Water supply and water security in the context of Russian aggression

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Content

“Water, thou hast no taste, no color, no odor; canst not be defined, art relished while ever mysterious. Not necessary to life, but rather life itself, thou fillest us with a gratification that exceeds the delight of the senses.”
Antoine de Saint-Exupéry, Wind, Sand and Stars

The world is on the verge of water drama. Today, about 2 billion people worldwide are denied access to safe drinking water. Most of them live in vulnerable regions of the world, where both civil and military conflicts often occur. In the context of modern armed conflicts and military operations, water resources and structures are increasingly being targeted or used as a means of warfare. Water scarcity is particularly acute in the face of rapid population growth and climate change. Despite these challenges, by the middle of the 21st century, humanity will have to find ways to produce 1.5 times more food and double energy production. And this is definitely directly related to the issues of water supply.

In a number of current armed conflicts, there is a growing trend to use water and infrastructure as targets for attacks or means of warfare, especially in urban settings. This practice is a gross violation of international humanitarian law, so all states are obliged to respect and ensure respect for and observance of international humanitarian law. The international community as a whole should promote the work of humanitarian and non-governmental organizations, as a permanent long-term partnership between them and local water service providers is important for the protection or restoration of water infrastructure.

International efforts to maintain peace and security should include effective policies to protect water infrastructure from all attacks, including acts of terrorism, and pay special attention to the humanitarian needs of the civilian population.

The water drama also affected Ukraine, when issues of water supply and water security became extremely relevant in the context of the armed conflict with the Russian aggressor.

Chapter 1. Water as a critical resource and the cause of armed conflict

1.1. The state of water supply in the world

Water supply is central to economic and social development: it is vital for health, food production, energy production, environmental management, economic development and job creation. In addition, water security is an integral part of achieving the Sustainable Development Goals (SDGs) [1]. The world will not be able to meet the sustainable development challenges of the 21st century, namely human development, sustainable urban development, climate change, food and energy security, without improving water management and access to reliable water and sanitation services.

Today, the total water supply on Earth is about 1.4 billion m^3. In this way, each person has about 200 million m^3. It would seem that this is a huge amount, but it is important to take into account the fact that 96.5% of these reserves are salt waters of the world's oceans, which are unfit for consumption, and another 1% - groundwater. According to the US Geological Survey, fresh water does not exceed 2.5% of the world's water resources. In fact, humans are left with 1.2% of fresh water located on the Earth's surface, 69% of which - permafrost and only 21% - rivers and lakes. Latin America has the largest supply of fresh water, with 30% of the world's drainage. The Eurasian continent, home to 70% of the world's population, accounts for only 40%, and sub-Saharan Africa accounts for 10% of the drain. The Middle East and North America are the least supplied with fresh water (only 1%).

According to scientists, under the current practice of using existing water reserves, the world will face a 40% deficit in projected demand by the beginning of 2030. Today, 70% of the world's water intake goes to agriculture. To feed 9 billion people, by 2050 we will need to increase agricultural production by 60% and increase water intake by 15%. The world will also need more water to produce electricity, although more than 1.3 billion people still do not have access to electricity.

Today, more than half of the world's population lives in cities, and the number of urban residents is growing rapidly. At the same time, groundwater reserves do not have time to replenish. By 2025, about 1.8 billion people will live in regions or countries with absolute water shortages.

A World Bank report released in May 2016 suggests that water scarcity exacerbated by climate change may cost some regions up to 6% of their GDP, encourage migration and provoke armed conflict.

Despite the impressive advances of the last few decades, 2.4 billion people today do not have access to improved hygiene and sanitation facilities. At least 663 million people do not have access to clean drinking water. Low levels of sanitation, water supply and hygiene lead to 675,000 premature deaths per year, and the annual economic losses of some countries are estimated at 7% of GDP.

By 2030, 47% of the world's population will experience acute water shortages. Water may soon be more important than oil or gas. Demand for fresh water, according to the American Population Institute, exceeds supply by 17%.

The world's lack of water resources is being compensated for by underground mining, which has almost tripled in the last 50 years and is draining groundwater. However, the available freshwater resources are still declining every year and do not have time to recover. Water may soon become a strategic resource that opens up opportunities for water wars and armed conflict.

In total, there are about 215 large rivers and more than 300 groundwater basins on Earth that control several countries at once. The peculiarity of water resources is the lack of political borders: at least one transboundary catchment area covers the territory of 148 countries [2].

There are a total of 276 transboundary basins in the world, of which 64 are in Africa, 60 in Asia, 68 in Europe, 46 in North America and 38 in South America. 256 pools are located in two, three or four countries. The Danube basin, for example, is shared by 18 countries. There are 30 watersheds in Russia, 19 in the United States, 18 each in Argentina and China, and 10 in France. About a third of all transboundary watersheds are located in Africa. There are 63 to 80 transboundary rivers and lakes on this continent.

The most dependent on water coming from neighboring countries are Kuwait (100%), Turkmenistan (97.1%), Egypt (96.9%), Mauritania (96.5%), Hungary (94.2%), Moldova (91.4%), Bangladesh (91.3%), Niger (89.6%), the Netherlands (87.9%). In the post-Soviet space, the dependence of countries on water resources from abroad is distributed as follows: Moldova (91.4%), Uzbekistan (77.4%), Azerbaijan (76.6%), Ukraine (62%), Latvia (52.8 %), Belarus (35.9%), Lithuania (37.5%), Kazakhstan (31.2%), Tajikistan (16.7%), Armenia (11.7%), Georgia (8.2%), Russia (4.3%), Estonia (0.8%), Kyrgyzstan (0%) [3].

Water supply per capita is one of the important indicators that can also influence policy decision-making and water management (Table 1.1) [4].

According to the Institute of Water Problems and Reclamation (IPI) of NAAS of Ukraine, the general picture of the distribution of water resources is shown in Fig. 1.1 [5].

Table 1.1. Provision of water resources of a number of countries

Country	**Provision (thousand m3/year)**	**Country**	**Provision (thousand m3/year)**
Iceland	550	Austria	9
Guyana	316	Ukraine	3
Papua New Guinea	170	France	3
Canada	87	Japan	3
Norway	77	Germany	2
New Zealand	75	CHPR	2
Peru	66	India	2
Brazil	42	RSA	1
Russia	32	Egypt	0,7
Australia	22	UAE	0 03
USA	10	Kuwait	0,007

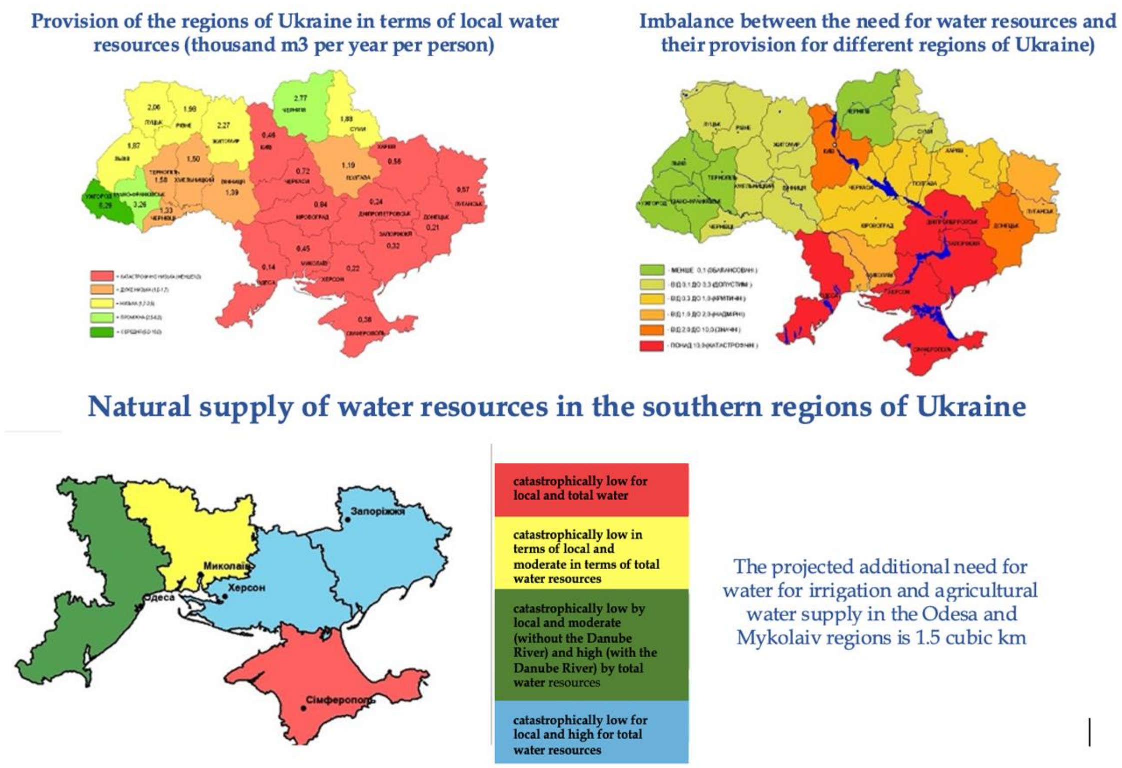

Fig. 1.1. Provision of regions of Ukraine with water resources

1.2. Armed struggle for water and its consequences

Historians and researchers have recorded more than 650 wars and armed conflicts over access to freshwater sources, including 66 in Europe. According to a study by the Pacific Institute, there have been 357 water disputes worldwide since 2000 (93 in Africa, 90 in the Middle East, 60- in southern Asia). According to estimates by the portal of the World's Water think tank Pacific Institute in California (USA), since 2010 there have been 466 conflicts and clashes related to the distribution of water resources, of which 36 were armed. In 2018 alone, there were 18 conflicts over water resources, and the probability of new ones in the next 50-100 years is estimated at 75-95%.

Experts from the Pacific Institute (USA) distinguish three types of violence in wars over water or its use:

– water is used as a weapon when artificial floods force the enemy to change their plans in favor of the other party;

– water can only be a good reason;

– water supply facilities belong to the category of critical infrastructure and the subject of hostilities, which are observed almost everywhere where there have been recent wars.

Most water disputes are subnational. In fact, today the world is divided into those who still have enough water and those who do not have enough. However, computer simulations of the situation indicate a high probability of cross-border conflicts over water in different parts of the world. Along with the famous basins (Lake Chad, the Nile, Brahmaputra, Ganges, Zambezi, Limpopo, Mekong, Senegal), the UN report also mentions Araks, Irtysh, Kuru, Ob. The most conflicting are the Nile, Indus, Tigris and Euphrates, Ganges and Colorado river basins.

