Strategy Notebook 233-B

Geopolitics of water: towards a new water scenario

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MINISTERIO DE DEFENSA

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MINISTERIO DE DEFENSA

Catálogo de Publicaciones de Defensa
publicaciones.defensa.gob.es

Catálogo de Publicaciones de la Administración General del Estado
cpage.mpr.gob.es

publicaciones.defensa.gob.es

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Edita:

MINISTERIO DE DEFENSA

SUBSECRETARÍA DE DEFENSA

SECRETARÍA GENERAL TÉCNICA

Paseo de la Castellana 109, 28046 Madrid

NIPO 083-26-095-4 (edición en línea)

Cuadernos de Estrategia, ISSN 2952-3443 (edición en línea)

Fecha de edición: abril de 2026
Maqueta: Imprenta Ministerio de Defensa

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Introduction

Alfonso Muñoz Martín

We live on a planet with more than eight billion inhabitants, who, with the improvement of living conditions and progress, demand more and more resources of all kinds (mineral resources, energy, water, food, etc.). Among these resources is one that is essential for life, and without which the survival of humanity would be impossible: water. This increase in demand for resources has accelerated dramatically throughout the 20th century and the beginning of the 21st century, due to two combined factors: on the one hand, the almost exponential increase in population from the early 1900s to the present day, and on the other hand, the increase in *per capita* demand for these resources. In addition to this increase in demand, there are other variables that depend on socio-economic developments or the existence of conflicts. Among these, the growing trend of population concentration in urban environments stands out, especially in coastal areas or large river basins. However, the planet is finite, and its resources are therefore limited, which means that these resources are of strategic importance, so they are potential causes of conflict, but also an opportunity to collaborate in their management and rational use. Water is one of those most abundant resources, but also the most necessary for life, making this book timely and essential, and a true journey through the water challenges of our time.

To ensure the sustainability of the human species and life on Earth, it is imperative to address the complex issue of water in a strategic manner. This implies approaching the issue from the analysis of the current situation and its evolution, analysing different scenarios, anticipating possible obstacles and opportunities, and seeing what informed decisions should guide actions towards the sustainability of the human species. Water thus ceases to be a mere resource and emerges as a central axis of global security, stability and development. Throughout the book's chapters, the many facets of this vital element are explored alongside its intricate relationship with strategy, geopolitics, science and technology, as well as with the needs of people in the most extreme and complex situations, is revealed. Water not only sustains life but is also a strategic resource: its availability or scarcity defines the wealth of a nation, the stability of its governments and the security of its citizens. This perspective forces us to look beyond domestic water management to understand how it has become a tool of power, a source of potential conflict and, at the same time, a catalyst for cooperation.

Throughout this book, the reader will become familiar with key concepts such as 'water security', 'integrated management', 'water footprint', 'hydropolitics' and 'water defence'. These terms are fundamental to understanding the importance of water not only as a strategic resource, but also in its most critical and complex aspects.

Chapter 1, 'Water as a Strategic Resource', lays the theoretical groundwork and analyses why water is such a valuable asset for security and the economy. It discusses how its control throughout history has been a determining factor in the rise and fall of civilisations and how, today, its management has become a key part of geopolitics. Water security, in this context, is not merely an environmental concern, but a matter of national security and social welfare. The author concludes that freshwater is not a globally scarce resource, but that its main problem lies in the irregularity of its spatial and temporal distribution. This situation, together with increasing demands in advanced and developing societies, are the real causes of potential future water crises. Water demands increase with socio-economic development in various sectors, ranging from irrigated agriculture (around 70% of global consumption), and industry (close to 20%). These sectors have seen significant growth in emerging countries such as China and India, which has led to serious pollution problems and pressure on groundwater aquifers. Other uses, such as power generation, mining and the more recent cooling of data centres for artificial intelligence also contribute to demand, and projections also point to a sharp increase in water needs in these sectors.

To meet these challenges, States implement various strategies, including the construction of hydraulic works such as reservoirs and water transfers, which, despite ensuring supply, can generate conflicts and environmental problems. To address these issues, integrated management of surface and groundwater resources and desalination are being considered, an increasingly common option in coastal countries with freshwater shortages, although it requires a lot of energy and incurs high costs. Water management in shared river basins is particularly complex, posing a geopolitical challenge requiring cooperation between States. This management is governed by principles such as prevention of harm, integrated management and participation, although the ambiguity of these principles can lead to conflicts between different states.

From this global vision, we move towards particular and complex scenarios or scenarios of extreme vulnerability. In Chapter 2 (‘Water Management in Towns’), it becomes clear that water is a fundamental pillar of society, as a large part of its economic fabric depends on water. However, population growth and the climate crisis are causing water scarcity and stress on supply systems, which is expected to affect large numbers of the urban population. To address these challenges, it is vital that better management and governance of water resources is promoted at global and multilateral levels. This includes investment in infrastructure and in the development of technological and innovative solutions. A clear example of these challenges can be seen in African megacities, where uncontrolled population growth and lack of adequate financing and infrastructure expose their inhabitants to great vulnerability. Cooperation between governments is key to ensure basic services such as access to clean water, electricity and sanitation for their people. On the other hand, cities must adapt to extreme weather events, such as torrential rainfall, which has increased significantly due to anthropogenic global warming. Investment in drainage and early warning systems is crucial to mitigate economic damage and save lives.

Chapter 3 ('Water Management in Refugee Camps') addresses the humanitarian crisis and examines the monumental challenges organisations face in providing safe and sufficient access to water in these settings. In these places, drinking water is not just a matter of health, but of dignity and survival, where every litre counts and every distribution decision can have critical consequences. This chapter highlights the harshest aspects of resource scarcity and shows how water crises are intrinsically linked to conflicts and forced displacement of populations.

Water management in refugee camps is a critical and complex task, fundamental to the survival and health of millions of people. According to UNHCR data, some 120 million people have been forcibly displaced worldwide. Of this number, 35 million are refugees, and 22% of them (some 6.6 million people) live in camps which, although conceived as temporary solutions, often last for years or even decades, as in the case of the Sahrawi refugee camps in Tindouf (Algeria). In these environments, the water cycle must be managed holistically to ensure the supply of drinking water, sanitation, and hygiene. These basic services are essential to prevent the spread of disease and safeguard public health. From the earliest stages of setting up a camp, planning is crucial and involves a project with clear and limited objectives, focusing on finding nearby water sources, both surface and groundwater. In this process, it is not only the quantity of water available that is important, but also its quality for human consumption.

The importance of water also has a technical and operational focus, which is shown in chapter 4 ('Integrated Water Management in Military Camps'). This section focuses on *integrated water management* (IWM) in military camps, a key technical and operational aspect of ensuring autonomy and security. This approach requires not only efficiency but also ingenuity, as a lack of water in hostile environments can put a mission and the lives of personnel at risk. IWM in camps is divided into two main processes: firstly, supply, which includes the collection, treatment and distribution of drinking water and other uses. To ensure effective supply, it is crucial to analyse the local water resources, climate and geography of the area. Secondly, wastewater sanitation, for proper disposal and treatment of sewage, greywater and rainwater to prevent pollution and protect health.

A key objective of IWM is to minimise the camp's water footprint. To this end, water use is optimised and reuse systems are implemented, such as rainwater and greywater reuse for non-potable uses, which promotes sustainability and reduces environmental impact. This chapter also explores technologically advanced solutions, such as portable purification systems, which are essential for operational success.

The future of water management is inextricably linked to technology. Chapter 5 ('Water and Artificial Intelligence') therefore delves into the promising field of AI, showing how it can optimise distribution, predict scarcity, detect leakage and improve decision-making in real time, thereby transforming water systems into smart and resilient networks. From predictive algorithms to advanced monitoring systems, technology is proving to be an essential tool for tackling the water challenges of tomorrow. The authors of the chapter examine the role of artificial intelligence (AI) in water management, a sector that has historically been reluctant to embrace innovation. AI is presented as a very useful tool for managing the complexity of water, as it can process large amounts of data to predict behaviour and solve problems, an advance facilitated by digitisation. From this analysis, conclusions emerge such as that machine learning can be a great ally in tackling the complexity of water management, which encompasses multiple factors such as hydrological, social, economic and ethical ones. On the other hand, the democratisation of AI and the digitisation of the sector have enabled the widespread adoption of these technologies.

But the use of AI also presents challenges, such as resistance to change in a conservative sector and the long-term, high-cost nature of water projects, which are significant obstacles. Nor should it be forgotten that AI itself poses an environmental challenge as it consumes large amounts of water for cooling data centres. Finally, and of great importance, are the risks involved in its use, in particular vulnerability to cyberattacks and the need to address ethical dilemmas on which there is still no consensus.

The book continues with a more geopolitical view in Chapter 6 ('Water as a Security Threat'), which examines the conflicts and tensions arising from the control of shared water resources, and identifies the hotspots and dynamics that define the current landscape. This chapter explores hydropolitics, disputes over transboundary basins, and the risk of water becoming a trigger for armed conflict in the future. It is concluded that water has been both a strategic resource and a source of tension and conflict from the earliest civilisations to the present day. Historically, it has been noted that water infrastructure remains a military target, such as the use of tactics like the poisoning of wells in Sun Tzu's time or the recent examples in the war in Ukraine. At present, this problem has been accentuated by the unequal distribution of the resource, increasing demand, growing scarcity, pollution and the effects of climate change.

