerals and nutrients can be provided from higher ground. There is a whole spectrum of mires of intermediate type where minerals are available to at least some parts of the area from groundwater inflow, while other parts are oligotrophic. Bogs can be further subdivided according to the dominant vegetation (scrub, dwarf shrubs, grasses, bogmosses, etc.) by micro-relief (hilly, flat, or domed), and macro-relief (valley, flood plain, slope, watershed), and other aspects.

2.4. Groundwater

This term refers to water in the Earth's crust in all physical states, in the sedimentary rock layers and massive-crystallized rock fractures. There are many groundwater classifications relying on different types of groundwater infiltration and distribution, lithological composition, geological age, and on differences in hydrodynamics, temperature, and chemical composition.

According to the conditions of their occurrence in rocks, the following types of groundwater are distinguished: free gravitational, in a solid state vaporous, physically bound, chemically bound, and water in a supercritical state. Free gravitational water, filling pores, voids, and fractures in rocks is the most widespread. This water percolates through rocks under a pressure drop. According to their ability to allow water to infiltrate, rocks can be classified as, on the one hand, water-bearing or water-permeable (loams, sandy clays), and, on the other, water-impermeable, or confining strata (clays, compact sandstones, and non-fractured rocks). Here, different types of water-bearing rocks can be distinguished: porous, fractured, fractured–porous, and karsts.

Water-bearing and poorly permeable or confining rocks usually occur as inter-bedded layers or zones of different thickness. Thus there is often the possibility of typifying a rock mass by identifying the aquifers and poorly permeable or confining beds within it.

Gravitational groundwater is mainly recharged by infiltrating rainfall, water vapor condensation (mainly in mountainous regions), and river runoff. This groundwater is discharged into rivers, gullies and ravines, seas and oceans, and also taken up by transpiration of plants and evaporation from the surface.

Groundwater is also subdivided according to its water exchange capacity. A zone of active water exchange is usually present near the surface, and is mainly characterized by fresh bicarbonate- and calcium-rich water. Then the occurs a zone of reduced water exchange with brackish, mainly calcium- and sodium-sulphate water, and, below this, a zone of very reduced water exchange, mainly with sodium- and calcium-chloride saline water. This zonality is disturbed in some areas due to peculiarities of hydrogeological conditions (e.g. the availability of salt-bearing or gypsum rocks, tectonic disturbances, etc. in the profile), causing the occurrence of so-called azonal groundwater.

The chemical composition of groundwater includes a mixture of many chemical elements, in the form of different ion types, neutral molecules, organic-mineral complexes, colloids, and isotopes. A complex of climatic, physical-geographical, soil-vegetation, structural-geologic and hydrogeological factors, produces groundwater from both infiltration and condensation. According to its general mineralization, groundwater is usually subdivided into fresh (with up 1 g/l mineralization), saline (from 1 to 25 g/l mineralization) and brine, with mineralization exceeding 25 g/l (in individual cases up to some hundred g/l).

When typifying groundwater according to its use, mineral water can be singled out on account of the concentrations of dissolved mineral salts, gases, and organic matters that allow its use for balneological treatment. The temperature of some groundwater allows it to be used as a thermal power source. Thermal water of a specific chemical composition can be also used for medical treatment.

Ground and surface water are often closely interrelated. Their interconnection is characterized by two opposite processes: augmentation of surface streams and reservoirs and groundwater recharge from surface water. A combination of these two processes is possible within one river basin both in time and space but the processes are considerably affected by groundwater exploitation. Processes of groundwater interrelations, caused primarily by geologic-hydrogeologic conditions of the river basins in the coastal zones, should be considered when assessing total water resources and the water balance of individual regions, in addition to groundwater withdrawal for different purposes.

2.5. Soil water.

The term “soil water” usually refers to the water localized in soil pore space (i.e. in the surficial part of the land) in the form of liquid moisture (both closely attached to soil skeletal particles and water freely able to move through the soil profile), a solid component in the form of ice in the soil pore space, and gaseous water in the form of soil air.

The proportion of soil water in the total volume of inland water is very small (0.06 percent). However its geo- and biophysical function on the Earth is no less important than that of groundwater. This function is connected with the boundary character of soil and soil water. Solar radiation energy reaching the Earth and driving the global circulation system is transformed into other forms of energy in a very thin planetary layer, on the boundary between atmosphere and lithosphere. This is where all the four components of the biosphere interact: the atmosphere, the upper part of the lithosphere, the hydrosphere, and terrestrial living mater.

Soil water occurs in the zone where solar radiation is transformed and assimilated by the biosphere. It thus has an important role, clearly accounting for three of the most important inter-related aspects and determining their place in the Earth hydrosphere. First, soil water is the most active link in mutual exchange of land water. In the terrestrial hydrological cycle, the soil layer serves as a specific “water separator,” controlling the partition distribution of incoming water (precipitation) into its three outgoing components: surface runoff, subsurface runoff, and evapotranspiration. Second, soil water is an important element of the Earth’s climatic system. Third, soil water is the most important factor controlling the presence and growth of vegetation cover; in other words, it is a primary link in the trophic system of terrestrial ecosystems. The dynamics of soil water stores has a major influence on vegetation cover.