Based on the analysis of surface water depletion in 167 countries, experts from the Institute of World Resources predict that nine countries in the Middle East will be at risk in 25 years.

In the Middle East, water has long been part of politics, and leaders in the Nile, Tigris and Euphrates basins are well aware of the link between water resources and foreign policy. Egyptian President Anwar Sadat said back in 1979: "The only thing that could force Egypt to go to war again is water." In the period 2000-2003 alone, analysts counted 15 armed conflicts related to water in different parts of the world, in 12 cases due to the fact that the parties could not share common water resources. Yes, D. Cooley [6] argues that the inability to share clean water was the main impetus for the 1967 Arab-Israeli war.

Some countries are located in the upper reaches of rivers, others - in the lower reaches. "Top countries" are in a better position: they have the ability to affect water levels (for example, using dams) and water quality (pollution). Such inequality, dictated by geographical conditions, is one of the causes of international conflicts over water.

Obviously, the consequences of contradictions and conflicts related to water scarcity depend on the size of the state, its level of economic development, military power: strong countries in the grassroots have leverage to achieve the most favorable distribution of water resources. When the "top state" is also strong, so in practice it turns out that those "below" are often ignored.

An example of the above is the situation in the Tigris and Euphrates basins.

In the upper reaches is Turkey, in the middle reaches - Syria, in the lower reaches - Iraq. On the territory of "strong" Turkey accumulates 2/3 of the Tigris and Euphrates. For the "weaker" Iraq and Syria, the importance of the Tigris and Euphrates is invaluable: without water, they would turn into a desert. Disagreements between Turkey, Syria and Iraq escalated in the 1970s, when population growth and industrialization required major projects, mainly irrigation and energy.

The dam, built in 1975 in Syria, blocked the waters of the Euphrates, affecting millions of Iraqi farmers and increasing political tensions in the region. Turkey has repeatedly stated that the water flowing through its territory is its exclusive property, and the lower states have no right to specify how to use this water. In the 1980s, Turkey announced the launch of a large-scale South-Eastern Anatolian Project, which included the construction of 22 dams, 19 hydropower plants and 25 irrigation systems on the Tigris and Euphrates. The project was not fully implemented, but in this form, it caused a lot of damage to downstream countries. Despite protests from Syria and Iraq, Turkey has not forgotten to take advantage of its geographical and economic position. That is why Iraq and Syria do not get enough water, which is also polluted. These countries call water the Turkish weapon and have concluded a joint agreement on the distribution of water resources. Turkey does not recognize this agreement, as it uses its own logic and considers rivers to be cross-border waters.

The drought in Syria in 2006-2011 and the waste of natural resources provided a fertile ground for conflict. As a result, about 800,000 people were left without means of subsistence. Harvest loss in some areas reached 75%, livestock loss - up to 85%. Almost 20% of citizens lost their jobs. The growing discontent of the population was among the factors that led to the riots and the beginning of the civil war [7]. Researchers at Stanford University have shown for the first time how water management practices have changed in the area of active hostilities. They focused on the changes that took place from 2013 to 2015 in the Jordan River area with its largest tributary, the Yarmouk River. Using images of the 11 largest water areas controlled by Syria, the researchers found that the volume of water in reservoirs decreased by 49% and the number of irrigated crops - by 47% (Fig. 1.2).

Today, Turkey continues to artificially reduce the level of water flowing from the Euphrates River into Syrian territory, causing significant damage to agricultural land in the region. In addition, this also causes power outages, which negatively affects industrial sector and, consequently, the livelihood of the Syrian people in general and in areas of northeastern Syria [8].

The factor in the struggle for water resources was one of the leading in the Arab-Israeli wars [6]. Thus, during the Six-Day War of 1967 with Syria, Israel addressed not only "security" but also the acquisition of water resources in neighboring countries, including the Golan Heights. After 1967, it provides itself with 15% of fresh water from the Golan Heights.

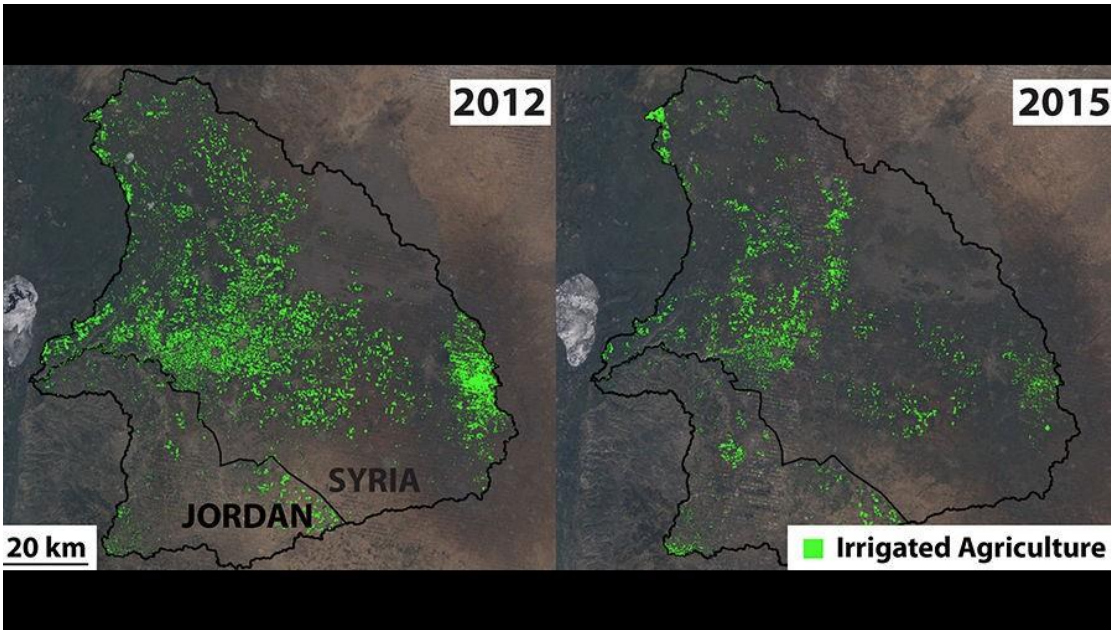

Fig. 1.2. The ratio of the number of irrigated crops in Syria in 2012 and 2015

At the same time, Israel finally destroyed the dam that the Syrians began building, seized the West Bank and Gaza Strip, and expanded access to the Yarmouk and Jordan Rivers, strengthening control over the region's three largest freshwater springs.

Israel has introduced its own water management system in the West Bank and restrictive quotas for local water intake and new wells. Jordan is experiencing even more water stress after accepting more than half a million Syrian refugees, as the only source of this resource is aquifers. In 2002, Israel opposed Lebanon's decision to build a dam in the upper reaches of the Jordan River.

In Central Asia, with its continental climate, the lack of fresh water has been felt for a long time - especially in the basins of the Ili, Syr Darya and Chu-Talas basins, which are formed by melting glaciers. Countries bordering the Fergana Valley are already experiencing radicalization of poor and vulnerable social groups due to drinking water problems, affecting the internal stability of local regimes.

The region's two largest rivers, the Amu Darya and the Syr Darya, are almost entirely owned by Kyrgyzstan and Tajikistan, which use water resources for irrigation and electricity generation. This does not suit the countries that lack water: Kazakhstan, Turkmenistan, Uzbekistan, Afghanistan.

In addition, Tajikistan is building the Rogun HPP on the Amu Darya (commissioning date - 2033), the launch of which could hit the agricultural sector of neighboring Uzbekistan. It is about blocking the riverbed for the time of filling the future reservoir, which threatens to destroy the crops of strategically important crops for Uzbekistan.

Kazakhstan is resolving joint water use issues with Kyrgyzstan and Uzbekistan in the Chu-Talas and Syr Darya basins on the basis of a 1992 agreement. But in the case of China's construction of an irrigation system network in the upper reaches of the Abo River since 2015, no agreement can be reached.

The situation is different on the African continent in the Nile basin for countries such as Egypt, Burundi, the Democratic Republic of the Congo, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Tanzania and Uganda. The economic and political leader of the region is Egypt, which uses the most Nile water. Interesting relations between Egypt and Ethiopia, near which accumulates about 85% of the waters of the Nile. Geographical location favors Egypt, it has long established a regime of distribution of Nile water, as it is much stronger than Ethiopia in economic and military terms. In 1978, A. Sadat declared: "Our lives depend 100 percent on the waters of the Nile, and if someone tries to take our lives, we will without hesitation go to war." It is true that Egypt has signed an agreement with Ethiopia and Sudan governing water use, but this document only confirmed the favorable status quo of Egypt.

In East Africa, economically strengthened Eritrea began to demand a revision of the distribution of Nile waters. Egypt is concerned about Ethiopia's possible agreement with Sudan to implement joint projects. This situation and the pressure of international organizations forced the Nile basin states to start negotiations in 1999: ten countries tried to reach a consensus, to create a balanced model of use of the waters of the great river. As a result, Egypt had to make concessions to the weaker countries of the upper Nile.

For a long time, there was a threat of military conflict between Egypt and Ethiopia through the construction of the last dam of Africa's largest hydropower plant "Hidas" ("Renaissance") in the upper reaches of the Blue Nile. The problem is the speed of filling the HPP reservoir with a volume of up to 74 billion m 3 of water. Ethiopia is interested in doing so as soon as possible, but other countries, especially Egypt and Sudan, have insisted on a gradual process to avoid the danger of a critical fall in the lower Nile.

Poor 100 million Ethiopia has high hopes for the new hydropower plant, as it will turn it from an importer to another on the continent producer and even the exporter of electricity, which will provide a profit in $27 million per day. Egypt was initially opposed to the construction of this hydraulic structure, sometimes even threatening Cairo to use military force to destroy the dam. At the same time, to protect it, Ethiopia acquired in 2019 SAM "Pantsir-C1" and S-300PMU1. Egypt has even complained about Ethiopia's actions to the UN Security Council.

Ethiopia, on the other hand, has exposed Egypt for insincerity. After all, when he complains about the lack of water, he is simultaneously implementing a large-scale agricultural project in the Sinai Desert to grow vegetables and fruits for export. For irrigation, Cairo is already building an underground water supply under the Suez Canal, which plans to transfer Nile water.