However, water, despite being a factor of conflict, can also become a catalyst for peace and cooperation between nations. To achieve this, it is essential to promote dialogue, shared governance and cooperation agreements in the management of transboundary river basins However, water management faces significant challenges. The main one is the vulnerability of water infrastructure to sabotage and cyber-attacks, which calls for the implementation of a comprehensive 'water defence' strategy. Added to this is the challenge of sustainably managing scarcity, pollution and the increasingly severe impacts of climate change on this fundamental pillar of life.

Chapter 7 ('Hydrographic projects as a geopolitical tool') concludes the book and reveals how large engineering works, such as dams and canals, are much more than infrastructure: they are instruments of influence, power and control. It analyses how these megaprojects can alter the balance of power in a region, creating dependencies and rivalries, and how, in turn, they can be a source of cooperation and diplomacy. The construction of hydrographic projects, such as dams, has proven to be a highly significant geopolitical tool that generates both opportunities and risks. While hydropower is essential for decarbonising the electricity system and meeting global climate objectives, its development, especially in shared basins, raises serious concerns. The emergence of disputes over the management of these resources can aggravate insecurity and, in the worst case, trigger armed conflict.

Each river basin has unique dynamics due to the geopolitical interests of the riparian countries. The lack of cooperation frameworks, interests unrelated to water management, and the influence of foreign powers can contribute to the emergence of conflicts, particularly with the construction of hydroelectric megaprojects. Although customary international law states that an upstream country cannot veto interventions by a downstream country, prior notification and consultations are expected to avoid 'substantial harm'. However, in practice, these conditions are often not met, leading to complex disputes. To illustrate these tensions, the chapter presents key examples in Asia, such as the Kunar River (Afghanistan and Pakistan), the Helmand River (Iran and Afghanistan) and the Indus River basin (Pakistan and India). In such cases, tensions between upstream and downstream countries are complicated by each country's pursuit of energy and food security. The situation is complicated by the lack of treaties between countries, their non-compliance or the interests of companies or third countries. There are other examples where water and energy go hand in hand, especially in Central Asia, where the source of discord is between the 'water-rich but energy-poor' nations upstream (Kyrgyzstan, Tajikistan) and the 'water-poor but energy-rich' nations downstream (Kazakhstan, Uzbekistan, Turkmenistan). In these cases, water scarcity aggravated by climate change is compounded by the lack of a unified management system and effective cooperation agreements since the break-up of the Soviet Union. Despite attempts to establish commissions and cooperation programmes, the imbalance between countries' energy and agricultural interests has undermined agreements and maintained a tense political climate in the region.

All that remains is for me to encourage readers to immerse themselves in these pages and discover that water security is a complex issue and a fundamental pillar of global peace and stability. In order to address how to achieve this long-awaited security, it is necessary to combine scientific, technical, ethical and political aspects. It is hoped that this book will not only inform, but also inspire reflection and action, as the future of humanity, if not the planet, will depend largely on how this invaluable resource is managed.

Chapter One

Water as a Strategic Resource

Javier del Valle Melendo

Abstract

Water, in addition to being necessary in the ordinary course of life, is an essential resource for many uses and, like other essential resources in early 21st century societies, it is becoming increasingly strategic, so the problems and tensions surrounding it will undoubtedly continue to grow.

Keywords

Water, Water security, Strategic resource.

1 Is freshwater a scarce resource?

On the planet, there are an estimated 1,386 million km^3 of water (Blanco de la Torre, 2017). This is an immense amount, consisting of approximately of just over 97% salt water and just under 3% fresh water, which means some 35 million km^3. Approximately 70% of this freshwater is in the form of ice in the ice caps (Antarctica, Greenland and continental and mountain glaciers), leaving just over eleven million km^3 in atmospheric water, surface water (rivers and lakes), groundwater and water that forms part of living beings (Fernández Jáuregui, 2017).

It is very difficult to estimate the amount of water readily available to human beings and ecosystems, considering as such that found in rivers, freshwater lakes and renewable groundwater. Blanco de la Torre (2017) estimate the aggregate amount at around 200,000 km^3. It is invariably mobilised by the water cycle or hydrological cycle, which makes it a renewable resource. This characteristic means that its use causes a possible transformation (surface water into groundwater, liquid into vapour, clean into dirty, etc.), but not its disappearance.

According to UNESCO (2006), by 2030 the amount of water extracted from its natural locations for all uses worldwide is estimated at just over 5,000 km^3, a figure far below the 200,000 km^3 available as previously indicated. Overall, it cannot be said that the amount of water available is less than that needed by humans, so it is difficult to affirm that water is a scarce resource. This does not mean that we cannot and should not talk about possible water crises or problems in meeting needs, but we must look for reasons for this situation beyond a possible global shortage, refuted by data.

2 The reasons for the possible future water crisis

2.1 The main water issues: spatial and temporal irregularity

Water has its own natural dynamics called the water cycle, which connects almost all of the planet's resources (except for confined aquifers). After evaporation from rivers, lakes, vegetation and, especially, seas and oceans, the general atmospheric circulation distributes water in the form of vapour or small liquid or solid droplets throughout the planet. When certain atmospheric conditions occur (instability, presence of condensation nuclei, etc.), precipitation occurs, causing water in solid or liquid form to fall onto the Earth's surface and, from there, flow via surface or underground channels (or a combination of both) towards the ocean. It is a closed cycle, driven by the sun's energy, which produces the heat necessary for evaporation and evapotranspiration and the differences in pressure and temperature that cause general atmospheric circulation.

However, the precipitation that irrigates the land and feeds lakes, rivers and groundwater (which, in turn, contribute materially to the regulation of the former) does not occur regularly in space or time. There are very rainy areas in the planet, especially in equatorial and tropical regions close to the ocean. Here, the instability typical of warm areas, together with the arrival of air masses laden with humidity, generally cause abundant rainfall. There are places in Southeast Asia affected by monsoons where the mean annual rainfall exceeds 12,000 l/m^2, as is the case on some Pacific islands. Even in temperate zones, there are areas with abundant rainfall, but less than in the regions described above. Areas close to the ocean, affected by prevailing westerly winds from the sea and also some mountain areas are abundantly irrigated with amounts that can exceed 2,000 l/m^2 per year.

On the contrary, tropical areas, especially those further inland, affected by the high-pressure belt that usually dominates the atmosphere here, and some regions in the interior of continents in temperate latitudes, which are difficult for humid air masses from the ocean to reach, receive very little rainfall. In large areas of the planet, rainfall is less than 300 l/m^2 per year, and in some extreme areas it may not even reach 100 l/m^2.

This same spatial irregularity is found, for instance, in Spain, despite its relatively small size. In some areas of Galicia, the Cantabrian coast, the western and central Pyrenees, and the mountain ranges near the Strait of Gibraltar, rainfall reaches or exceeds 2,000 l/m^2, while in the interior of the large river basins (Duero, Ebro, Tajo, and Guadiana), the annual average barely reaches 300 l/m2. In Southeast Spain (south of Alicante, Murcia and Almeria), the figures are even lower, as well as in the eastern Canary Islands and in the south of the more mountainous islands, with values of around 100 to 200 l/m^2 per year.

Logically, this spatial irregularity is reflected in river flows. There are rivers in the planet with abundant flows, such as the Amazon, Congo, Paraná, and Mekong. On the contrary, there are large regions where surface run-off is so scarce that they do not even have an organised river network to allow water to flow into the sea. These are known as arid regions, and they contain many endorheic areas where scarce surface water accumulates until it evaporates, causing salts to concentrate in the soil. This worsens soil quality, hindering or preventing agricultural development and limiting plant growth to those species that are better adapted to salinity.

Similarly, there are many climates in which seasonal rainfall irregularity is intense. In tropical climates, the difference between the rainy season (summer) and the dry season (winter) can be extreme, with abundant rainfall in the summer months (sometimes torrential, especially in tropical monsoon climates), while in the winter months there can be long periods without any precipitation. Continental climates also have, albeit to a lesser extent, a concentration of rainfall in summer, although in these climates winter is not usually as dry and low temperatures greatly limit evapotranspiration.

The case of the Mediterranean climate, which covers much of Spain, for instance, is also worth noting, as rainfall is particularly scarce during the summer months. In the Mediterranean summer, low rainfall is compounded by high temperatures that cause high evapotranspiration, meaning that during the periods when plants need the most water, they receive the least natural precipitation. In addition to this seasonal irregularity, there is also interannual irregularity, i.e. the difference in rainfall patterns from one year to another. There are many climates, including the Mediterranean, where rainfall is not guaranteed even in the statistically wettest seasons. Severe droughts have been frequent occurrences in many of the climates for which records exist. The droughts that affected Spain. For example, in the mid-1980s and 1990s are relatively recent and forced severe restrictions across much of the country, However, this is not exclusive to the Mediterranean climate. Other examples include the severe droughts suffered by the Mississippi and Rocky Mountain basins between 1909 and 1914, the drought that affected the normally rainy Western Europe between 1975 and 1976, and those in north-eastern Brazil and the Sahel during the 1970s and 1980s.

These climatic circumstances force species to adapt by developing strategies to capture as much moisture as possible from the soil (such as extensive root systems) or to reduce water loss from their tissues.