As an important component of the hydrogeological cycle, evapotranspiration deserves special mention. Global evapotranspiration (of which 80–90 percent is transpiration) represents about two-thirds of the overall precipitation on the land surface. It seems that a great water volume precipitates on the land surface to no purpose. Indeed, a plant needs no more than 1–3 percent of all the water it uses in transpiration. This small amount is required for the production of plant material through photosynthesis, and to maintain the required concentrations and osmotic pressures. The remaining 97–99 percent is returned to the atmosphere. "It can be compared to using Niagara Falls to fill a bath." However, analysis of terrestrial vegetation in relation to the theory of dissipative structures, and consideration of their role in production of entropy, which is permanently produced by plants, demonstrates that during the evolution of life on Earth, transpiration may be the only mechanism that can do this without causing temperature increases which would damage plant tissues. Thus, transpiration in terrestrial vegetation (the expendable component of the soil water balance) is an important part of global biogeochemical cycling.

2.6. Glaciers, icebergs, and ground ice

Ice is the most abundant "'mineral" on the Earth. The total mass of ice enclosed in glaciers, icebergs, ground ice, snow cover, and the atmosphere is 2.423 x10^{22} tons. Ice covers more than 16.3 x 10^6 km^2, or 11 percent of the Earth surface. The total ice volume of modern glaciers ranges from 26.8 x 10^6 km^3 to 30.3 x 10^6 km^3. If the ice layer covered the Earth uniformly, its thickness would be approximately 55–60 meters.

A glacier is a moving natural accumulation of ice on the land, under a negative balance of the solid phase of water. Glaciers are confined to those places on the Earth surface where solid precipitation exceeds evaporation. Most glaciers consist of an alimentation zone, where the snow is accumulated and transformed into firn and ice, and an ablation zone, where ice is lost from the glacier by melting and evaporation. There are two main types of glaciers: mountainous (flowing down) and covering (spreading). Net-shaped and piedmont types of glaciation are transient between mountainous and covering glaciers.

Mountain glaciers occupy mainly negative elements of the relief, forming cirque (corrie), valley, and other types of glaciers; ice moves slowly downslope under gravitational force. In many dry areas of the Earth, mountain glaciers supply a considerable part of the water used for irrigation. Glaciers are only found in the vicinity of the snow line. Above the snow line the accumulation of solid precipitation is greater than the combined thawing, evaporation, and run off. The level of the snowline oscillates widely, depending on the moisture and heat balance and local climatic conditions Its altitude may vary from sea level in the Antarctic Continent to 6,000–6,500 m above sea level on the Tibetan Plateau.

In Europe modern glaciers are concentrated in Scandinavia, the Alps, the Caucasus, and the Urals. There are small glaciers in the Khibiny and Perinea Mountains. There are 9,529 glaciers in Europe, with a total area of 7,395 km^2. In Asia, ice covers high mountains areas of the Tien Shan, Pamirs, Karakorum, and Himalayas, where many very large dendritic and complex mountain valley glaciers descend well below the snow line. The largest centers of modern glaciation in Northern America are located in the Northern America Cordillera. The Alaska Ridge also has large centers of glaciation, which aliment from the Pacific.

Cover glaciers spread over many million square kilometers, blanketing even mountains with a domed surface, moving slowly from the center to the periphery in a radiating pattern. More than 96.6 percent of the area of cover glaciers and 90 percent of the volume of ice are concentrated in the *Greenland* and *Antarctic* ice sheets. The Antarctic Continent covers $14 \cdot 10^6$ km^2; the mean diameter of the Antarctic ice sheet is 4,000 km, with a minimum of 2,900 km, and a maximum of 5,500 km. Most glaciers of Eurasia and the Canadian Arctic are classified as ice caps by their morphology, and as diffluent glaciers by their movement features. The largest Eurasian ice caps are located in Iceland, Franz Josef Land, Spitsbergen, Novaya Zemlya Island, Severnaya Zemlya Island, Bennett Island, Henriette Island, Jeannette Island, Victoria Island, Ushakov Island, and Schmidt Island. The largest ice caps of the Canadian Arctic Archipelago are those of Baffin Land, Ellesmere Island, Devon Island, Axel-Heiberg, Melville Island, and Meighen Island. To the north of Ellesmere Island, there is a small shelf glacier, on Ward Hunt Island, that produces table icebergs. Shelf ice, partially resting on the sea bottom, is a continuation of terrestrial ice and is mainly found in the Antarctic.