The conflict between India and Pakistan, which compete for water resources, is particularly likely. Claims to this resource are also central to bilateral disputes over Kashmir, which have been going on for more than 60 years. At the same time, 80% of Pakistan's water supply depends on India, for which it is a matter of survival.

In 1948, during the first Indo-Pakistani war in Kashmir, India even cut off water supplies to the Pakistani province of Punjab. In 1960, with the mediation of the World Bank, the parties concluded a bilateral agreement on the division of the Indus River Basin. India received the Sutledge, Beas, and Ravi rivers, and Pakistan the Chinab, Jellum, and Indus rivers. However, India has repeatedly violated the main provisions of this document. So, in 2005, she decided to build a hydroelectric power plant on the Pakistan-controlled Chinab River, which sparked a protest in Islamabad. And in 2016, due to the intensification of militants in Kashmir, Delhi threatened to break the agreement with Pakistan, which resulted in a real war between these nuclear countries.

Instead, India itself depends on China, which is located even higher upstream of the rivers that originate in the Himalayas. China, which itself has problems with fresh water, plans to block 8-10 large rivers, which originate on the plateau of Tibet, the world's largest water reservoir. We are talking about irrigation of plantations in the central and eastern provinces, where in 2030 25% of water shortage is expected. China has already built 10 dams on Brahmaputra and is building 18 more, which will further reduce the amount of water India and Bangladesh receive.

Particularly dangerous is the Chinese project on the Yarlung-Tsangpo River (upper reaches of the Brahmaputra) in southern Tibet. It is a plan to build a 1,000-kilometer underground water pipeline to transfer water to the Takla-Makan Desert (Xinjiang) to grow agricultural products there. This threatens the outflow of significant amounts of water and falling its level in the lower reaches of the river with catastrophic consequences for the population. Another Chinese project involves building a 300-kilometer canal to divert up to 17 billion m3 of fresh water a year from Tibet to save the Yellow River, which feeds China's vast population but is critically depleted and depleted.

India also suffers from drought and persistent water shortages not only for the agricultural sector but also for industry and energy. By 2030, 70% of India's CHPs are projected to face water shortages due to increased demand in other sectors.

In the United States, fresh water is already a key element of security, and there are even voices in favor of giving water a higher priority in international politics, seeing it as a leading factor. There are concerns about the prospect of further use by the United States (along with Canada, which Washington ignores protests) of a resource for industrial waste polluted by the Great Lakes, where water levels are falling. The United States also cannot agree with Mexico on a fair distribution of water in the Rio Grande Basin (Colorado, Tijuana and Rio Grande).

1.3. Ukrainian water issues in the conditions of Russian aggression

According to the reserves of water resources available for use, Ukraine is one of the poor. According to this indicator, Ukraine ranks 111th among 152 countries. It ranks 17th among 20 European countries.

The climate in Ukraine is becoming tropical with long rainy periods, falling groundwater levels and massive drying up of small rivers and wells. According to forecasts, further shortages of fresh water should be expected over the next 30 years, and after 2050 Ukraine may even switch to its imports.

In one study [9], Ukrainian scientists analyzed how rivers will change under two different climate change scenarios:

– "soft", which provides for the reduction of greenhouse gas emissions in accordance with the Paris Agreement;

– "tough", under which no measures to combat the climate crisis will take place.

The results of this study show that by the end of the century in most basins of Ukraine river runoff will decrease in both scenarios:

– in the Dnieper basin is expected to reduce water runoff by an average of -20% (up to 24% in summer), from January to March a slight increase in runoff is possible;

– in the Western Bug basin runoff may decrease on average from 28% to 30% in all months except February; the largest decline is expected in the fall (up to 32%);

– in the Dniester basin, according to the "hard" scenario, a catastrophic decrease in runoff is expected at the end of the century - up to 36-38% in some months;

– reduction of water runoff in the Pripyat River basin will be in the range from -12 to -23%, but the reduction of water runoff during the summer season may reach 37%;

– no significant changes are forecast in the Desna basin, but in January-March the water runoff may increase from 28% to 45%; other months, an unknown decrease in runoff is expected;

– in the basin of the Southern Bug at the end of the century is expected to significantly reduce the average annual runoff - up to 30%, and in some months up to 45%;

It is important to note that under the scenario of a significant increase concentrations of greenhouse gases, the reduction of water in rivers will be significantly stronger than in the "soft" scenario.

The worst situation is in the basins of the Southern Bug and the Dniester, where by the end of the century the river runoff may be reduced by more than a third. In addition, the water flow of small rivers (particularly in the Southern Bug basin) is also gradually declining, and from the middle of the century may stop completely. Thus, at the end of the century water resources.

The war that Russia started against Ukraine in 2014 had the greatest impact on those regions where the situation with water supply was the worst before the war. In particular, this applies to the Autonomous Republic of Crimea, which received most of its water from the mainland - an average of about 85% [10]. Due to the occupation of Crimea by Russian troops, water supply through the North Crimean Canal was cut off, as international humanitarian law, which protects civilians during the war, obliges the occupier to meet the needs of the people in these territories.

Shallowing of many reservoirs, including Simferopol, was observed from the first years of occupation. But the abnormally warm and arid winter-spring period of 2020 exacerbated the situation and led to a drought in Ukraine. In Crimea, in particular, since the beginning of spring 2020, natural runoff reservoirs have been filled almost half less than in the spring of 2019, and at the beginning of summer - 2.3 times less than in 2019. Therefore, in the fall of 2020, there were numerous interruptions in water supply and water outages in many regions of Crimea.

In 2022, water became one of the reasons for the Russian army's attack on the Kherson region. The intention of this strike is to unblock the supply of Dnieper water to the temporarily occupied Crimean Peninsula from the Nova Kakhovka region. This is a crucial task because since 2014 the occupiers have depleted the water-poor Crimean underground water horizons. At the end of February 2022, the occupiers seized the main building of the North Crimean Canal, the Kakhovka HPP and all hydraulic structures that regulated the supply of water from the Kakhovka Reservoir to the Crimean Peninsula. The occupiers also destroyed a temporary dam, a road bridge and the main partition structure of the canal.

The seizure of water supplies by Russian troops and the temporary resumption of water supplies to Crimea could exacerbate water shortages on both the mainland and the peninsula. After all, the southern regions are, on the one hand, the least supplied with water resources, on the other - and the largest consumers.

An additional problem is the impact of climate change on these regions. Scientists note that from 2041 it is possible to stop local surface runoff into shallow rivers in Kherson, Odessa, Mykolaiv, Dnipropetrovsk and Zaporizhzhia regions. For example, in the Zaporizhzhia region "Climate runoff" can be reduced tenfold, in Dnipropetrovsk - 6 times, in Mykolaiv - 3.6 times, and in the Crimea - twice [10].

In March 2022, during the Russian aggression, shelling and shelling of water pumping stations, water mains, and sewage treatment plants were recorded, leading to accidents and depriving people of access to drinking water. In particular, residents of Mariupol are left without water, where Russian troops are deliberately destroying civilians.

Finally, the problem of groundwater pollution is urgent in Ukraine. There is a danger of environmental disaster due to the flooding of a number of looted by the Russian occupiers and abandoned coal mines in the temporarily occupied areas of Donbass.

For 1.5 months of Russian aggression in Ukraine, a public organization Ecodia (https://ecoaction.org.ua) counted about 150 environmental crimes (Fig. 1.3), which negatively affect the state of land, water and air, as well as cause irreparable damage to ecosystems. Dozens of these crimes directly or indirectly cause pollution of water resources, which are very limited.

Fig. 1.3. Environmental crimes in the first 1.5 months of Russian aggression in Ukraine

The Russian occupiers are shelling water infrastructure, bypassing dams, and conducting military operations in the Black and Azov Seas. Thus, as a result of the shelling of the treatment facilities of the Vasylkiv Water Supply and Sewerage Operational Shop, the Russian army destroyed the sewage pumping station building. As a result of such actions, return water enters the Dnieper River without any treatment.

During the month of the war, the strategic goals of the occupiers were oil depots in Kharkiv, Chernihiv, Luhansk, Zhytomyr, Kalynivka, Lviv, Dubna, Lutsk, and others. Such explosions and fires can contaminate both soil and water resources.

Naturally, a new global trend in modern development is the transformation of water resources into key strategic resources, which are increasingly the subject of international conflicts, armed conflicts and even armed conflicts. Water is a valuable but limited resource, especially in the southern and eastern regions of Ukraine. Russia's military actions worsen the water situation in our country.

Chapter 2. Legal protection and safety of water

2.1. Humanitarian law on water safety

The rules of international humanitarian law developed and applied during military operations have for a long time not directly regulated the protection of the environment during war. On the other hand, restricting or banning the use of weapons or methods of warfare to reduce the impact of death or the health of civilians also has the effect of reducing the impact on the environment: air, water, biodiversity, etc. International legal regulation of hostilities and protection of the population, civilian and military facilities, tactics and methods of warfare in one way or another affects the preservation of environmental elements during the war [11].

It is known that international humanitarian law provides protection to certain categories of persons and objects. It does not contain special provisions relating to water, as such provisions are part of the law applicable in time of war. At the same time, the consequences of hostilities may extend to water, and certain provisions of humanitarian law, including clear prohibitions, should be applied. Water is also seen as an element needed to meet the most pressing needs of people.

In addition to the general protection provided to all civilian objects, water, being an integral part of the environment, is protected by all regulations. Without dwelling on this aspect, four main prohibitions directly related to water should be mentioned in particular [12]:

– ban on the use of poison as a means of warfare;
– ban on destroying enemy property;
– ban on attacking objects necessary for the survival of the civilian population;
– ban on attacks and structures containing hazardous industries.

Humanitarian law aims to provide at least the minimum conditions for the normal life of the persons it must protect in order to be a concrete expression of the satisfaction of basic human needs. But when we talk about basic needs, we always mean the need for water. It should be noted that in principle it is impossible to help the wounded and sick and provide them with care without water. In order to do their job, medical staff need water. The same can be said about sanitary equipment and sanitary facilities, as well as about the needs of hygienic order in all those places where internally displaced persons are. This fact is so obvious that it was decided not to adopt special provisions in this regard.

International humanitarian law contains provisions on the protection of civilians, civilian infrastructure and natural resources under time of armed conflict. Additional Protocols of 1977 to the Geneva Convention of 1949 prohibit attacks on facilities "necessary for the survival of the civilian population", including drinking water facilities and irrigation networks [13]. However, as noted in recent studies, international law is insufficient to protect aquatic systems in modern conflicts, which are no longer conducted mainly between states, but include non-state parties to the conflict who do not comply with various conventions [13-15].