The distribution of water resources therefore presents significant irregularities in terms of both spatial and temporal distribution across the planet. The water cycle has its own dynamics that depend on natural factors, although human beings have made and continue to make many attempts to modify rainfall and adapt it to their needs (currently, fifty-three countries, including Spain, acknowledge having climate modification programmes). Regardless of the outcome of these programmes, natural factors currently determine the spatial and temporal distribution of rainfall, which does not necessarily adapt to human needs, leading to frequent imbalances between the two. However, it is an issue that requires attention, as improvements in climate modification techniques and their growing scope and impact may change this scenario in the future, giving rise to considerable uncertainty and concern.

2.2 Growing water demands in advanced societies

As socio-economic development advances, so do water demands. The relationship between socio-economic development and water is very close. One of the main achievements of advanced society is having secure, high-quality water that is universally available to the entire population, something that is considered normal in developed countries but is a real luxury in many others. According to the United Nations (UN) more than two billion people do not have access to safe drinking water or basic sanitation.

There is a direct relationship between access to quality water supply and sanitation and the level of human development. For example, in the Democratic Republic of Congo, a country with abundant water resources as it occupies a large part of the Congo River basin (the second-largest river in the world in terms of flow at its mouth), approximately 70% of the population does not have access to quality drinking water and sanitation. The country ranks 180th in the Human Development Index (HDI) in 2022 according to the United Nations out of 193 states analysed.

Ecuador ranks 83rd on the same list, with the percentage of the population without access to improved drinking water falling to approximately 34% and the percentage without access to sanitation to 10%. Some countries stand out for having significantly improved their population’s access to water despite their scarce water resources, such as Jordan, which ranks 99th in the HDI and where virtually the entire population has access to these services.

Of course, in more developed countries, the percentage of the population with access to drinking water and sanitation reaches 100%, even in examples with scarce resources such as Israel (ranked 25th in the HDI).

The provision of safe, reliable and equitable water and sanitation services is the basis of citizens' relationship with their local public authorities. In both the developed and developing worlds, daily life is disrupted by the constant need for water. Water supply creates a relationship of total dependence between people and service providers. A failure in this supply can quickly weaken the moral authority of the administration responsible for the service and cause civil unrest, which in extreme cases can lead to riots and instability.

However, the development of societies means an increase in water demand, not only for supply and sanitation, as many sectors of the economy become water consumers.

Human beings only need to drink 2.5 to 5 litres of water per day to survive (depending on numerous social and climatic factors, etc.), but to produce enough food to meet a person's daily dietary needs, around 3,000 litres of water are required, which is transformed from liquid to vapour, from surface to underground, from clean to dirty, etc. so it does not disappear, as it changes characteristics or is incorporated into the ascending branch of the water cycle, but it is no longer available in the descending branch. This means that almost one litre is needed per calorie consumed. The consumption of 'blue' water (water from rivers, lakes, wetlands and aquifers) for irrigation purposes amounts to approximately 2,700 km^3 per year. Total evapotranspiration from irrigated agriculture amounts to around 2,200 km^3, of which 1,550 km^3 comes from blue water (i.e. derived from its natural source) and the rest from rainfall directly on irrigated areas.

One of the sectors that has contributed most to lifting large sections of the world's population out of food scarcity has been irrigated agriculture. The increase in irrigated land worldwide has led to a significant increase in food production and diversification.

According to the report 'The State of Water and Agriculture in the World' published by the FAO in 2020, in 2018, the total area under irrigation worldwide was approximately 330 million hectares, representing 20% of the world's cultivated area.

The continent with the largest area of irrigated land is Asia, accounting for almost 46% of the world's total. In large areas of the continent, rice is the staple food, and part of its life cycle requires flooding, so its cultivation is associated with irrigation systems made possible by the abundant summer monsoon rains that fall in the south and south-east of the continent. In the Aral Sea region, there was also a significant increase in irrigated land, mainly used for cotton cultivation.

Africa accounts for 17% of the planet's irrigated land, and several countries, such as Egypt, Morocco, South Africa and Madagascar, have seen significant increases in irrigated land over the last thirty years. Irrigation has been key to reducing food shortages and extreme poverty on the continent, but it has also contributed to the decline of West Africa's main freshwater body, Lake Chad. This lake receives water from a large endorheic basin covering more than two million square kilometres and is located between Nigeria, Cameroon, Chad and Niger. In 1960, it covered some 26,000 km^2, but has now shrunk to around 900 km^2, although there are significant fluctuations depending on whether it is the dry or rainy season. The extraction of water directly from the lake and its main tributaries (the Chari and Logone rivers), together with the periodic droughts that affect the Sahel region, explain this drastic decline, which has had significant consequences for the economy of the area due to the sharp reduction in fishing.

North America accounts for 15% of irrigated land, and irrigated areas have increased in all three countries. In the United States, mainly in Texas, California, and the Great Lakes region. In Canada, although the area under irrigation is not significant in relation to the country's total area, it has also increased in the provinces of Alberta and Manitoba. As for Mexico, it has grown particularly in the arid regions of the north.

Europe accounts for almost 11% of the world's irrigated land, concentrated mainly in southern countries, where the Mediterranean climate makes irrigation a very efficient way of securing harvests, improving production and introducing crops that would otherwise be unviable. Spain, Italy and Portugal stand out for the significant increases in irrigated land over the last thirty years, but France and even Hungary and Romania have also seen significant increases to boost or improve maize productivity.

Ibero-America accounts for only 7% of the planet's irrigated land, but Brazil and Chile have significantly increased their irrigated areas; in the former case, especially for soybeans and cotton; and, in the latter, for export fruits.

Oceania accounts for only 4% of the planet's irrigated area, but there has also been a significant increase in Australia in the Murray-Darling basin for cotton, rice and vines, in Queensland for sugar cane, and in the western region, which has a Mediterranean climate, for vines and horticultural crops. In New Zealand, the most significant growth has occurred on the South Island for viticulture and fruit and vegetable crops.

Although irrigation accounts for approximately 70% of global water demand, the growing demand for other uses must also be considered.

The growth of industry, inherent in any process of socio-economic development, also means an increase in demand for water. It is estimated that, on a global scale, industrial demand accounts for around 20% of the total.

The demand for water for industrial use has grown significantly in some emerging countries, particularly in Asia (mainly China and India). In China, industrial water demand is increasing by almost 5% annually (Hidalgo García, 2022), while in more advanced Western countries it remains stable or in some cases has decreased slightly as efficiency of use has increased.

In many emerging countries, industrial and urban water treatment systems are inadequate, meaning that discharges cause serious pollution problems. In 2021, China's discharges reached 55.7 billion m^3, of which approximately 15.6 billion came from industry and the rest from domestic use. As a result of this situation, more than half of the population drinks water contaminated with organic waste and 75% drinks poor-quality water. Thirty per cent is not even usable by industry or agriculture despite its lower quality requirements (Hidalgo García, 2022).

In India, the picture is not very different. The world's most populous country is currently facing rapid growth in demand for water for industrial use. It is estimated to reach fifty billion m^3 by 2025 (Amarasinghe *et al*.,2009). Treatment capacity is around 40%, but it is estimated that only slightly less than 30% of urban wastewater is treated, resulting in serious pollution problems with 70% of surface waters in poor condition (Iagua, 2021). There is also significant pressure on groundwater resources, which in many regions is leading to significant declines in water table levels. China and India account for 18% of the world's population, which adds up to a hefty 36% of the total. China has 6-7% of the world's water resources, while in India the percentage drops to 4%.

Although it is difficult to distinguish between domestic and industrial demand, improvements in living conditions, progressive urbanisation and certain common uses in advanced societies, such as leisure activities, tourism, etc., also mean an increase in demand for these uses. It is estimated that demand for domestic use accounts for around 10% of the total.

The overall picture is one of progressive growth in water demand with limited purification systems at present, which prevents significant flows from being used for many purposes, especially those that are most demanding in terms of quality, pressure on groundwater and relatively scarce resources in relation to the population. It can therefore be deduced that the problems will worsen if demand continues to grow and there is no material improvement in purification systems and in the control of aquifer levels and quality.

China and India have been cited as examples due to their significant demographic weight in the global context, but a similar scenario, albeit with nuances and particularities, can be found in most emerging and developing countries. As societies advance in socio-economic development, water demand increases and the priority is often to meet this demand to prevent scarcity from becoming a limiting factor. In the case of developed countries, demand is growing moderately or stagnating, and, in many cases, policies are applied to increase efficiency in irrigation, water supply to the population and wastewater treatment, but a high level of security of supply also needs to be assured in order to avoid shortages.

Water and energy are two closely interconnected sectors: energy is necessary throughout many water use processes, from supplying the resource to various users (distribution and purification), including the urban population, to the collection and treatment of wastewater, which is essential for maintaining high quality standards and enabling the reuse of the resource, thereby preventing the accumulation of pollutants.

On the other hand, water is essential for energy production, from the production of hydroelectricity itself to the manufacture of components needed for other renewable energies, and cooling in thermal and nuclear power stations. Hydroelectric power generation does not reduce water resources, but it does cause changes in the river regime downstream from power stations, which turbine water when demand requires it, which can limit or damage some water uses located further downstream. In the case of international rivers, these alterations can cause tensions between the countries that control the headwaters and those located in the middle and lower reaches, as they may have conflicting interests regarding the periods of retention or release of flows (as in the cases of Kyrgyzstan and Tajikistan *vis-à-vis* Uzbekistan and Turkmenistan with the flows of the Amu Darya and Syr Darya, or Ethiopia *vis-à-vis* Egypt in relation to the regulation of the Blue Nile).