Icebergs are masses of continental ice, which have separated from a glacier or glacial barrier and float in the polar and adjoining seas and oceans. Continental ice from Antarctica, Greenland, and the glaciers of Severnaya Zemlya is the major center of iceberg formation. Due to the similarity of the densities of ice and seawater, the greater part of an iceberg (80–85 percent of the total height) is under the water. Icebergs are moved by currents and are gradually destroyed by thawing and weathering. There are the following types of iceberg: tabular, domelike, pyramidal, and destroyed. Tabular icebergs have a flat surface because they usually break off shelf glaciers. They may be several kilometers in length and width. They are often found around the Antarctic Continent, but sometimes they form near Greenland and around the ice caps of Arctic Islands. Domelike icebergs mainly come from diffluent glaciers or from ice bluffs; their height is about 70–100 m. Pyramidal icebergs are pyramidal in shape, and destroyed icebergs have an irregular shape, often with several summits. Separation of icebergs sometimes happens as a result of tides. A large iceberg can traverse a great distance, more than 4,000–6,000 km from its place of origin.

Snow cover is a layer of snow, produced by snowfalls and lying on the land or ice surface. According to its appearance and conditions of formation, snow can be subdivided into newly fallen, compacted (stable) and old (firnified, neve). The density of snow varies from 0.01 g/cm^3 for newly fallen to 0.70 g/cm^3 for highly wet and then frozen forms. Globally, snow covers an area from 115 to 126 x 10^6 km^2 (about a third of this area is sea ice). Snow reflects solar radiation, and protects soil from overcooling and winter crops from freezing.

Solid atmospheric precipitation, accumulated on the land surface, changes considerably over time. During snow accumulation there is freezing and melting of snowflakes, their compaction, and structural change. As a result, snow layers are transformed into a porous, white-gray mass, called firn. In the process of being compacted, firn (which has a density of 0.3-0.5 g/cm^3) is first transformed into white ice with a density of about 0.85 g/cm^3, and then into transparent ice with a density of 0.91 g/cm^3. Pieces of ice can grow together into a uniform mass (regelation). Another important ice property is its plasticity, which allows it to move under gravitation. Ice is the most widespread solid material on the Earth, forming glaciers, icebergs, and marine and ground ice.

Ground ice is a general term used to refer to all types of ice formed in freezing and frozen ground. Ground ice occurs in the pores, cavities, voids, or other openings in soil or rock and includes massive ice. Buried glacier, lake, river, and snow bank ice are all categorized together as a single type of ground ice. Traditionally permafrost is defined on the basis of temperature: soil or rock that remains at or below 0 °C for at least at two consecutive years.

The ice content in permafrost is probably the most important feature relevant to human life in the northern regions of Siberia, Scandinavia, Alaska, Canada, and subpolar regions of the Southern Hemishpere. Ice in perennially frozen ground exists in various sizes and shapes, with definite distribution characteristics grouped into five main types: pore ice, segregated or taber ice, foliated ice or ice wedges, pingo ice, and buried ice. Around 10 percent by volume of the upper 3–5 m of the permafrost of the Siberian, Alaskan, and Canadian coastal plain is composed of ice wedges. Taber ice is the most extensive type, in places representing 75 percent of the ground ice by volume.

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Biographical Sketch

Academician Martin Gaykovich Khublaryan, born in Georgia on March 5 1935, has been Director of the Water Problems Institute of Russian Academy of Sciences since 1988. He has also served as Chief of the Laboratory of Theoretical Problems of Water Protection; Deputy Director, Chief of the Laboratory of Modeling Hydrophysical Processes; Chief of the laboratory at the All-Union Scientific Research Institute for Hydrotechniques and Reclamation; and Senior Scientist at the All-Union Scientific Research Institute for Natural Gas. He was elected a full Member of the Russian Academy of Sciences in 1994, and has been a member of the Working Group of the International Hydrological Program (from1989), the Russian National Committee for International Association of Hydraulic Research (since 1987), and the American Institute of Hydrology(President of its Russian section, 1991).

He studied at the Armenian Agricultural Institute, Department of Hydrotechniques and Reclamation, and served as a scientist at the Institute for Power and Hydraulics of the Academy of Sciences of Armenian Republic, and as an engineer at the Erevanproekt Institute (Armenia). In 1964 he was a Candidate of Sciences (Physics and Mathematics), Institute of Mechanics, USSR Academy of Sciences, subsequently attaining a Doctorate in Engineering at the All-Union Scientific Research Institute for Hydrotechniques and Reclamation in 1975. He was appointed Professor in 1992.

Professor Khublaryan's publications include *Water Streams: Models of Flow and Quality Surface Water* (Moscow, Nauka, 1991, *Water Pollution and its Consequences in the Former USSR*, *Pollution Knows No Frontiers* (New York, PWPA, 1992), *Basic Problems in Protection of Natural Waters*, and *Water Management AND Protection* (AIH, 1993). among more than 150 other publications.

He is married with two daughters. His interests include painting, classical music, chess, and memoirs.