In [12] it was concluded that in armed conflicts water can be attacked and even become a means of warfare. In both cases, it is a civilian object that is essential for the survival of the population, and therefore military action against water or its use as a means of warfare is completely incompatible with the principles and provisions of humanitarian law.

In addition, it is noted that the threat to water is identical factors that pose a threat to the environment as a whole. The mandate of the International Committee of the Red Cross (ICR) in the field of environmental protection in times of armed conflict is recognized by the entire international community. In various situations of armed violence (conflicts, riots, situations of tension), the Ministry of Foreign Affairs has certain powers, which allows it to exercise its presence, to take any immediate action, including preventive ones.

Most of the provisions of humanitarian law related to this problem related to situations of international armed conflicts, and the rules applied during internal conflicts are still insufficiently developed; as for some other cases of armed violence within the country, they remain outside the scope of international humanitarian law. However, tensions over water supply and attacks on water resources and hydraulic structures often occur in situations of internal conflict and unrest.

Whatever the objectives and priorities of water protection activities, its main actors must act on the basis of information exchange, coherence and coordination. Adherence to these principles is essential both when implementing contingency plans and when making preventive decisions. However, the consequences of armed conflicts are so numerous and complex that the involvement of other organizations is needed to solve them.

2.2. Water safety concept

Water scarcity describes the relationship between water demand and its availability [16]. There are two types of water shortage:

– *physical deficit* - when the demand for water exceeds its supply; it occurs in case of excessive exploitation of water resources;

– *socio-economic* - when investment, capacity or political will are insufficient to keep up with growing water needs, thereby hindering access to its resources.

Both forms of scarcity are due to poor management of water resources, not their absolute availability, i.e. "lack of water" does not necessarily mean the lack of adequate water resources in a particular place. Water scarcity should be distinguished from the biological concept of "water scarcity", which means a lack of water saturation of plant cells, resulting from the intensive loss of water by a plant that is not filled by absorbing it from the soil.

Water stress is the result of water scarcity and can manifest itself as insecurity of drinking water, poor access to or conflict with water, crop failure, food and / or energy insecurity.

Water security as a concept embodies complex and interrelated challenges, emphasizing the central role of water in achieving a sense of greater security, sustainable development and human well-being. At the same time, there is no single, widely accepted definition of the term "water security"; it usually depends on its applications, for example, to humans or the environment.

Of the various definitions in the context of this study, the most acceptable is: “Water security is the ability of the population to have safe and sustainable access to adequate amounts of acceptable water quality to support its livelihoods, well-being and socio-economic development. ensuring protection against water-related pollution and preserving ecosystems in peace and political stability "[17].

Key elements of water safety:

– access to sufficient safe and affordable water needed to meet the basic needs of the population, including the sanitary and hygienic protection of its health and well-being;

– ensuring human rights to water, as well as cultural and recreational values provided by water;

– protection and conservation of aquatic ecosystems to support their capacity to provide and maintain basic ecosystem services;

– providing water for socio-economic development and functioning of industry, energy, transport, tourism, etc.;

– collection and treatment of drinking water to protect against pollution of public health and the environment;

– common approaches to the management of transboundary water resources within and between countries in order to ensure sustainability and cooperation in the field of freshwater resources;

– ability to withstand water-related uncertainties and risks such as floods, droughts and hazardous pollution;

– good governance and accountability, taking into account the interests of all stakeholders, through effective, transparent and accountable, including public, legal regimes and institutions, as well as well-planned and efficient infrastructure.

The concept of water security, which reflects the dynamic aspects of water and water-related issues, offers a holistic view of the challenges it faces. According to researchers [18], the main threats to water safety include the following group of factors:

– weak political will and low institutional capacity for water resources management and water supply services;

– lack of universal access to water due to inability to pay, social or political status, incapacity, age or other reasons;

– low resilience of the population in the face of stress;

– poor sanitation and hygiene of water supply systems;

– rapid population growth and urbanization;
– climate variability and change.

2.3. Practical dimension of water safety

There is a growing need for practical approaches to the application of quantitative indicators in national and development planning water and land resources of the river basin and management activities.

To measure water safety, there are several parameters involved that combine several indicators. In addition, the level of importance of the parameters may vary depending on the situation and the severity of the problem. Water safety may also need to be measured differently at the national, river basin and city levels. However, you can get a general framework to describe your specific water safety issues and help them identify a set of relevant quantitative indicators.

For example, the OVRA framework [19] defines 5 key parameters:

– water security at the household level (КП 1);
– economic water security (КП 2);
– urban water safety (КП 3);
– water safety of the environment (КП 4);
– resistance to water disasters (КП 5).

Points from 1 to 5 are assigned to each parameter, which are formed on the basis of publicly available data, supplemented by expert assessment where such data are not available. The obtained results are presented visually in pentagrams (Fig. 2.1). The scores for each key parameter are part of a series of indicators that describe the sub-elements of each of the key parameters, which are briefly described below.

Key parameter 1 (КП 1): water safety of households. Objective: to measure the safety of domestic water supply at the household level. Indicators: access to the water supply network (%); access to sewerage (%); hygiene.

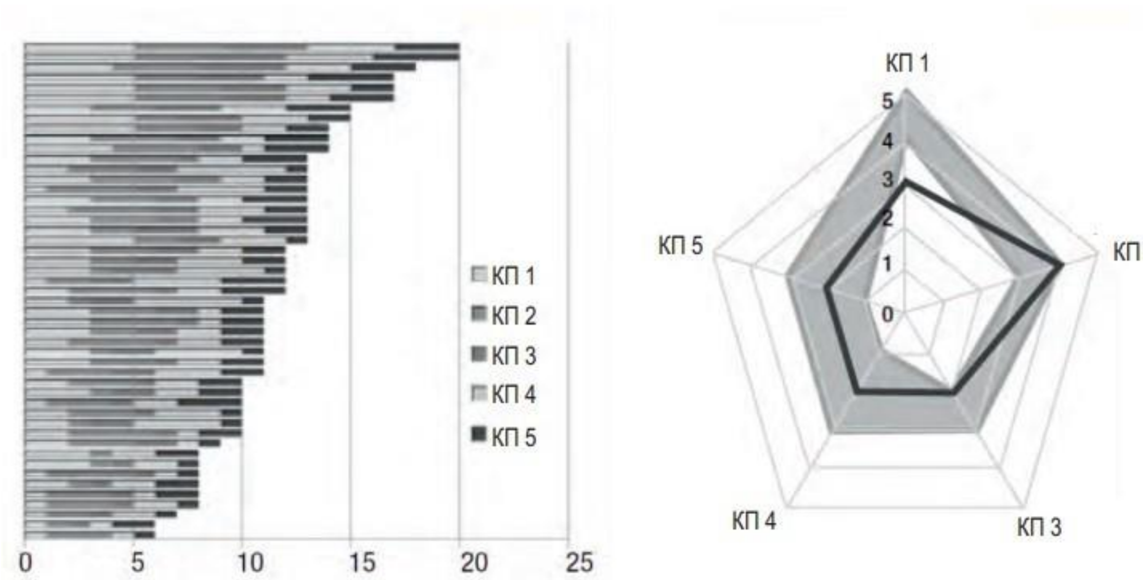

Fig. 2.1. Formation of key parameters

Key parameter 2 (КП 2): water security of the economy. Objective: To measure how countries ensure productive water use to support economic growth in food, industry and energy. Indicators: productive sectors of agriculture (agricultural dependence, efficiency of use); industry (industrial water productivity, industrial consumption); and energy (% of developed hydropower potential, % of hydropower dependence); with the indicator of stability added on storage and inter- and intra-annual variability of precipitation.

Key parameter 3 (КП 3): water safety of cities. Objective: to create better management of water resources and services to maintain acceptable living conditions in cities with water problems. Indicators: water supply (%), wastewater treatment (%), sewerage (damage from floods and storms), with coefficients that take into account the impact of urban growth rates and environmental health.

Key parameter 4 (КП 4): water safety of ecosystems. Objective: to measure the progress of restoration of river basins and ecosystems for good ecology on a national and regional scale. Indicators: sanitation of rivers, including pressures / threats to the river system, vulnerability / resistance to changes in natural flows.

Key parameter 5 (КП 5): protection against water elements. Objective: to measure the level of hazard, degree of vulnerability and ability adapt to change. Indicators: resilience index according to the type of danger (floods and hurricanes, droughts and storms and coastal floods), which measures: susceptibility to impacts (e.g., population density, growth rate), main vulnerability of the population (e.g., poverty, land use); "Hard methods of overcoming", for example, the level of development of telecommunications and "soft methods of overcoming", for example, the level of literacy.

Indicators are used to shape the nature of key parameters, and their choice will depend on the purpose and specific assessment. 2-4 indicators (and sometimes sub-indicators) are used for each of these five key parameters. When adapting the methodology for river basins and cities, adjustments can be made to local priorities and available data sets.

Chapter 3. Water as a weapon and hydrodynamic danger of Ukraine

3.1. Using water as a weapon

It is important to note that the concentration of water in artificial reservoirs is a threat in peacetime. There are several examples of huge dam destruction resulting in the destruction of settlements and deaths [20]. Thus, after the break of the Banqiao Dam on the Zhu River in Henan Province (China) with a height of 118 m and a reservoir volume of 375 million m 3, 62 dams were demolished downstream. According to the Henan Province Hydrological Department, a total of 26,000 people died as a result of the floods, and another 145,000 died immediately after the famine and epidemics. 5.96 million houses were destroyed, one way or another, 11 million people were affected.

The breakthrough of the St. Francis Dam (Los Angeles, USA), which designed and built a giant aqueduct (372 km) across the Sierra Nevada Mountains, killed more than 600 people.

The arched concrete dam of Viont near Mount Toc in the province of Venice (Italy) after the natural destruction caused the deaths of about 350 families. As a result of the accident on the dam of the most powerful Sayano-Shushenskaya HPP on the Yenisei River (Russia), 75 people died.

Therefore, the use of water as a tool to achieve military goals is not a new phenomenon. Much of Iraq's water infrastructure was built as part of Britain's military efforts against the Ottoman Empire during World War I to gain control of the Euphrates and Tigris rivers and gain strategic advantage. For Israel, the expansion of irrigated agriculture, and thus the allocation of water resources for agricultural production, has become an important tool for strengthening territorial control in recent decades [22].