The use of water flows to cool thermal or nuclear power plants requires high safety guarantees to meet these demands, which often necessitates the construction of regulation and distribution infrastructure and involves the transformation of a large part of the surface water resource into water vapour, with the consequent reduction in availability for other uses in the environment. This may cause tensions with other users who may see their interests harmed by such a reduction.

The widespread use of cloud storage and artificial intelligence has led to an increase in a new demand: water for cooling data centres, which have to operate within certain thermal limits. This new sector of the technology industry, like all others, has its water needs, which explains why its location prioritises places where, among other factors, water is available. The relatively rapid emergence of these new demands, although not representing large amounts in total, can generate rejection and conflict with previously established uses, and is often used as an argument against their installation by some social sectors.

3 The effort of States to meet the demands

Each State has sovereignty over its own water resources, although with limitations in the case of shared river basins, as will be seen below. Therefore, it is responsible for the proper management of these resources with the aim of meeting the demands of society (which, as already noted, are generally increasing) whilst maintaining biodiversity and the good condition of water ecosystems. It is not easy to achieve both objectives simultaneously; balance is difficult to achieve and one of them (often the first) is usually considered a priority, especially in emerging economies.

There is a wide variety of strategies employed by States to achieve these objectives, and they are usually combined according to geographical and climate characteristics, the geopolitical environment, available technology and political decisions.

Among the internal policies implemented with these objectives in mind, the following are particularly noteworthy:

- Carrying out hydraulic works, mainly reservoirs, canal networks, irrigation channels and pipes, and water transfers connecting different river basins. The aim of these works is to create large water reservoirs that allow water to be stored in times of abundance and made available in times of scarcity, enabling it to be distributed throughout the territory. It has been one of the oldest and most widely implemented systems. These works often have serious environmental impacts by flooding areas that sometimes have high natural value, as well as causing territorial disruption. For this reason, in democratic countries, they often encounter social opposition from nearby populations, but their usefulness in ensuring supplies is indisputable. Spain has traditionally been a country that has used, and continues to use, hydraulic works, as have Portugal, Italy, the United States, Egypt and China, where the world's largest dam has been built, resulting in the relocation of more than a million people.

  Within these types of projects, water transfers deserve special treatment. They allow different river basins to be connected, thereby disrupting the natural unity of surface water management. Some countries use them to distribute water resources within their territory which, as mentioned above, tend to be unevenly distributed both territorially and spatially (as in the case of the United States and Spain, among others). They tend to be controversial and generate support in the receiving basin and opposition in the transferring basin due to fears that they will cause environmental degradation in river ecosystems through loss of flowing water and possible water shortages or insecurity in supply. For this reason, countries such as Chile and Spain have seen significant controversy when the possibility of water transfers has been raised.

  China is also creating a system of river basin connections through large water transfers to carry water from the south (the area richest in water resources) to the north, regions with fewer resources and more intense industrialisation.

- Integrated management of surface and underground resources. Groundwater and surface water have often been managed separately, but the water cycle integrates and links them. In permeable areas, surface water infiltrates and recharges aquifers, which in turn feed surface water in springs, water sources, or seeps. The use of groundwater goes beyond being a reserve for periods of drought or scarcity. More States are implementing integrated management techniques in which aquifers are recharged for use as permanent reservoirs, controlled extraction with monitoring of water table levels, establishment of protection perimeters to prevent or reduce the arrival of contaminants to groundwater and prevent its degradation, etc.

Many States have abundant underground resources, which become key assets in arid areas. These are reserves that nature makes available to human beings, and their sustainable management is increasingly important in helping to meet growing water demands. They already cover significant percentages in many countries in arid regions, such as Algeria, where 65% of demand is covered by groundwater, Israel and Jordan, with percentages around 50%, and Libya, where it rises to 95%, which is one of most dependent countries in the world on this resource.

– Desalination. If seawater is considered as part of the planet's water resources, they become practically inexhaustible. Many uses of ocean water require prior desalination, and this process consumes energy and generates waste with a high concentration of salt accompanied by chemicals (known as brine), which, if returned to the sea, can cause degradation of nearby ecosystems. However, desalination is a system that in coastal countries with scarce freshwater resources becomes a widely used way to meet demands. A good example is Israel, which has scarce water resources per capita, around 250 m^3 per person per year (UNESCO, 2006). Although this figure may have decreased due to population growth, around 75% of the water supplied to the population comes from this system, which consists of five large desalination plants located on the Mediterranean coast. In the Gulf region, almost all countries (Saudi Arabia, United Arab Emirates, Kuwait, Qatar and Bahrain) obtain almost all their water supply through this system, and Australia is also building major desalination plants. The case of Spain also deserves attention, as almost 10% of its water supply comes from this source. Although the overall percentage is not very high, in regions such as the south-east and, especially, the Canary Islands and the Balearic Islands, percentages of 80% are reached, making it the fourth-largest producer of desalinated water in the world, with more than seven hundred desalination plants for seawater or saline aquifers.

3.1 The case of shared basins

A river basin comprises all the land whose surface water drains into a main river, with the drained water flowing out at a single point into a sea or lake. This main river has its network of tributaries, each with its own sub-basin. There are no basins without rivers (except for arid regions), or rivers without basins. Every territory has a drainage network, although it sometimes ends up disappearing in arid inland areas (endorheic basins) that can form lakes such as those mentioned in the text (Lake Chad or the Aral Sea).

Every river basin is a dynamic natural water unit, where precipitation, infiltration and aquifer recharge, surface run-off and the organisation of drainage networks occur until the water reaches the sea or a lake. Its boundaries are natural, in no case established by human beings, so they may or may not coincide with administrative boundaries. River basins and administrative boundaries rarely coincide, which often leads to management difficulties.

The concept of shared basins was first adopted in the New York Declaration in 1958. At the Helsinki Conference, it is included in the Rules on the Uses of the Waters of International Rivers. The 1997 Convention on the Law of the Non-navigational Uses of International Watercourses incorporates the concept of international watercourses (United Nations, 1997).

However, it is necessary to differentiate between two concepts:

- An international river basin is a geographical area that includes all the territory whose waters flow into the same main river, with a single point of exit to the sea or lake, which may belong to two or more States.
- A river course is a system of surface and underground waters, a unified whole that flows towards a common mouth. Rather, it is a river system or network. The course may belong to two or more States and therefore is international in nature.

There are many examples of shared basins on the planet (Danube, Nile, Amazon, Douro, Tagus, etc.). In all the above examples, the river course is also international in nature, but there are cases in which the course is national, but the basin is international, such as the Ebro, which flows entirely within Spain, but whose basin includes territory in France and Andorra as well as Spain.

International law is based on the premise that a State belongs to the international community, thus renouncing the unlimited exercise of its territorial sovereignty and the invocation of the absolute integrity of its territory (Aguilar and Iza, 2006). Therefore, the territorial sovereignty of the State is restricted, as it must refrain from acting when it harms a neighbouring country. The principles governing this matter have led to the definition of the duties and powers of States when managing a shared basin, which are as follows:

- Cooperation: the duty to cooperate derives from the unity of the river basin and the resulting community of interests among the States that have territory within it.
- Integrated management: States are to achieve unified management of surface water and groundwater, among others.
- Sustainability: in the current context of increasing pressure on water resources, as discussed above, it is essential to strike a balance between development and the conservation of natural values.
- Prevention of damage: each State party to a shared basin may utilise the part of the basin under its jurisdiction, provided that this does not significantly affect the rights of the other States. Hence the obligation to anticipate and minimise environmental damage, in accordance with the principle of sustainability.
- Participation, with two aspects:
  - Equal participation. It indicates that no agreement may affect the rights of a State party to the Convention to the basin without its consent.
  - Public participation. It indicates that affected users should be allowed to participate in water management.

These are very general principles, which leaves room for ambiguity and different interpretations, which can be a source of conflict.

The duties of States (United Nations, 1997) are:

- Duty not to cause harm. There is no absolute prohibition against pollution in international law. States, when utilising an international watercourse within their territories, shall take appropriate measures to prevent significant damage to other States of the watercourse. States parties to the Convention shall avoid, within their jurisdictions, modifications that would impair the utilisation of the basin by another State party.

- Procedural duties. States have a duty to exchange information about the basin, mainly on aspects of a hydrological, meteorological, ecological and water quality nature.
- Protection of ecosystems. States shall individually or jointly preserve the ecosystems of international watercourses. There is a provision on the obligation to adopt measures to control the introduction of alien species that cause harmful effects on the ecosystem of the international watercourse. However, the concept of ecosystem is not very clear in the Convention; it is unclear whether it refers to the riparian communities of each country or to the river ecosystem. An important part of protecting ecosystems is preserving *environmental or ecological flows*, commonly accepted as an essential component of integrated water management, particularly for addressing issues related to the health of freshwater ecosystems, their sustainable development and the equitable distribution of the benefits they provide.

The concept of environmental or ecological flow has evolved considerably and has been subject to multiple interpretations. In general, it refers to the need to respect a minimum flow in natural water bodies in order to maintain their values and the goods and services they provide (drinking water, aquifer recharge, recreational uses, fisheries, etc.). Although there is consensus on its meaning and objectives, there is no consensus on the methods of calculation, which are numerous and, in some cases, prioritise conservation objectives and, in others, the maintenance of goods and services that water provides to society.

In addition to the right of navigation:

> 'Watercourse States shall in their respective territories utilise an international watercourse in an equitable and reasonable manner. In particular, an international watercourse shall be used and developed by watercourse States with a view to attaining optimal and sustainable utilization thereof and benefits therefrom, taking into account the interests of the watercourse States concerned, consistent with adequate protection of the watercourse' (United nations, 1997).

