Global problems of water resources scarcity

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SUMMARY

The problem of water scarcity on the planet due to geographical (mismatch between fresh water demand and availability) and socio-economic (growing world population, improving living standards, changing consumption patterns and increasing irrigated land areas) factors is investigated. Methods for assessing water scarcity are considered. The state of water resources in Ukraine was assessed using the water stress indicator. A comparison is made with other countries of the world that are in approximately the same conditions in terms of the amount of water resources per person (Germany, Belgium, Poland, Denmark, and the Republic of Korea). Attention is drawn to alternative sources of water (desalinated water, recovered wastewater, gray water, collected rainwater, etc.).

Introduction

Water resources in the broad sense are all waters of the hydrosphere, including the waters of oceans and seas, rivers and lakes, groundwater, and glaciers. The total volume of water on Earth is huge, but, in general, it is the salt water of the oceans. The use of fresh water in the world is 3853 km^3/year, that is, only 9% of the river flow of the planet. Theoretically, this means that there are enough fresh water resources in the world. Why, then, was the issue of water scarcity on the planet included in the list of the World Economic Forum 2015 in Davos, as one of the largest global risks in terms of impact on human society in the next decade (*Water crises, 2015*)?

Methods of investigation

Water scarcity is a shortage of fresh water resources to meet the needs of the population in drinking water and use for household needs. Some regions of the Earth have historically suffered from water scarcity. However, in recent decades, the problem of water scarcity has begun to affect all continents. In the work on Ukraine, the hydrological method for assessing the shortage of water resources is used – calculating the ratio of total annual renewable water resources to the number of people in a country or region (Falkenmark water stress indicator). The predicted data on water scarcity are analyzed using the green-blue water accounting approach.

Results

The total amount of water on Earth is estimated at 1386 million km^3 (*Shiklomanov, 1998*). About 97.5% is the salt water of the oceans and seas (average salinity is 35‰), parts of the underground aquifers and salt lakes. Only 2.5% of the total amount of water is fresh water (with salinity up to 1‰). Most of fresh water (68.7%) is accumulated in the ice and snow of the Arctic and Antarctica, as well as in mountain glaciers. About 30.1% are represented by fresh groundwater, and only 0.3% of fresh water is located in easily accessible surface water bodies – lakes (0.26%) and rivers (0.006%). Fresh water resources are divided into renewable and non-renewable. Renewable freshwater resources are river runoff into the oceans. Non-renewable (static) water resources are deep horizons of groundwater with replenishment rate being insignificant on a human time scale.

1. Water use in the world

Over the past 100 years, total water use has increased 4.5 times: from 885 km^3 (1920) to 4001 km^3 (2020). The population increased by 4.2 times: from 1.86 billion people (1920) to 7.8 billion people (2020). In Table 1, based on the synthesis of data from various sources, the dynamics of indicators of total water use and population during 1901-2020 is presented, as well as the forecast by 2050 according to (*Environmental, 2012*).

Table 1 *Dynamics of total water use (km^3) and population (billion people) on Earth during the years 1901-2020 and forecast for 2050*

Indicator	Years							
	1901	1920	1940	1960	1980	2000	2020	2050
Water use, $км^3$	670	885	1110	1752	3073	3786	4001	5500
Population, billion	1.6	1.86	2.3	3.03	4.46	6/14	7.8	9.74

The main three types of water use for which statistics are conducted are as follows: agricultural (69% of world water use), industrial (19%); household and drinking (12%) (Aquastat, 2017). The use of water for the same needs in the world varies greatly depending on the region. For example, in Asia, water use for agricultural, industrial, household and drinking needs is 81, 10, and 9%, respectively. In Europe, this proportion looks completely different – 25, 54 and 21%.

2. Water scarcity

The global water scarcity has geographic and socio-economic causes. Geographical reasons are the spatial and temporal (seasonal) mismatch of fresh water demand and its availability. The Middle East and North Africa suffer from water scarcity throughout the year. The socio-economic causes of the water deficit are results of the growing world's population, increase in living standards, changes in consumption patterns and increase in irrigated land (*Ercin et al., 2014*). The issue of accessibility of water resources is associated not only with their quantity, but quality as well (*Khil'chevskii et al., 1999*).
The results of the forecast prepared by OECD experts, in which 2000 and 2050 are taken as base levels, show that the shortage of fresh water in 2050 may affect 3.3 billion people more than in 2000. More than 40% of the world's population is projected to live in river basins, which will feel severe water stress, especially in North and South Africa, South and Central Asia (*Environmental, 2012*).