Von Lossov (2016) [23] identifies three approaches to the use of water in conflict: political, tactical and psychological.

The political approach entails the dominance of access to water as a means of strengthening one's own position in power. This often manifests itself as pressure on political leaders or local people to line up or suffer from water shortages. The tactical approach is closely linked to the mental image evoked by the term "water as a weapon". From this point of view, water and water infrastructure are directly used for military gains, for example, by flooding the territory to block the invasion of enemies, as was done by Chinese troops in 1938 during the Second Sino-Japanese War. Psychologically, the very threat of water weapons can create a disturbing atmosphere among the local population, which suffers great and potentially long-term damage.

Water infrastructure is also an attractive target, in addition to its role as a resource, as direct hit can have far-reaching and far-reaching consequences. For example, during the Gulf War, Kurdish forces attacked Iraqi waterworks, which they perceived as symbols of the state's presence [24], and Glick emphasizes the attractiveness of water bodies as targets for terrorist attacks in the form of infrastructure destruction or water pollution. [25].

3.2. Consequences of undermining Dniprohes during the Second World War

It is known that the accumulation of large amounts of water in artificial reservoirs during hostilities is quite a dangerous factor. The example of Dniprohes is a classic.

Units of the Soviet army, fulfilling the order in July 1941, switching the generators of hydroelectric power plants to self-immolation, retreated to the Left Bank. On August 18, 1941, Dniprohes was operating at full capacity, although German shells flew through the dam and engine room of the power plant. In the event of a retreat by Soviet troops, it was decided to disable the station's equipment and dam, not to allow the enemy to use the Dnieper. In addition to the planned destruction of the turbines, the dam itself had to be blown up.

German troops were still on the right bank of the Dnieper, near Nikopol and Kryvyi Rih. No one was warned about the planned explosion of the Dnieper Dam either on the dam itself, which was moving along the military convoys and troops retreating to the left bank of the Dnieper, or the population and institutions of Zapizhzhia - 10-12 km from the hydroelectric power plant downstream. The military units located down from Zaporizhzhia in the Dnieper floodplains were also not warned, although the telephone connection on the Left Bank was functioning normally at that time.

A study of the available documents of the 157th Regiment of the NKVD troops for the protection of particularly important industrial enterprises, which guarded and defended the Dnieper until the last minute, allows to determine the time of blasting: up to 20.00-20.30 August 18, 1941. It was at this time that the Dnieper River, the Dnieper Dam, and the railway bridge across the Dnieper River were blown up. Naturally, military convoys and people moving along the dam died. As a result of the explosion of the bridge and dam on the island of Khortytsia, the infantry regiment, which was crossing to the east coast at that time, was cut off. A large breach was formed in the body of the dam, there was an active discharge of water (Fig. 3.1).

As a result, there was a large flood zone in the lower reaches of the Dnieper. The giant wave washed away several enemy crossings, sank many fascist units hiding in the floodplains. But the water that broke free did not divide people into "own" and "foreign". An almost thirty-meter avalanche of water flashed across the Dnieper floodplain, flooding everything in its path. The entire lower part of

Zapizhzhia with huge reserves of different goods, military materials and tens of thousands of tons of food and other property in an hour demolished. Dozens of ships, along with ship's crews, perished in that horrific stream.

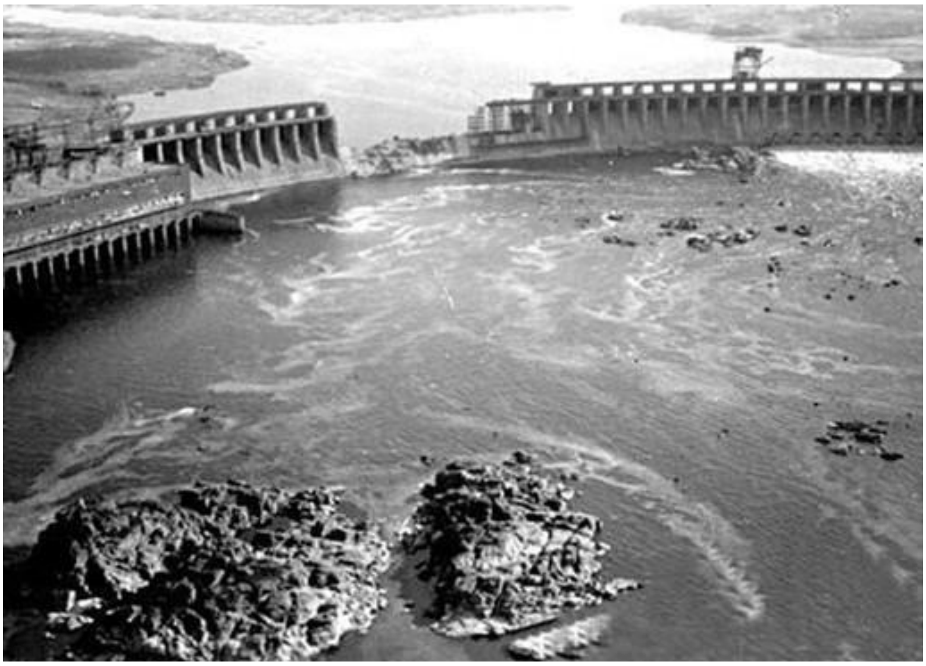

Fig. 3.1. Destruction after the explosion of the Dnieper Dam in 1941 [20]

In the autumn of 1943, during the retreat of the Germans, the Dnieper dam was blown up again. However, the plan to completely destroy the dam was not fully implemented, as Soviet sappers and scouts managed to damage some of the wires to the detonators. By the way, the undermining of the Dnieper Dam was among the charges against German war criminals during the Nuremberg Trials.

3.3. Threats to the hydrodynamic danger of the regions of modern Ukraine

Today in Ukraine, water can also be used as a weapon that has occurred in other modern armed conflicts. Destroyed dam can flood lands and cities far downstream. Capturing strategic water infrastructure can be a military goal. For example, Russia has captured the Kakhovka HPP, one of the largest in Ukraine. The HPP is located on a reservoir that cools the Zaporizhzhya NPP, the largest in Europe and one of the ten largest in the world.

A detailed description of the threat of hydrodynamic danger on rivers and reservoirs of Ukraine is given in [26].

The main sources of hydrodynamic danger for the population of the Carpathian economic region are 4 reservoirs. Yes, in Transcarpathia The main source of hydrodynamic danger for the population is the Tereble-Rika HPP reservoir with a volume of 24 million m 3, located on the Tereblya River. If the dam of the reservoir breaks in the flood zone, there will be 11 rural settlements with a total population of 25 thousand people. The water level in mountain villages will be from 8.2 to 27.9 m.

There are 2 reservoirs in Ivano-Frankivsk region (Burshtynske and Chechvynske), the break of dams which can cause catastrophic flooding. Thus, the reservoir of Burshtyn GRES (Burshtyn) is located on the river Hnyla Lypa and has a volume of retained water of 50 million m 3. As a result of the breakthrough of its dam, a catastrophic flood zone with a total area of 32.6 km 2 thousand people. And the Chechvyn Reservoir, which belongs to the Oriana concern (Rozhnyatyn town) and was formed on the Chechva River, holds 10.5 million m 3 of water. 12 thousand people live.

In the Chernivtsi region the main source of hydrodynamic danger for the population there is a reservoir of the Dniester HPP with a water volume of 3300 million m 3. When the dam of the reservoir is destroyed, a flood zone with an area of 24 km2 will appear, in which there are 3 settlements with a population of 3.5 thousand people.

For the Southern Economic Region, the greatest hydrodynamic dangers for the population are: Bakhchisaray, Belogorsk, Taygan, Feodosiya, Alminsk, Old Crimean, Balashiv, Chornorichensk, Oktyabrsky, Tashlyk, Kakhovka reservoirs and Khadzhibeysky estuary. Reservoirs located outside the region: Ladyzhynske (Vinnytsia region) and Dubosarskoe (Republic of Moldova) also pose a significant hydrodynamic danger to the population.

In the Autonomous Republic of Crimea there are 8 reservoirs - Bakhchisaray, Belogorsk, Taygan, Feodosia, Almin, Old Crimea, Balanov and Chornorichensk, the destruction of dams which will lead to catastrophic flooding of the total area of over 1 thousand km 2, with 86 settlements. 50 thousand people will get into the flood zone.

The Oktyabrsky, Ladyzhyn and Tashlyk reservoirs are located in the Mykolayiv region. As a result of break of the dam of the October reservoir one third of inhabitants (4,5 thousand persons) of the Ship area of Nikolaev will get to a zone of catastrophic flooding. If the dam of the Tashlyk Reservoir breaks along the Southern Bug, the territory with 10 settlements and up to 20,000 people will be flooded. At break of dams of other reservoirs of the Nikolaev area (Taborovsky, Shcherbanovsky, Sofievsky, Ekaterinovsky, Vedyano-Larynsky, Danilovsky and Shirokolanovsky) in the formed zones catastrophic flooding affects from 1 to 7 settlements with a population of 5 to 75 thousand people.

And as a result of the breach of the dam of the Ladyzhyn Reservoir, located outside the Southern Economic District (in Vinnytsia region) within the region along the Southern Bug will be flooded area, which houses 10 settlements and is home to 15 thousand people.

In Odesa oblast, critical flooding of the territory may occur as a result of an accident on the dams of 3 reservoirs: Hadzhibeysky estuary, Ladyzhyn (Vinnytsia oblast) and Dubossary (Republic of Moldova) reservoirs. The destruction of the Khadzhibey estuary dam will cause a catastrophic flooding of the territory of the Suvorov district of Odessa with a total area of 15 km 2. In the flood zone will be

31 industrial facilities with production staff of 20 thousand people. When the dam of the Ladyzhynskaya GRES reservoir is destroyed, the territory with a total area of 20 km2 will be flooded, in which 4 settlements of the Savran district with a population of 15 thousand people are located.

Breakthrough of the dam of the Dubossary hydroelectric power plant in Moldova will lead to catastrophic flooding of the region with a total area of 150 km 2. In the flood zone will be 16 settlements Bilyaevsky, Rozdilnyansky and Belgorod-Dniester districts, home to more than 20 thousand people.

In the Kherson region, catastrophic flooding of the area will occur during the destruction of the dam of the Kakhovka hydroelectric reservoir (volume 18,200 million m 3). In case of destruction of its dam, the territory with a total area of 340 km2 with 43 settlements located on it and the population living in them in the amount of 125 thousand people will be flooded. At the same time, 18 settlements with a population of 65.5 thousand people will be completely flooded and 25 settlements with a population of 60.5 thousand people will be partially flooded.