Approximately 40% of the world's population lives in shared river basins, which means there is an enormous potential for conflict, but also for cooperation. Currently, the international trend is moving towards a comprehensive approach to river basins and watercourses that establishes some kind of border area between States (Valle and Escribano, 2014). Experience shows that cooperation prevails in shared basins, although according to UN data, by 2030, growing pressure on this resource could lead to increased conflict (Unesco, 2003).

3.2 The case of shared aquifers

When an aquifer or aquifer system is referred to as 'transboundary', it means that parts of it are located in different States. Transboundary aquifers include a natural underground pathway for groundwater flow that crosses an international boundary, allowing water to flow from one side of the boundary to the other (Unesco, 2001).

The relationship between surface and groundwater flows is very close and must be managed as a single resource (Winter *et al*., 1998). Aquifers are sources of water that can be very abundant, so their storage, distribution and treatment are complementary to those of surface water and, in some cases, such as countries with scarce surface resources, they are a priority.

The first step in this integrated management is the identification and delimitation of shared aquifers. According to Unesco's database (Transboundary Aquifers of the World) on transboundary aquifers, there are 468 shared aquifers in the world. These aquifers are distributed as follows: Africa, 72; the Americas, 73; Asia, 90; and Europe, 226.

Although progress is being made in the integrated management of aquifers and surface waters, and technology is making this increasingly easier, there are still significant shortcomings which, in the case of shared basins and aquifers, are exacerbated by the fact that the boundaries of basins and aquifers shared between several States do not usually coincide. Integrated management of shared aquifers faces numerous problems, for example:

There are usually different levels of implementation of integrated management between surface water and groundwater in different States, different technologies, and the exchange of information between them is not always adequate. There may be tensions between countries, unequal distribution of resources depending on the surface area of the aquifer in each State, a decrease in the quantity and quality of groundwater depending on the amount extracted by each country, which in turn can alter the flow of water, limited knowledge of its hydrogeological functioning and, in many cases, an inability or unwillingness to create formal joint management institutions. The need to create protection zones to prevent contamination of a shared aquifer with restrictions or prohibitions on certain uses can also be a source of tension.

There are still few cases worldwide of inter-State agreements on transboundary aquifers in force, but examples include the Geneva Aquifer (France and Switzerland), the North-Western Sahara Aquifer System (Algeria, Libya and Tunisia), the Guaraní Aquifer (Argentina, Brazil, Paraguay and Uruguay) and the Saq-Disi Aquifer (Jordan and Saudi Arabia). Undoubtedly, advancing in the integrated management of shared aquifers is a challenge of great technical, institutional and political complexity in which the countries affected must move forward towards better water governance and the reduction of tensions.

4 The uncertainties posed by climate change

The climate, like all natural factors, is changeable, and human activity adds to its natural variability in the complex climate equation. It is not the aim of this paper to decide on the greater or lesser influence of human beings on climate variability, but all societies throughout history have been vulnerable to climate variations, which have been intense over the last two thousand years and have had a strong influence on many civilisations. Our way of life, which is highly dependent on the availability of water among other factors, is not immune to this influence. The future scenario is a possible continuation of the warming observed over the last century, as predicted by the Intergovernmental Panel on Climate Change (IPCC), or a possible cooling due to the expected decrease in solar activity after the 2024 maximum (véase: www.eltiempo.es).

In any case, there are numerous uncertainties regarding water availability. A continuation of the warming observed over the last century could mean a greater presence of water vapour in the atmosphere and changes in the distribution of rainfall, with some regions becoming rainier and others more arid, leading to periods of intense rainfall and others of prolonged drought. This climatic behaviour may intensify water stress in some regions, while in others available resources may increase. A possible cooling trend would mean less water vapour in the atmosphere and greater retention in the form of snow and ice in cold and high mountain areas. Knowledge of historical climate patterns shows that cold periods are more conducive to long and intense droughts, so a scenario of this nature could exacerbate tensions over water resources, especially in the areas most affected in a context, already exposed, of growing demand for water and different responses by States to meet that demand.

5 Based on the current reality, how is the future water scenario expected to unfold?

Water is a powerful source of tension and conflict due to its irreplaceable nature and, in some circumstances and regions of the world, its scarcity (although not globally), but it is also a factor for peace and security.

In the 20th century, it was relatively common to hear claims that the next world war would be over water, or that the next century would see widespread conflict over this resource, mainly due to its scarcity. Fortunately, the current reality does not reflect this situation, but rather one of enormous complexity in which there are some points of conflict, but also others of cooperation between both users and States.

A priori, it seems logical to think that a scarcity of a resource, largely caused by increased demand for different uses, would lead to greater conflict. However, systematic research on indicators of transboundary water conflicts by Kramer *et al*. (2013) did not find statistically significant physical parameters. According to this paper, arid climates are no more prone to conflict than humid ones, and during periods of drought, international cooperation increased. According to this study, no causal link was demonstrated with almost any variable in itself: democracies were as prone to conflict as autocracies, as well as rich countries versus poor countries, densely populated countries versus sparsely populated countries, and large countries versus small countries. According to these authors, the key to successful management practices in arid areas is institutional capacity. They assert that naturally arid countries cooperate to obtain water: in order to live in an environment where water is scarce, populations adapt by developing institutional strategies such as formal agreements, informal working groups, or generally cordial relations. It follows, therefore, that institutional strengthening, a concept opposed to that of State fragility, is key to avoiding conflict and advancing good water resource management, thus defining an important line of international cooperation.

These researchers also concluded that the probability of conflict increased significantly when two factors came into play:

- If the physical or political environment of the basin undergoes a major or rapid change, such as the construction of a dam, a large irrigation programme or territorial restructuring. An example of this circumstance is the Southeastern Anatolia Project (GAP, Turkish acronym) implemented by Turkey in this region, traditionally one of the poorest in the country. It involves the construction of twenty-two dams and nineteen hydroelectric plants on the Tigris and Euphrates rivers (both of which originate in this country) and the transformation of 1.7 million hectares into land for irrigation, as well as improving drinking water and the sanitation infrastructure. The use of water from these rivers is intended for energy generation, increased agricultural production and socio-economic development in the area, but it also means a significant increase in tensions with downstream countries (Syria and Iraq), which are highly dependent on the waters of the same rivers. The construction of the Great Renaissance Dam by Ethiopia on the Blue Nile, not far from its border with Sudan, can also be included in this case. It is projected to have a capacity of 6,450 megawatts and is intended to meet the domestic electricity demand of the whole of Ethiopia, improving the quality of life of its people and boosting industrialisation in a country that ranks among the lowest on the UN Human Development Index. It also aims to export surplus energy to neighbouring countries, which would bring significant economic benefits to the Ethiopian State. This major project is raising concerns in Sudan, which may reap benefits but also suffer some negative consequences, and particularly in Egypt, which depends on the Nile for 90% of its water supply, with most of it coming from the Blue Nile. Egypt bases its arguments on historical treaties (mainly the 1929 and 1959 Treaties), which granted it priority rights over the waters of the Nile, but Ethiopia does not recognise these Treaties because it did not sign them. Tension is therefore considerable between the two countries, with Egypt even threatening to bomb the dam if Ethiopia continued with its construction, although it later toned down its threats.

- If existing institutions are unable to assimilate and deal effectively with this change. This is a problem that can be considered quite common in many parts of the world, as low levels of development are often associated with institutional incapacity, both in terms of the internal expression of States and their external expression, reflected in their ability to negotiate with other States and reach enforceable agreements.

Also, Carius *et al*. (2004) assert that conflict is not the inevitable result of scarcity, although, in our opinion, scarcity or the perception of scarcity (which is highly subjective) is a factor that can intensify tensions.

Poverty and scarcity are factors that cause or intensify conflict. In times of political or ethnic tension, and in civil, regional or post-war reconstruction conflicts, having a solid and well-implemented water strategy that takes into account both the natural resource and its management and distribution is crucial to preventing violence and facilitating peace and stability. The best way to create long-term peace is to combat poverty, hunger and disease, and water is key to achieving this. Some studies have revealed that two of the clearest indicators of high-intensity conflicts are prolonged droughts and high infant mortality, which constitute a particularly deadly cocktail when combined with the proliferation of small calibre weapons (Gorbachev, 2008).

Although it has been pointed out that cooperative relationships predominate when dealing with the issue of resource management in shared basins, it would be unrealistic to deny that there are conflicts over water in some areas of the world, either openly or as part of complex conflicts in which this resource is just one variable among many. Some regional cases that are considered significant are mentioned below.

Without a doubt, one of the regions where conflict over water reaches the highest levels, but is intertwined with many other factors, is the Middle East, and here several different territories must be distinguished.

The situation surrounding the Jordan River: following Israel's occupation of the Golan Heights in 1967, Israel became the dominant power in controlling the region's water resources, as the river's main sources are located here. Israel's interest in this mountainous area rich in water is evident and is reflected in the unilateral annexation of 1981, which is not recognised by the international community.

Jordan depends almost exclusively on the Jordan River (its territory is located on the left bank) and groundwater for its water supply. As it has no oil, it faces difficulties in developing large desalination plants along its very limited coastline on the Red Sea around Aqaba.

The conflict between Turkey and Syria is very complex, as factors such as Syrian support for the Kurds in Turkey, Daesh control of part of northern Syria, etc. are intertwined. It also has strong links to the control of water resources, as noted above. The situation is exacerbated by the fact that there is no treaty governing the joint use of the two major rivers, which flow through a highly conflictive area.