There are various methods for water scarcity assessment. According to the Falkenmark water stress indicator, the threshold values of the general renewable water resources for the countries are as follows, m^3/year/person: 1) < 1700 – water stress; 2) < 1000 – water scarcity; 3) < 500 – absolute water scarcity (*Falkenmark, 1995*). FAO considers the indicator of 1000 m^3/year/person of the total renewable water resources to be minimally acceptable for the country's economy and agricultural production (Figure 1).

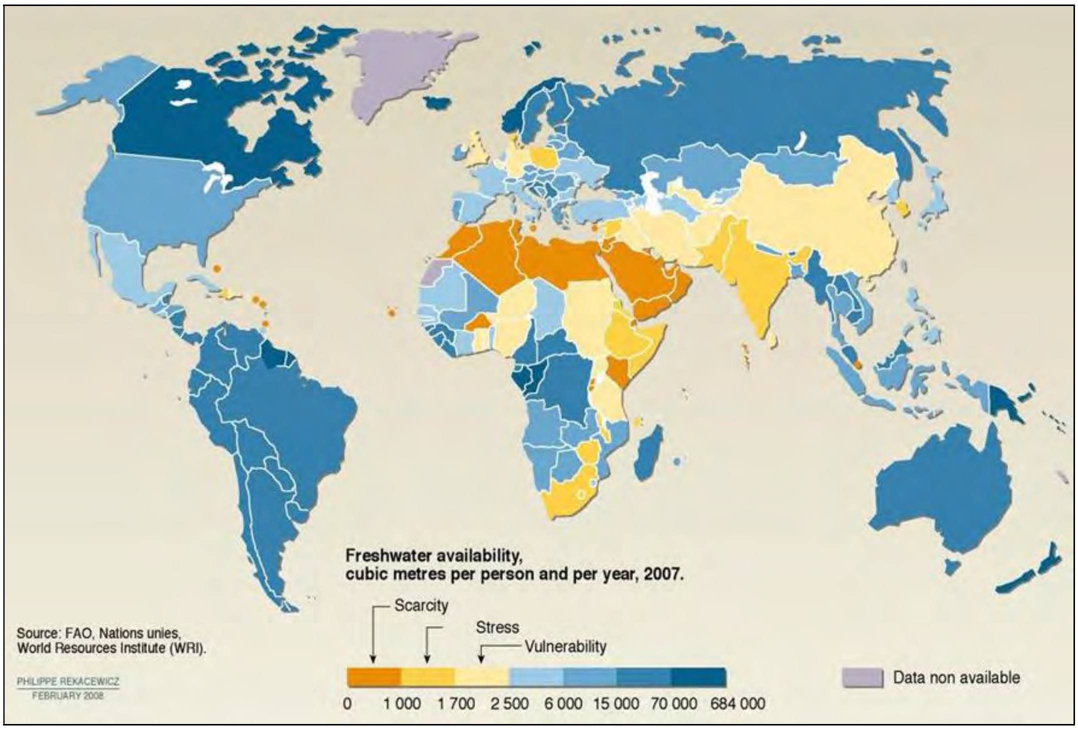

Figure 1 *Provision of shared renewable water resources in countries and regions of the world,* m^3/year/*person (FAO, 2007)*

The method of blue and green water was elaborated in 1995. The concept of green and blue water underlies the paradigm of the total resource (blue water + green water) in assessing the potential of the world agricultural sector for food production (*Rockström et al., 2009*) – Table 2. Green water is water concentrated in unsaturated layer of soil, formed by precipitation and available for plant nutrition. Blue ater is the water of rivers, lakes, wetlands and underground aquifers, which can be withdrawn for irrigation and other uses. Both resources are important for agricultural production. Rainfed agriculture uses only green water, while irrigated agriculture uses both green and blue water. The problem of water scarcity acquires a somewhat milder character when applying the paradigm of the total resource (green water + blue water) to water accounting (Table 2). The threshold value of the blue water deficit in these calculations is 1000 m^3/year person; total threshold value (blue + green water) – 1300 m^3/year/person. World population: 2000 – 6.14 billion people; 2050 – 9.74 billion people.