In the Podilsk economic region, the main sources of hydrodynamic danger to the population are 6 reservoirs. Thus, in Vinnytsia region the main sources of hydrodynamic danger to the population are 2 reservoirs: Dniester and Ladyzhyn. When the dam of the Dniester Reservoir is destroyed, a zone of catastrophic flooding of the territory with a total area of 84.4 km 2 will appear, in which there are 25 settlements with a population of 70.6 thousand people. With the destruction of the reservoir Ladyzhynskaya GRES in the flood zone will be an area with a total area of 50.5 km2, which is located 26 settlements inhabited by 11 thousand people.

In Khmelnytsky region, the hydrodynamic danger for the population is posed by 4 reservoirs: Netishyn, Martyniv, Shchedriv and Novokostiantyniv. Netishyn reservoir-cooler of Khmelnitsky NPP holds water in the amount of 120 million m 3. The destruction of its dam will cause a breakthrough of 3.9 million m 3 of water with catastrophic flooding of the region on section of 4 km from the reservoir. A wave of water 3.6 m high will flood 6 settlements only in Khmelnytsky region.

The reservoir of the Martynivka hydroelectric power plant with a volume of 3.27 million m 3 of water was formed on the Zbruch River. There will be 6 settlements in the flood zone. The Shchedrivska HPP reservoir with a volume of 28.5 million m 3 of water was formed on the Southern Buza. The total area of the catastrophic flood zone, which includes 5 settlements, will be 12 km 2. The reservoir of Novokostyantynivska HPP with a volume of 2 million m 3 of water is also formed on the Southern Bug. There will be 4 settlements in the catastrophic zone.

There are no sources of hydrodynamic danger for the population within the Polissya economic region. There is only one dangerous object - Netishyn Reservoir, which is located outside the region (in Khmelnytsky region). Due to the destruction of the dam of the reservoir, there will be catastrophic flooding in the neighboring Rivne region. The flood zone only in Rivne region will have a total area of 70 km 2. It includes the city of Ostrog and 8 settlements with a population of 14.8 thousand. persons.

The main sources of hydrodynamic danger for the population of Prydniprovsky economic district are 3 reservoirs (Dniprodzerzhynsk, Karachunivske, Kremenchug), dam accidents which will cause catastrophic consequences for the population of Dnipropetrovsk, Zaporizhia and Kirovohrad regions.

For the population of Dnipropetrovsk region, the hydrodynamic danger is posed by the reservoirs of Dniprodzerzhynsk and Karachunivska HPPs, the destruction of dams which can lead to dangerous flooding of large areas. For example, the breach of the Dneprodzerzhinsk Reservoir dam creates a flood zone with a total area of 769 km 2, which includes 5 cities (Kamyanske, Dnipro, Novomoskovsk, Marhanets and Nikopol) and 43 rural settlements in 8 districts of Dnipropetrovsk region.

In the flood zone will be about 500 thousand people, 87 household facilities. If the dam of the Karachunovskaya HPP dam breaks, a catastrophic flood zone with a total area of 12 km 2 with a population of 38,000 people will appear.

The dam of the Dniprodzerzhynsk Reservoir will be destroyed flooding is also part of the territory of Zaporozhye region with a total area of 342 km 2 on which the city of Zaporozhye and 33 settlements are located. About 500,000 people will have to be evacuated from the catastrophic flood zone.

In the Kirovohrad region, a significant danger to the population is the reservoir of the Kremenchug HPP (volume 13,500 million m 3). With the destruction of its dam within the region may be flooded area with a total area of 116 km2 with settlements inhabited by 28 thousand people.

In the Eastern Economic Region, the main source of hydrodynamic danger of the population is the reservoir of Kremenchug HPP with a volume of 13.5 million m3. The destruction of its dam in the Poltava region will create a catastrophic flood zone with a total area of 1,200 km 2, which includes 68 settlements (including the cities of Kremenchuk and Horishni Plavni) with a population of over 256 thousand people. The zone of probable flooding will include 22.6 thousand residential and more than 2.1 thousand public buildings, 88 km of railways and 87.4 km of roads, more than 222 km of power lines and more than 214 km of communication lines, 87 km of pipelines.

The greatest hydrodynamic danger for the population in the Donetsk region for the population are 10 reservoirs: Krasnooskol, Kleban-Binsk, Volyntsev, Khanzhenkiv, Olkhov, Zuiv, Karliv, Starokrymsk, Pavlopol, Starobeshiv. As a result of the destruction of their dams in each case there may be a catastrophic flood zone with an area of 7 to 45 km 2, which may be up to 6 settlements with a population of up to 40 thousand people.

The main sources of hydrodynamic danger for the population of the Central Economic Region are 2 large reservoirs located on the Dnieper River. In the Kyiv region, the main source of this danger for the population is the reservoir of the

Kyiv HPP (volume 3730 million m 3). The destruction of its dam within the region will create a zone of dangerous flooding with a total area of 1130 km 2. In the zone of probable flooding are the city of Kyiv and 50 settlements, in dangerous areas of which live 80.8 thousand people.

In Cherkasy oblast, the main source of hydrodynamic danger is the Kanivska HPP reservoir (2,500 million m 3). With the destruction of its dam, there will be a catastrophic flood zone with a total area of 780 km 2. In this zone will be the city of Cherkasy and 66 settlements with a population of over 65 thousand people.

Chapter 4. The impact of war on water resources and their management

4.1. Analysis of world research

In recent decades, several international organizations have studied and evaluated the impact of armed conflict on water. For example, in 2011 the World Bank reported that the population in conflict-affected countries was disproportionately affected by lack of access to safe water and sanitation. According to the same report, children born in conflict-affected countries are almost twice as likely to have no access to an improved water source [27]. A report by the United Nations Children's Fund (UNICEF) states that children are more likely to die from clean water-related illnesses in protracted armed conflicts than from violence directly related to the conflict itself [28].

In order to evaluate the relevant scientific data through a systematic review of the literature in [29], the considered publications cover the period from 1992 to 2019 with a clear increase in the number over the past 15 years. 7 of the 48 publications analyze problems on a global scale, rather than in individual countries or regions. This is mainly a study of international law on the use and protection of water during conflict. Remaining publications include a clear geographical focus on the Middle East, Africa and Asia.

4.1.1. Impact of the conflict on water resources

In a review of the literature on the impact of modern warfare on freshwater ecosystems, Francis [30] identifies various ways in which armed conflict can affect water resources. It is believed that modern warfare, since the First World War, has had a greater impact on ecosystems than previous, less industrial wars because of the greater potential of modern weapons to harm the environment. R. Francis concludes that the consequences of war can materialize both directly, causing damage to water resources and pollution from the remnants of weapons, and indirectly by increasing the frequency or intensity of destructive processes. The literature review of the environmental causes and consequences of the armed conflict in the African Horn also highlights pollution as the main impact of the conflict on water resources [31].

Conflict pollution research identifies several possible sources of pollution. For example, during the Gulf War, Kuwait's water resources were heavily polluted due to oil spills following attacks on oil fields. During the Syrian civil war, the discharge of untreated wastewater into the environment, both intentionally and unintentionally, worsened water quality in the affected areas. After the Sri Lankan civil war, explosive remnants of war, such as landmines, remain scattered throughout the landscape. J. Gunavardan [34] notes higher than usual concentrations of heavy metals, fluorine and calcium in the groundwater of these areas.

Pollution of water resources due to damage to infrastructure is a constant topic in studies of the consequences of hostilities. Specific examples include damage to sewage treatment plants in the Gaza Strip during the Israeli military operations Cast Lead in 2008 [35] and Protective Edge in 2014 [36], which resulted in untreated wastewater, as well as damage to sewage and sewage treatment plants. structures in Israel during the 2006 Lebanese war, where large amounts of sludge were deposited directly in the Mediterranean [37].

Another impact of conflicts on water resources is related to forced displacement: in Sierra Leone in the 1990s [38] and Syria [39]. Researchers M. Baumann and T. Kummerle [40] made similar observations on the abandonment of agricultural lands in conflict zones and their further expansion in internally displaced persons (IDPs) areas, citing examples from Africa, Asia and the Middle East.

4.1.2. The impact of conflict on water management

Armed conflicts often significantly reduce the operational capacity of government agencies and other key actors in the water sector. Such restrictions may be associated with a reduction in staff numbers, as staff members lose their lives, are injured or flee the area during the conflict, and priorities are shifted towards ending the conflict itself [41]. During the Gulf War, most international experts were evacuated from the country, and local personnel either fled or were mobilized to take part in the fighting. Those who remained often became apathetic due to the conflict situation as such and the lack of state support for their work in the water sector.

As well as declining water coverage, reduced operational capacity can also affect water quality and ecosystem health. This happened in Syria, where the lack of state supervision has led to reduced compliance with environmental standards and increased discharges of untreated wastewater [33].

During an armed conflict, centralized and hierarchical management systems can be transformed to meet localized needs for water supply reconstruction or maintenance, giving way to a decentralized "hybrid management" system in which government agencies work with local NGOs such as the community. or individuals [37, 42]. Desai and Sangui point to similar cases where informal water providers gain power without state oversight and form strategic alliances with local leaders to strengthen positions of power, for example, by establishing a local monopoly on the provision of services [43].

External actors, often international organizations, also play an important role in restructuring water management during and after conflict. The study [21] analyzes the impact of a new model of governance introduced in the Iraqi water sector by US forces after the fall of Saddam Hussein's regime. The model has changed governance mechanisms from the national to the local level and aims to improve the participation of the public and private sectors in the reconstruction.

4.1.3. Implications for the provision of water supply services

Water supply is one of the biggest and most important problems in the regions affected by the armed conflict. Household surveys conducted in southern Syria in 2016-2017 show the devastating impact of armed conflict on urban water networks: before the civil war, tap water was the main source of water for more than 90% of households, while only 22% of households responded in the same way. 2016 and 15.3% in 2017 [44]. A survey of communities affected by the conflict in South Sudan shows that drinking water shortages are the most serious problem facing the local population, which is above the problems of nutrition, health and education [45].

Along with the obvious humanitarian consequences, the deterioration of water supply has a profound impact on the situation and capacity of water supply companies. Based on a comparative study of urban water services in the six countries affected by the conflict, J. Pinera identifies three stages of decline [46]:

- limiting the ability of the municipal water utility to reliably supply water of sufficient quantity and quality;

– poor service delivery causes the utility to lose trust and authority over its customers and administration, potentially encouraging customers to withhold payments until a satisfactory level of service is restored;

– without income from its customers, the utility is no longer financially self-sufficient and needs to reduce or reduce wages, or become dependent on external financial support.