In South Asia, there are also complex conflicts in which water is one of the elements of discord.

Within the vast and populous continent of Asia, the region of Tibet has become the key to controlling water resources. Its occupation by China in 1950 and progressive consolidation of its dominance is closely related to the fact that it is the birthplace of many of Asia's major rivers, some of which are entirely Chinese, such as the Huang He and the Yangtze, and most of which are shared, such as the Indus, Brahmaputra, Salween, Irrawaddy and Mekong. China is building large hydroelectric projects on the upper reaches of these rivers with the intention of harnessing their enormous energy generation potential, as well as others in Nepal. Downstream countries have expressed concern about the consequences and accuse China of exercising hydro-hegemony and even hydro-domination, by taking advantage of its privileged position. This country, which has not signed the Convention on the Law of the Non-navigational Uses of International Watercourses, claims that reservoirs do not reduce flow, but it has been accused of using the flows of rivers whose upper reaches it controls for its own benefit and even to the deliberate detriment of those downstream.

The tensions between India and Pakistan over Kashmir are territorial, but they are also related to control of the Indus River, which originates in China and immediately enters India, but whose middle and lower reaches are located in Pakistan, which is of vital importance to Pakistan as it is its main river. In 1970, both countries signed a treaty on the use of the river's waters, but it has been greatly affected by alternating periods of confrontation and *détente* between the two countries.

The Mekong basin is also becoming an area of growing tensions over water. It is a large river, almost five thousand kilometers long, in a region of the globe that has stabilised considerably since the Cold War and is enjoying rapid economic growth. It is a complex area, as its basin encompasses territory from six countries, all of which are members of the Mekong River Commission. Its source and upper course are in China, a country whose rapid growth with few environmental safeguards causes spills and increased pollution, affecting countries downstream, with a population of some seventy million people dependent on its waters. Numerous new hydroelectric facilities are planned for the basin, in addition to those already in existence. A strategic environmental assessment conducted in 2010 and commissioned by the Mekong River Commission concluded that the dams would cause severe damage to the ecological functioning of the river. The sediments carried by the river will also decrease, which would negatively affect the Delta, limit its food supply and causing it to stagnate or even enter a phase of recession, thereby increasing the salinity of groundwater and soil as a result of the advance of seawater, with the consequent economic damage to Vietnam.

In 2011, the Mekong Commission announced that there was no consensus among the countries in the basin on Laos's plan to build a dam to meet its electricity needs and for export. The original project, which had a significant environmental impact, was modified to reduce this impact, and in 2012, Laos announced that the project would go ahead.

Africa is not immune to this situation either, and perhaps some of the most intense conflicts over water resources are found here, although we must not forget the context of significant tensions of an ethnic or religious extremist nature, or those arising from the control of mineral resources.

The growing conflict over control of the Nile is becoming increasingly apparent. Its origin lies in Ethiopia's refusal to accept the 1959 agreements on its distribution, as it considers them unfair. These agreements stipulate that no dams or hydraulic works may be built on the river without the consent of Egypt, which is the main beneficiary, as it is guaranteed some fifty billion m^3/year, while its contribution to the river is practically nil. Eleven countries lie within its basin, and the country that contributes the most water resources is Ethiopia through the Blue Nile, which, although hydrologically considered a tributary of the White Nile, contributes 85% of the Nile's flow, as the White Nile is exhausted by the time it crosses the Sudanese desert. Seven non-Arab countries in the basin signed the Entebbe agreement in 2010, which modifies the distribution of water flows in their favour, putting Egypt on alert. Neither Egypt nor Sudan signed this agreement, which increased tensions when, a year later, Ethiopia announced a significant expansion of its aforementioned 'Great Renaissance' water project.

Currently, there is no widespread conflict over the use of water resources, but rather regions and basins where tensions are observed, many of them framed within complex conflicts. Some trends observed as we move forward in the 21st century are as follows:

- Increased pressure on water resources, especially for use in irrigation to produce food directly for the population (a successful way to combat hunger) or for fodder for livestock, which improves the supply of animal protein.
- Increased use of water to improve supply and sanitation for the population in less developed countries, which is a significant step forward in the fight against extreme poverty and certain diseases related to inadequate hygiene.
- Increasing demands for leisure activities (tourism, gardening, various water activities), especially in developed countries. It can be compensated by greater efficiency in use.
- Increase in discharges with inadequate treatment, especially in areas of rapid industrial growth and permissive legislation. The consequences would be environmental damage to the river ecosystem and possible limitations on subsequent uses of these contaminated waters (especially those requiring the highest quality), which could cause or exacerbate water scarcity problems.
- Significant changes in wetlands, either due to a reduction in the water flows that feed them or changes to their environment caused by urbanisation, the installation of irrigation systems, etc.
- Increased pressure on groundwater resources, especially in arid and semi-arid areas experiencing rapid population growth.
- Large-scale privatisation of water resources in countries where legislation permits this.

- Increased internal conflict within States, either between users with divergent interests in management or between territories with highly contrasting resource availability.
- States' efforts to guarantee the growing demands in the different sectors and to avoid a possible slowdown in development due to lack of water. It will mean more infrastructure construction (dams, canals, wells, or water transfers). Uncertainty about climate change may increase these policies aimed at securing resources.

Environmental security has become a crucial issue in the field of international relations, with the links between the environment, conflicts and international cooperation becoming increasingly important. Within these, water-related issues are particularly important, to the extent that some authors (Carrillo, 2008) refer to 'geohydrics' as a new paradigm in international relations, based on the following elements:

- Water as a source of power. Its scarcity in some parts of the world (real or perceived) makes it a strategic issue.
- Water as a strategic resource.
- Geopolitical revaluation of water, with greater interest in the main reserves (Amazon, Guaraní Aquifer, Congo Basin, African Great Lakes and even Antarctica).

6 Some management proposals

Conflict over water can be partly related to scarcity, but also to the institutional weakness of some States in guaranteeing the needs of their own territory and in reaching joint management agreements with neighbouring States in cases of shared basins and aquifers. These agreements must be implemented within each State's territory and require, in addition to diplomatic efforts, preliminary studies, qualified personnel and equipment, as well as sufficient capacity for territorial management, which is not always possible in weak States. For this reason, it is considered necessary to strengthen water resource management bodies, adapting them to the specific characteristics and needs of each country and reinforcing the most necessary aspects in each case (management of aquifers, surface waters, wetlands, active participation in shared basins, etc.).

The situation in shared river basins varies greatly. In some cases, there are agreements or international management bodies involving the States, aimed at maintaining a situation that is acceptable to all of them. In other cases, these structures do not exist. It is foreseeable that there will be an increased interest on the part of States in participatory and as consensual as possible management as an instrument to avoid possible tensions. An increase in diplomatic and technical activity is therefore foreseen in order to reach agreements between States or to create international management bodies following the models of those already in existence or with new formulas adapted to the needs of each area.

The current trend towards a comprehensive approach to river basins, which takes into account both surface and groundwater resources, is considered appropriate. They are home to approximately 40% of the world's population and this trend opens up enormous possibilities for international cooperation, already embodied in actual agreements and experiences. International cooperation for integrated resource management of international river basins can become a highly effective tool for reducing or avoiding future tensions over the use of water resources.

The increase in demand for resources for different uses in many areas of the globe is accompanied by inadequate purification systems, which leads to water quality problems with environmental and economic repercussions, as well as repercussions on international relations in the case of shared bodies of water. Therefore, there is a clear need to develop adequate urban and industrial water treatment systems to minimise these impacts.

It is foreseeable that water use will continue to increase in order to expand irrigated land, or to increase its guarantees and improve the food conditions of the population, which is a significant factor putting pressure on the resource. This means a decrease in circulating flows, as only a small part of the water used for irrigation returns to the river network in the form of surface or underground runoff, and normally with low quality levels. Therefore, it is necessary to plan new irrigation systems and optimise water use as much as possible, while limiting the use of chemicals to minimise the impact on the quantity and quality of circulating water.

Advances in the level of development of communities are accompanied by greater demands for water to cover multiple aspects related to changes in lifestyles. It is therefore necessary to accompany this with techniques and technologies for optimising the use of the resource, as well as environmental education and awareness campaigns for the population on the need for rational use of the resource that also preserves, as far as possible, its quality and the environmental values of river and wetland ecosystems.

An increase in internal conflict within States between different water users with conflicting interests is foreseeable, which could result in territorial conflicts or conflicts between socio-economic sectors. To prevent its occurrence or reduce its intensity, it is advisable for States to design mechanisms for participation among water users in which needs and interests are expressed, and which allow for management agreements to be reached that are accepted by the majority.

Faced with growing demand for water, many States will opt for water transfer projects, river regulation, or a combination of both to distribute the resource throughout their territory and guarantee its availability in periods of scarcity. These works have a significant environmental impact, so it would be advisable to leave some rivers intact or sections of rivers without major alterations in order to maintain river systems with natural dynamics. They can also have significant social consequences, resulting in territorial tensions between areas negatively affected by these works (watersheds that lose flow or areas flooded by reservoirs) and those that benefit (those that receive the transferred flow or benefit from the guarantee and regulation provided by reservoirs). To reduce these conflicts, rigorous studies must be carried out on projects with the least environmental and social impact, and these must be given priority over other projects. Similarly, it is necessary to establish compensation measures commensurate with the damage caused to the populations and territories that have been negatively affected.