Table 2 *The number of people on Earth affected by the shortage of water resources in 2000 and the forecast for 2050, billion people (Rockström et al., 2009)*

Continent	Water scarcity, 2000		Water scarcity, 2050	
	blue water	blue + green	blue water	blue + green
Africa	0.25	0.02	0.83	0.57
North America	0	0	0.05	0.0052
South America	0	0	0	0
Asia	2.76	0.26	5.46	3.35
Oceania	0	0	0	0
Europe	0.16	0	0.16	0.00081
World total	3.17	0.27	6.50	3.93

3. Water resources of Ukraine

According to the FAO, in Ukraine, local surface water resources (SWR) or river runoff is estimated at 50.1 km³/year, transit – 120.2 km³/year (36.1 – from Russia and Belarus, 84.1 – from Romania). General SWR are 50.1 +120.2 = 170.3 km³/year. Local underground water resources (LUWR) account for 22.0 km³/year, of which 17 km³/year are provided by underground nutrition of rivers and surface water bodies and therefore cannot be extracted. Thus, the volume of operational LUWR is 5.0 km³/year. In accordance with foregoing, the total renewable water resources (SWR together with LUWR) of Ukraine are: 170.3 + 5.0 = 175.3 km³ per year (*Aquastat, 2017*).

In 2017 in Ukraine, 1 person accounted for 3964 m³/year of total renewable water resources, of which 1246 m³/year are internal (*Aquastat, 2017*). According to our estimates, as of 2017, Ukraine was in 26th place among about 50 European countries in terms of total water resources per year for 1 person and in 33rd place – in terms of domestic. Interaction with neighboring countries in the field of water research is crucial for Ukraine (*Khilchevskiy et al., 2019*). Not all developed countries have high water availability indicators. Here examples by countrys (general and internal water resources), m^3/year/person: Germany (1875, 1303); Belgium (1601, 1050); Denmark (1046, 1046); Poland (1585, 1404); Republic of Korea (1367, 1272) – Figure 2.

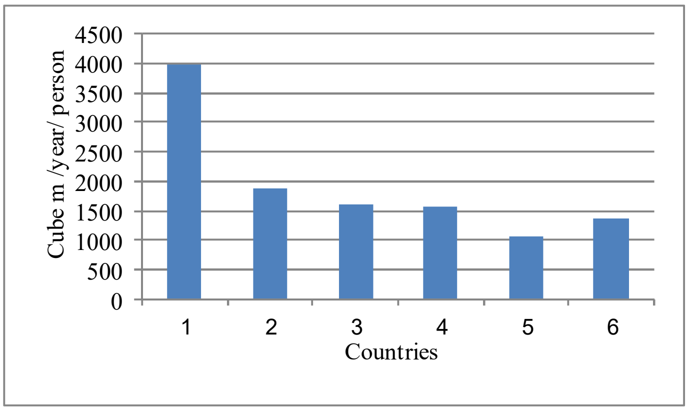

Figure 2 *Provision with common water resources for some countries of the world, m^3/year/person: 1 – Ukraine; 2 – Germany; 3 – Belgium; 4 – Poland; 6 – Denmark; 7 – Republic of Korea*

4. Unconventional water sources

Limited access to traditional water resources requires new methods to include unconventional water sources in the global water strategy. The main trends show that the reuse of wastewater and desalination of sea water are the most common ways of exploring unconventional water sources. For example, in 2019, the total annual use of unconventional water resources in China exceeded 9 billion m^3 (1.5% of the country's total water use per year), of which more than 80% account for recovered wastewater. In 2018, about 95 million m³ per day of desalinated water for human use was produced at 15906 operating desalination plants in the world (Jones et al., 2019). About 300 million people were provided with fresh water. The Middle East concentrates 70% of the world's desalination plants. Most of them are in Saudi Arabia, the United Arab Emirates, Kuwait and Bahrain. Seven countries of the Arabian Peninsula produce about 50% of desalinated water in the world, the USA – 10%.

Nowadays, the use of gray water – that part of household wastewater, which is formed from wash basins, bathtubs and showers – is gaining popularity. Unlike black water (wastewater from toilets), it does not contain fecal contaminants. Gray water is effective for: irrigating farmland, city parks and golf courses; replenishment of surface and underground water bodies; cooling units, etc. Approximately 50 countries use wastewater for irrigation (they account for 10% of the irrigated land area). In Israel, recovered wastewater accounts for nearly 50% of all water used for irrigation. With methodological approaches for monitoring water use, the introduction of the concepts of "virtual water" (1993) and "water footprint" (2002) should be emphasized.

Conclusions

1). The planet is facing a real shortage of water resources, recognized among the largest global risks in terms of potential impact on human society in the next decade. 2). Limited access to traditional water resources leads to the search for new approaches and their implementation to include unconventional water sources in the future water use strategy (desalinated water, recovered wastewater, gray water, collected rainwater, etc.), development of a green and blue water paradigm. 3). A number of considered areas of activity mobilizing the efforts of the world community in front of the challenges of the 21st century in the field of global water resources have not yet received in Ukraine the necessary dynamics for their implementation.

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