There is no definitive study on how to address the financial survival of utilities during the conflict. Instead, the measures proposed in the scientific literature should be applied to the conflict in order to strengthen the sustainability of the utility later. Based on a statistical analysis of the municipalities of Côte d'Ivoire, it is concluded that fiscal decentralization can lead to more reliable service delivery in times of conflict [47].

In the absence of functional public water services, informal suppliers often fill gaps in this area. The most common type of such informal suppliers are private water trucks.

Another informal, highly localized approach to water supply is the use of manually dug wells. In a study of living conditions in Eastern and Western Mosul under ISIS occupation, 96.6% of respondents indicated that they received water from such an improvised well [48]. Wells unofficially dug by locals have been actively used as a key coping mechanism in conflict-affected regions of the Philippines.

4.1.4. Transboundary water management in conflict situations

Considering potential cross-border management during the interstate conflict between coastal states, S. Libishevsky identifies two common points of view in his analysis of the Israeli-Jordanian water talks in the early 1990s [50]. On the one hand, the functionalist perspective implies that states can cooperate on “low policy” issues, such as resource management in times of greater conflict, and that water negotiations may even create an opportunity for reconciliation between the two sides. On the other hand, from a realistic point of view, cooperation on "low politics" is seen as impossible until a greater conflict is resolved, as all issues are internally interlinked. But the reality of the Israeli-Jordanian talks on water and the origins of the 1994 peace treaty lies somewhere between the two.

As stable institutions play a key role in the management of transboundary water resources and are a prerequisite for participation in multilateral platforms, civil wars that weaken state institutions can lead to a stalemate in the process of negotiation and cooperation [51].

The emergence of a strong non-state entity that takes control of water resources adds a new dimension to transboundary water negotiations, as such non-state actors do not adhere to formal agreements between states. The capture of ISIS's key water infrastructure in Iraq and Syria is significant. It is usually not in the interest of coastal states to include non-state actors in formal negotiations in order to deprive them of any legitimacy as a state-like entity. At the same time, the presence of armed non-state actors can also be an entry point for cross-border cooperation between states, as they cooperate to limit the control of such non-state actors over shared water resources [51].

Another possible way to cooperate on water resources, whether between states or at a lower level, is interdependence. An example is the island of Cyprus, where there is a political conflict between the Republic of Cyprus and Turkey. The Republic of Northern Cyprus has exacerbated the island's water problems due to inconsistent water management on both sides of the border and the refusal of cost-effective cooperation based on political considerations. However, there is a working joint water supply system that connects the cities of Nicosia in the Republic of Cyprus and Famagusta in the Turkish Republic of Northern Cyprus [52].

4.2. Methodology for assessing the system of water resources in wartime

To assess the system of water resources and study the main factors and their potential impact with the help of indicators in [33] developed a conceptual model (Fig. 4.1). The assessment included an assessment of surface and groundwater resources, a study of environmental and man-made factors, and the potential consequences of armed conflict.

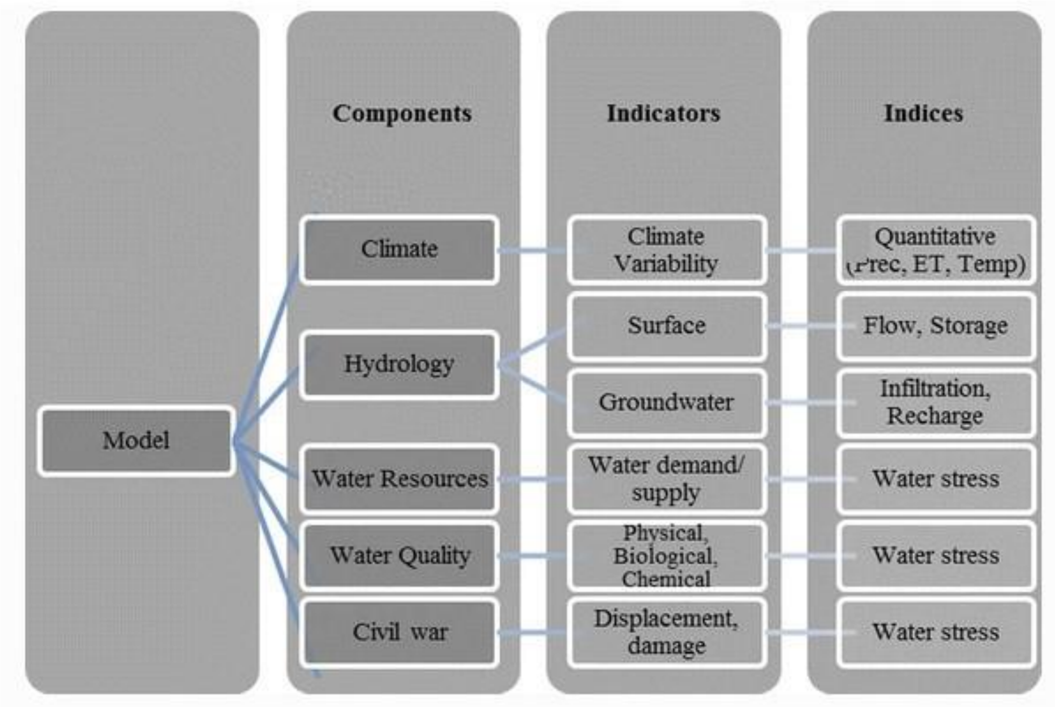

Fig. 4.1. Syrian Water Security Impact Assessment Model [33]

The study of water resources focused on:

– reflection of climate variables;

– mapping the location and boundaries of surface water resources (i.e., watersheds, rivers, streams, etc.) and groundwater resources (i.e., geological and hydrogeological, springs, wells, etc.);

– determination of basic conditions for surface waters (i.e., hydrological cycle) and groundwater (groundwater levels / levels);

– determination of basic conditions for the use of water resources (needs and consumption of water for agriculture and agriculture) and their impact on the state of surface and groundwater

– determination of water quality indices and assessment of water vulnerability;

– assessment of demography, social and water economy;

– assessment of increased risk to the water system due to civil war or aggression.

The vulnerability of the water supply system and its sensitivity to various factors of climate, water use and military influence are usually associated with uncertainty. It is important to determine both qualitative and quantitative indicators to assess the importance of water impact on life.

In the table. 4.1 presents one of the components of the overall model and its indicators and risks, which should be assessed in Ukraine.

Table 4.1. Indicators and risks of the war's impact on water supply

Parameter B	**Physical scale**	**Value**	**Indicator**	**Risk**
Impact of war	Population	Moderate	Displacement	Increased demand of water
	Water supply	High	Change of preferences	Reduced availability and supply of water
	Water supply management	High	Management percentage	Reduced water supply
	Water quality	High	Decrease in water quality	Increased health risk

Estimation of population movement

To assess the factor of population movement in Ukraine can be based, for example, on the results of a study by the International Organization for Migration (IOM), which in April 2022 conducted a second round of representative rapid assessment of the total population of Ukraine [53]. The aim of this study was to collect data on internal movement and mobility flows, as well as to assess local needs, including water needs.

This assessment of the general population is the primary source for identifying areas with high humanitarian needs and identifying targeted responses to provide assistance to the war-affected population. The geographical coverage of this assessment covers the entire territory of Ukraine, all 5 macro-regions (west, east, north, center, south and the city of Kyiv), except for the Crimean Peninsula. In fig. 4.2 presents data on internally displaced persons by regions of Ukraine, which can be used for the indicator of Displacement (see Table 4.1).

IDP BY MACRO-REGIONS OF ORIGIN (COMPARISON OF ROUND 1 AND ROUND 2)

Where do those displaced by the war come from?
The obtained data indicate a difference in the intensity of migration flows at the macro-regional level. Within the 10 percent increase in the total number of IDPs within Ukraine in round 2 compared to round 1, the most significant increase was recorded in the north of the country: the share of IDPs within Ukraine originating from the north of the country increased by 35% compared to March 16.
The share of IDPs from Kyiv in the total number of IDPs increased by 23%. The share of IDPs from the east almost did not change.

Macro-region	% of IDPs origin	IDPs estimate according to the microregion of origins
KYIV	33%	2 384 331
EAST	33%	2 362 915
SOUTH	6%	399 768
CENTRE	2%	121 358
NORTH	23%	1 656 182
WEST	3%	214 161
Total number estimate of the internally displaced persons within Ukraine		**7 138 715**

IDPS BY MACRO-REGIONS OF THE CURRENT PLACE OF RESIDENCE (COMPARISON OF THE RESULTS OF ROUND 1 AND ROUND 2)

Where are those displaced as a result of the war now?
The number of IDPs in Kyiv has almost doubled since March 16, but remains insignificant compared to other macro-regions.
The number of IDPs in western Ukraine increased by 13% in the total number of IDPs admitted after the first round of this assessment.
Despite the overall increase in the number of IDPs across the country (in total), the number of IDPs has decreased by approximately 320,000 people to date.