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Chapter Two

Water Management in Towns

Jesús Mateos Robledo

Abstract

Water in town is a fundamental pillar of society. Much of the economic fabric of urban environments depends, directly or indirectly, on this precious resource. Ensuring the quantity and quality of this basic commodity is one of the challenges facing global society in this decade.

Population growth in towns around the world will increase current pressures on drinking water supply systems. According to current forecasts, a large proportion of the world's urban population will live in towns with permanent water shortages. These scenarios will be more common in areas that currently enjoy favourable water conditions. The climate crisis is increasing episodes of water stress in many regions. It is anticipated that future scenarios for this development will be unfavourable and may potentially challenge the drinking water supply systems of the largest urban conurbations inn our planet.

In the future, it will be vital to develop plans that promote better management and governance of water resources in towns. It is a global and multilateral objective in which all States must be

part of the change towards a transition that provides positive and proactive solutions with environmental care. If joint action is not taken, all countries will be affected in one way or another by water shortages in cities.

Keywords

Water scarcity, Water governance, Tap water, Urban water, Resilient cities.

Introduction

> 'We are poisoning our water with pollution, draining it through excessive use and wreaking havoc on its natural cycle through climate change and uncontrolled urbanisation, with unsustainable models of consumption, production and urban development. Meanwhile, we face worsening water-related disasters, disease outbreaks, water shortages and deadly droughts'.
>
> António Guterres (United Nations, 2023)

Population growth in urban areas around the world is making it increasingly necessary to analyse the challenges of supplying drinking water and sanitation systems to the global population in order to ensure decent living conditions in cities.

Current forecasts are very alarming, and it is necessary to bear in mind the new challenges posed by urban environments in relation to adverse water scenarios in strategic national defence analyses.

The current number of people worldwide living in areas where adequate water supply and sanitation systems are not guaranteed to protect the population are of great concern. This will increase the vulnerability of the population in many cities and cause significant social and economic tensions.

The impact of the climate crisis means towns having to face increasingly extreme weather events. A large part of these towns will suffer from perennial, problematic water scenarios and extreme rainfall events that will endanger a large number of people living there.

If adequate measures are not taken to address climate change, global stability in terms of security and defence could be compromised. Demographic shifts from rural areas to cities, combined with water scarcity scenarios, will mean that a large part of the population will be exposed to the virulence of adverse water and economic situations.

Against this complex future scenario, great opportunities nevertheless arise to improve the lives of all the people who will inhabit cities in the future. All of this shall be addressed in this chapter, evidencing that there are long-term solutions for making urban environments more resilient.

1 Water and cities

In 2022, approximately 2.2 billion people lacked access to safe drinking water and 3.5 billion did not have access to safe basic sanitation systems (United Nations, 2023).

The prosperity and well-being of people in cities is closely linked to their water sources. Responsible use of this resource, combined with good urban drainage infrastructure and sanitation networks, will ensure a higher standard of living for the people who live in these cities. 'Almost half of the world's population suffers from water scarcity at least during part of the year. A quarter of the world's population faces extremely high levels of water stress and uses more than 80% of its annual renewable freshwater supply' (United Nations, 2023).

According to the UN, water stress is defined as 'when a territory extracts 25% or more of its renewable water resources'.

> 'Although agriculture accounts for approximately 70% of freshwater withdrawals, industrial (just under 20%) and domestic (close to 10%) uses are the main drivers of growing water demand. As economies industrialise, populations become more urbanised and water supply and sanitation systems expand' (United Nations, 2023).

It is estimated that by 2050, a population greater than that currently living in China or India will be living in cities affected by water scarcity across the globe. The number of people affected will be between 1.7 and 2.4 billion, approximately one-third of the world's population and nearly half of those who will be living in cities by that year (He *et al*., 2021).

There are 526 large cities (with more than one million inhabitants) in the world, 193 of which are located in areas with water scarcity, 96 in areas with perpetual water scarcity, and another 97 in areas with seasonal water scarcity (He *et al*., 2021).

It is a fact that the growth of cities will turn them into places where the greatest challenges related to the supply of drinking water to the population will arise. In addition, flood protection will be necessary through the construction of optimal sanitation systems, as well as the conservation of ecosystems and available water bodies in downstream river basins.

The growing exodus from rural areas to cities is not being orderly managed in many countries, thus creating major demographic and land-use challenges.

In numerous urban settings, large, uncontrolled metropolitan areas are emerging. These areas lack all kinds of basic services and are inhabited by people seeking economic opportunities that will enable them to survive.

Local governments are unable to respond adequately to the population growth they are experiencing and expose a large number of their inhabitants to areas where there are no water supply systems, electricity, wastewater sanitation, urban drainage or sustainable urban development.

The climate crisis is one of the main reasons for this population displacement. Many farmers and livestock breeders around the world are seeing their harvests and livestock farming capacities decline. Unfortunately, this problem will increase in the coming decades.

From a water resources perspective, the existing problems related to water in urban environments are as follows:

- Scenarios of perpetual water scarcity.
- Adverse weather events that cause heavy rainfall, flooding large areas.
- Pollution of available water resources by industrial and agricultural waste or by inadequate treatment of urban wastewater.

All the above highlights the fact that local and regional governments around the world must begin to work on water governance in large cities. It is estimated that global urban demand for water for industrial and domestic use will grow by between 50% and 80% over the next three decades (Planeta en Verde, 2022).

In future action plans, an important tool will be innovation and the development of creative solutions. Many of the challenges ahead will need to be solved with technologies and plans that are far removed from conventional solutions.

The technologies available to mitigate water scarcity in towns require planning and a significant investment of financial resources. Therefore, specific plans for the development of these technologies must be drawn up as soon as possible. Priority should be given to areas where water scarcity is most problematic.

1.1 Tap water as a key element of prosperity

Turning on a tap and getting drinking water to flow out of a wall would be difficult to explain to our ancestors who lived in caves. A somewhat everyday gesture for part of the world's population and, at the same time, unimaginable for more than two billion individuals on our planet (UNU INWEH, 2023).

Sustainable Development Goal no. 6 of the 2030 Agenda promoted by the United Nations states that access to safe drinking water and sanitation must be guaranteed for the entire world population by 2030. Given the current scenarios, there is much work to be done and less time to achieve this goal, as set out in the United Nations action plan for the year 2030.

Having good quality tap water is synonymous with living in a country that has sufficient capacity to provide its population with a basic commodity. Meeting the population's demand for drinking water guarantees a country's social stability.

The ownership of water worldwide, except in exceptional cases, is a public domain resource that public administrations are responsible for managing for their people. In many countries, local or regional authorities are responsible for managing their water resources.

Domestic water consumption worldwide accounts for around 10% of global water consumption. Even though it may seem like a small figure in percentage terms, it is a vital link for global peace and stability.

For society and individuals, prosperity means having the opportunity and freedom to grow without taking risks. Water fosters prosperity by meeting basic human needs, promoting health, livelihoods and economic development; it also ensures food and energy security and protects the integrity of the environment.

Countries with the highest quality of life worldwide provide their populations with basic benefits, including a supply of high-quality drinking water. It is vital to legislate internal directives that protect this basic right for their citizens and to reach cross-border agreements with neighbouring countries with which they share river basins.

If one imagines cities where this basic good is not guaranteed, one can glimpse vulnerable people who are unable to meet their basic needs. In such places, it would be out of the ordinary to be able to cook with drinking water, sanitise kitchen utensils or even wash clothes.

> ‘It is estimated that nearly one million people die each year from diarrhoeal diseases contracted as a result of unsafe water, inadequate sanitation or poor hand hygiene. However, in most cases, these diseases can be prevented: if these risk factors were addressed, some 395,000 children under the age of five could be saved each year’ (WHO, 2023).

All governments must be aware that cooperation on issues related to quality drinking water will lead to scenarios of joint prosperity that will guide humanity in future challenges.

It will be vital to work toward stable local governments and are free of corruption. By monitoring water policy practices, governments will ensure safer access to safe drinking water for its entire population, whilst establishing agencies to help them manage their infrastructure investment effectively and provide their regions with greater protection against stress scenarios.

1.2 Water governance in urban environments

Water governance is not a straightforward issue. In fact, the vast majority of citizens are unaware of the complexity surrounding water resource management in the regions where they live. In countries that share transboundary basins, regional tensions and interests increase the complexity surrounding water management.

According to the OECD, it is considered that:

> ‘Water governance as a means to an end and not an end in itself. That is, the range of political, institutional and administrative rules, practices and processes (both formal and informal) through which decisions are made and implemented. Stakeholders can articulate their interests and have their concerns taken into consideration, and decision-makers are held accountable for their water management’ (OECD, 2018).

Water governance, in many regions of the world, is one of the fundamental pillars for ensuring geopolitical stability. Furthermore, it is a tool that seeks to promote cooperation between economic sectors, regional entities, and even border states.

Many countries find themselves unable to access the water resources they need for various reasons, such as: dependence on other countries that control resources upstream of the river basin, conflicting interests between different water uses (agricultural, industrial and domestic) within a territory, legislative fragility among the entities involved in water management, and contamination of the sources used to supply the population.

> 'The functions and responsibilities of water management in cities are distributed among different levels of government and a wide range of stakeholders, such as government authorities, service providers, regulators and river basin organisations' (OECD, 2016).

Water governance in the territories is increasingly strained by the effects of the climate crisis. Transboundary river basins around the world are facing increasing challenges. A key factor is the increasing frequency of water stress scenarios.