Macro-region	% of IDPs origin	IDPs estimate according to the microregion of origins
KYIV	5%	356 936
EAST	12%	856 646
SOUTH	6%	356 936
CENTRE	19%	1 356 356
NORTH	18%	1 284 969
WEST	41%	2 926 873
Total number estimate of the internally displaced persons within Ukraine		**7 138 715**

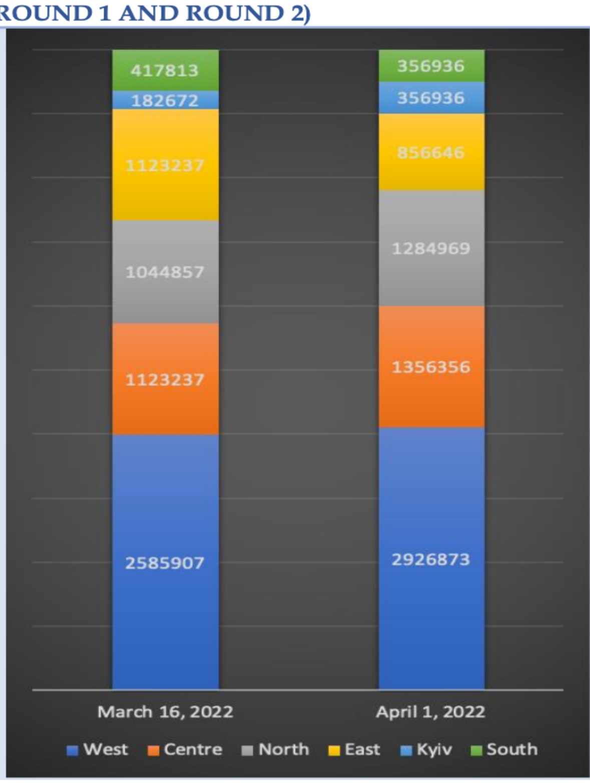

Fig. 4.2. Data on the origin of IDPs and their stay in Ukraine during the Russian aggression in 2022

Assessment of the water supply system

The reliability (R) and vulnerability (V) indices can be used to assess the impact of war on the water system. These indices cover the assessment of water availability, water supply, demand sustainability, socio-economic changes in water quality. Reliability (R) represents the reliability of the water supply system in meeting the needs at every step of the time, and vulnerability (V) represents the total unsatisfied bulk water during the system deficit. R and V are defined as follows:

$$R = \frac{\sum_{t=1}^{T} Z_t}{T}$$

$$V = \max\left\{ \sum_{t \in U_i} \left(D_{(t)} - S_{D(t)}\right), \qquad i = 1, \ldots, N \right\}$$

where: Zt is the total variable that indicates whether the performance of the system is considered satisfactory or not;

D - the minimum monthly volume of water needed to meet all needs (i.e., agricultural, domestic and industrial);

SD is the monthly water supply from all surface and groundwater.

At each point in time t and in relation to D S D is classified as satisfactory (S) or unsatisfactory (U) demand, and Z t receives a value of 1 or 0, respectively, as in the following formula (see below). N is the total number of unsatisfactory periods (U) reported for the entire time series of length T.

$$
\begin{aligned}
&If S_{D(t)} \geq D_{(t)} then\ S_{D(t)} \in S\ and\ Z_t = 1 \\
&\qquad else\ S_{D(t)} \in\ U\ and\ Z_t = 0
\end{aligned}
$$

Assessment of water supply management

It is important to focus on the principles of water governance in OECD countries, which aim to support a realistic public policy that is goal-oriented and based on three mutually reinforcing and complementary aspects of water supply management:

1) effectiveness refers to the contribution of management to the definition of clear objectives and targets for sustainable water policy at all levels of government, the implementation of these policy objectives and the achievement of expected targets;

2) efficiency refers to the contribution of management to maximize the benefits of sustainable water management and welfare at the lowest cost to society;

3) trust and participation refer to the contribution of governance aimed at strengthening public confidence and ensuring stakeholder participation through democratic legitimacy and justice for society as a whole [54].

In recent years, Ukraine has been modernizing pumping stations for water supply and replacing emergency and worn-out pipelines [55]. This is the main solution to improve the quality of drinking water, increase the efficiency of technological processes and the reliability of water supply systems and ensure the rational use of material and energy resources. The implementation of these measures will contribute to the rational distribution of water flows and optimize the pressure in the distribution network, save energy resources up to 40% and reduce water losses in the system, reduce the actual volume of its supply and pumping, and reduce leakage.

Water quality assessment

Water quality indicators are used in advance to assess water pollution to protect public health. In this context, the US Environmental Protection Agency and the WHO propose and various recommendations for risk management of contaminated drinking water due to the lack of a national standard have been recommended. In the table 4.2. the main source of pollution, recommended ranges and potential health risks are summarized.

Table 4.2. Water quality indicators

Indicator (Type*)	**Unit**	**Source/origin**	**Restrictions**	**Health symptoms**
Temperature (Ph)	°C	Climatological effect	n/a	None
Hardness (Ph)	mg/l	Rocks (e.g., limestone)	n/a	n/a
pH (Ch)	mg/l	Physical characteristics of water	6,5-8,5	None – except of extreme acidity or associated with organoleptic effects (e.g., taste and smell)
TDS (Ph)	mg/l	Natural or added to water solutes	500	Organoleptic effects (e.g., taste and smell)
Chloride (Ch)	mg/l	Soil and mountain formation, penetration of sea water and waste discharges	250	None, organoleptic (e.g., taste)
Sulfate (Ch)	mg/l	Rocks, geological formations and emissions	250	Excess sulfate has laxative effect, especially in combination with higher concentrations of magnesium and/or sodium
Calcium (Ch)	mg/l	Occurs in rocks		Indirect (connected with hardness)
Magnesium (Ch) formation	mg/l	Geological		Indirect (in combination with sulfate)
Nitrates (Ch)	mg/l	Drainage of fertilizers and untreated wastewater	10	Shortness of breath and blue baby syndrome
Ammonia (Ch)	mg/l	Present in nature; excess amounts associated with wastewater or industrial pollution	0,1-0,3	Indirect (pollution wastewater and the potential presence of pathogens)
Phosphate (Ch)	mg/l	Plants, microorganisms,	0,03	None

		animal waste, sewage and wastewater discharges		
DO (Ch)	mg/l		8,5-11,5	Not significant organoleptic beginnings
BOD (X)	mg/l		3	None
Turbidity (Ch)	NTU	Soil runoff	n/a	Nausea, cramps, diarrhea and headaches
Total E. coli (B)	mg/l	Human and animal faecal waste	0	Nausea, cramps, diarrhea and headaches and other symptoms due to the presence of germs (pathogens)

** Ph – physical, Ch – chemical, B – biological*

Using this assessment methodology, it was determined that the consequences of the war and conflicts in Syria are high. The impact of the war has damaged the existing system and low investment in water utilities and water treatment. Population displacement, growing demand and water pollution are important factors. The most critical factors were reduced control parameters, reduced system reliability due to damage and increased pollution.

4.3. AQUEDUCT 3.0 methodology

Responding to growing concerns from the private sector and others about water availability, water quality, climate change and increasing demand, the Composite Index approach has been used as a reliable communication tool to turn hydrological data into intuitive indicators of water risks. Today, an updated solution for calculating water hazard indicators AQUEDUCT 3.0 is available for water risk assessment.

The structure of water risks follows the approach of the composite index and allows you to combine several risks associated with water. There are three hierarchical levels (Table 4.3) and 13 parameters (indicators) covering different types of water risk [56]. After grouping the parameters and calculating the water risk scores (composite score), using the default weighing schemes defined by industry or user, the indicators of the three groups are combined into a single overall water risk indicator. For each of the 13 indicators, a description, calculation of initial values and conversion into points (from 0 to 5) are offered. This allows you to group the indicators together and calculate an overall water risk assessment.

The AQUEDUCT 3.0 methodology uses terminology for *hazards, impacts and vulnerabilities*. Each indicator is assigned an element of risk (Fig. 4.3):

– *danger:* threatening event or condition (e.g., flood, water, stress);

– *impact:* elements present in the danger area (e.g., population, assets, economic value);

– *vulnerability*: the stability or lack of stability of hazardous elements.

Table 4.3. Levels and indicators of water risk

Total water risk	Magnitude of physical risk	Basic water stress
		Depletion of the water baseline
		Inter-river variability
		Seasonal variability
		Decrease in groundwater level
		Risk of river floods
		Coastal floodplain
		Risk of drought
	Quality of physical risk	Untreated associated wastewater
		Eutrophication potential of coastal floodplain
		Not improved/ without drinking water
	Regulatory and reputational risk	Not improved/ without sanitation
		RepRisk peak ESG risk index

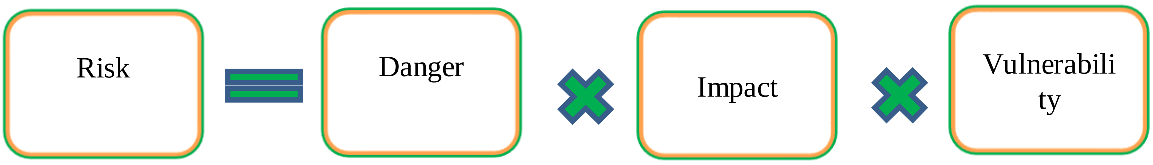

Fig. 4.3. Total risk calculation for the parameter

AQUEDUCT 3.0 introduces an updated water risk system and new and improved performance. Indicators based on a new hydrological model containing:

– integrated model of water supply and demand;

– modeling of surface and groundwater;

– higher spatial resolution;

– monthly time series, which allows you to provide monthly scores on selected indicators.

Key elements of AQUEDUCT 3.0, such as the overall risk to water, cannot be directly measured and are therefore not confirmed. AQUEDUCT 3.0 remains primarily a priority setting tool and should be complemented by local and regional deep dives.

Conclusions

1. In terms of reserves of water resources available for use, Ukraine belongs to the low-income countries. According to this indicator, Ukraine ranks 111th among 152 countries, and 17th among 20 European countries.
2. Under the current practice of using existing water resources, the world will face a 40% deficit in projected demand by the beginning of 2030. By the end of the XXI century, in most basins of Ukraine, river runoff will be significantly reduced in any scenario: "soft" or "hard", so today we need to prepare for a potential water problem.
3. A new global trend in modern development is the transformation of water resources into key strategic resources, which are increasingly the subject of international conflicts, armed conflicts and even armed conflicts. More than 650 wars and armed conflicts over access to freshwater sources have been recorded, including 66 in Europe. According to a study by the Pacific Institute, there have been 357 water disputes worldwide since 2000 alone.
4. International humanitarian law contains provisions for the protection of civilians, civilian infrastructure and natural resources in armed conflict. Additional 1977 Protocols to the 1949 Geneva Convention prohibit attacks on facilities "necessary for the survival of the civilian population", including drinking water facilities and irrigation networks. At the same time, it is very difficult to exercise this right in armed conflict.
5. To measure water safety, you can use several parameters that combine several indicators. For example, such key parameters could be: water security at the household level; economic water security; urban water safety; water safety of the environment; resistance to water disasters.
6. The accumulation of large amounts of water in artificial reservoirs during hostilities is quite a dangerous factor. Destroyed dams of Ukrainian reservoirs can flood lands and cities far downstream. Such a danger for Ukraine exists for a significant number of territories, covering hundreds of settlements, for hundreds of thousands of citizens.
7. To date, a large database of publications and research is available, which studied and assessed the impact of armed conflict on water, namely the impact on water resources, water supply system, water management, transboundary water management.
8. To analyze the water system, the increased risk to the water system due to war or aggression can be assessed, the model of which includes estimates of such indicators as population movement, water supply system management, water supply, water quality.

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