The stability and economic growth of cities have a major influence on the management of water scarcity scenarios. These scenarios will generate significant conflicts of interest between water management entities, the agri-food sector and the industrial sector. Cooperation and collaboration between the various stakeholders will drive the development of tools that will ensure the needs of all involved parties are met.

Local governments, together with various regional and State governments, must draw up strategic plans that guarantee access to drinking water for their populations, seeking to minimise the impact on other sectors of the economy and promote sustainable coexistence that safeguards their economic competitiveness.

Governments have an obligation to establish bodies and legislation that safeguard good practices in water governance. Failure to act, on the part of the governing bodies, would mean missing a key opportunity to ensure coexistence between economic, social and legislative powers.

1.3 Funding to adapt cities to new water scenarios

The adaptation of towns to the new water scenarios requires a large investment. Currently, this investment is well below the rate of population growth in large cities around the world. This is more significant in countries with less developed economies.

Countries with fewer resources will be the most exposed to the consequences arising from both the new water scenarios and the rapid and uncontrolled growth of their urban centres. Government entities should focus their efforts on creating plans that mitigate the consequences of these new challenges.

It is estimated that the global investment required to achieve the objectives outlined in the 2030 Agenda will be approximately USD 1.04 trillion per year (Strong *et al*., 2020). This figure represents almost 1.21% of global gross domestic product. This investment will be directly affected by increased direct and indirect demand for water, population growth and declining water resource availability.

At the United Nations Climate Change Conference, COP 27, held in Egypt in November 2022, a subsidy fund was created for countries suffering environmental loss and damage due to the climate emergency (United Nations Climate Change, 2022).

Subsequently, in March 2023, a conference on water was held, organised by the United Nations, fourty-six years after the one held in Mar del Plata (Argentina). More than ten thousand delegates and representatives from all over the world attended the conference. An important topic discussed during this conference was the Water Positive initiative, due to the importance given to the water footprint as a vector for change among organisations (Zarzo and Sturniolo, 2023).

The Water Positive initiative is a great opportunity to channel large sources of investment into projects that aim to promote a positive water footprint and offset water consumption by promoting projects that have a positive impact on water consumption. This, by placing value on the resource and thus avoiding speculative terms derived from economic transactions linked to a market.

At the end of that same year, in November 2023, COP28 was held in the United Arab Emirates. At this Summit, delegates from participating countries agreed on the implementation of the agreement and announced immediate contributions totalling USD four hundred million for the least developed countries suffering the impacts of climate change (McGrath, 2023).

Ensuring the robustness of these financing systems will drive projects that adapt cities to new climate needs. This will be an opportunity for countries with fewer economic resources and will improve both the quality of life in their cities and their economic resilience

Public entities should encourage public-private partnerships with investments to build new infrastructure. It is a way of attracting investment, thereby providing the population with better water supply and sanitation services. This will be one of the keys to achieving the goals set out in the 2030 Agenda.

If effective measures are not taken, significant imbalances will arise in regions with fewer resources. These imbalances will trigger global geopolitical tensions, amplified by scenarios of permanent water scarcity and an increasingly vulnerable population.

1.4 A major challenge for urban water: African megacities

The African continent will be the region of the planet that will experience the greatest growth in its urban population in the coming decades. It is estimated that by 2033 there will be more Africans living in cities than in rural areas. In addition, by 2050, Africa’s population will double and the number of people living on the outskirts of cities without access to running water and other services will increase (Worldometer, n. d.).

Today, half of the individuals of sub-Saharan Africa live in these peripheries. The challenges facing local governments in these cities are one of the most important issues that will need to be addressed in the near future.

> ‘In sub-Saharan Africa, population growth, rapid urbanisation, economic development, changing lifestyles and consumption patterns are increasing demand for water throughout the region. Much of its population suffers from economic water scarcity, as water infrastructure is often inadequate (or non-existent) and water resource management is poor, mainly due to a lack of funding. Furthermore, water quality appears to be deteriorating significantly’.

By 2050, water demand in sub-Saharan Africa is expected to skyrocket by 163%, four times the rate of change compared to Ibero-America, the region with the second highest demand, which is expected to experience a 43% increase in water demand (UNESCO, 2024).

> ‘Africa is the continent with the highest proportion of transboundary river basins. According to estimates, they cover

> 64% of the territory. Cross-border cooperation can facilitate closer ties between riparian states and stakeholders, with a view to jointly promoting water, energy and food security. Of the 72 transboundary aquifers mapped in Africa (which run beneath 40% of the territory), cooperation agreements have been established in only seven' (UNESCO, 2024).

These data highlight the importance of implementing regional policies that address the challenges posed by future water stress scenarios and promote cross-border collaboration to ensure the supply of drinking water to their populations, as well as to the agricultural and industrial sectors.

Many African governments are implementing mega urban projects that could solve the demographic challenges facing their cities. These projects seek to build cities that alleviate population growth in urban areas and guarantee standards of habitability for their inhabitants.

Glittering cities are being built, such as: Diamniadio (Senegal), The New Capital (Egypt), Konza (Kenya), Green City Kigali (Rwanda) (Planeta Futuro, 2023).

Diamniadio (Senegal): a city that has emerged as a result of the growth experienced by the country's capital, Dakar, in recent decades. Its population has increased more than tenfold, resulting in highly populated areas with insufficient basic services. For this reason, the Senegalese government began implementing a project to build a new city that would mitigate Dakar's future demographic problems.

The New Administrative Capital (Egypt): the Egyptian government is seeking to build a city that will help alleviate the problems existing in Cairo. This mega-project aims to carry out a profound transformation of the current administrative capital.

Konza (Kenya), 'the eternal dream of an African Silicon Valley': this city is a government project launched in 2008 to become a global centre for technological innovation. With this project, Kenya seeks to become one of the leading countries in technology and transform its economy. Bureaucracy and funding issues are significantly slowing down its construction.

Green City Kigali (Rwanda): the significant population challenges facing Kigali, where new neighbourhoods are growing uncontrollably without any planning, have led the government to draw up a project for a new city in order to guarantee a sustainable and inclusive solution for its inhabitants.

Only time will tell whether these ambitious population projects will become part of the solution to the urban growth that Africa will experience. All these projects face significant funding challenges for their construction. Later on, one of the biggest challenges will be to repopulate these new cities.

African governments have a great opportunity to build cities that create environments conducive to sustainability and human well-being. One of the keys will be to catalyse the growth of cities and develop ambitious urban planning schemes focused on the sustainable management of water resources.

These projects will require significant funding and lasting political stability to enable long-term strategic plans to be established. Achieving a decent environment for the people who live in these megacities will be of utmost importance for both future geopolitical and economic scenarios.

The future of the planet and of future generations will depend on the plans that are put in place to tackle the water challenges facing African urban environments. It is the responsibility of all governments to actively participate in the implementation of projects that guarantee basic services such as access to drinking water, electricity and sanitation systems.

Inaction on water policy in African countries could lead to a demographic and economic crisis of unknown proportions. Therefore, it is necessary to continue working towards finding a real solution to the water challenges facing the future African megacities.

2 Adaptation of cities in mitigating the effects of adverse climatic events

Can you imagine a region’s annual rainfall being concentrated into just five or six episodes of torrential rain? This is what is happening in numerous cities around the world, influenced by the current climate emergency.

Many cities are being affected by intense and heavy rainfall, with more than three hundred litres per square metre accumulating in a short period of time. These events are incredibly destructive and, if protective infrastructure is not in place, can result in significant loss of life and considerable economic costs.

Unfortunately, it is increasingly common to read news reports on torrential rains affecting towns around the world. In fact, there are numerous examples on every continent of adverse weather events that have caused significant flooding in urban areas.

New climate scenarios are forcing cities to redesign their drainage systems. The frequency and severity of these adverse weather events are forcing the construction of infrastructure to mitigate the damage they cause. Absorbing these flows is becoming one of the greatest challenges facing urban drainage systems worldwide.

Since 2000, flood-related disasters have increased by 134% compared to the previous two decades. Most flood-related deaths and economic losses have occurred in Asia (United Nations, n. d.).

The ten most significant climate disasters that occurred during 2022 had cumulative direct costs of close to USD 168 billion (Christian Aid, 2022). This cost is twelve times higher than the budget allocated, for example, by the Spanish Government to the Ministry of Defence in 2023 (Ministry of Defence, 2022).

These disasters were mostly related to flooding caused mainly by storms, cyclones and hurricanes. This highlights the increasing exposure of countries and cities to adverse weather events worldwide.

2.1 Early warning systems for floods

The management of extreme weather events, such as torrential rains, is one of the critical points of water resilience in cities. These events can only be addressed with systems that promote prevention and effective early prediction.

Receiving an alert on one’s mobile phone hours before a natural disaster strike can save many lives. These types of alerts are known as Early Warning Systems and aim to reduce the risks of people being exposed to extreme events that could cause natural disasters.

Creating effective systems to prevent and inform the population is the best way to reduce damage and deaths caused by floods. These systems complement the construction of flood protection infrastructure. To this end, work must continue in parallel on the planning and construction of these infrastructures. The United Nations defines Early Warning Systems as:

> 'An integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities, systems and processes that enable individuals, communities, governments, businesses and other actors to take timely action to reduce disaster risks in the face of hazardous events (UNDRR, n. d.)'.

> 'For decades, science and government agencies have been developing hydrometeorological monitoring and forecasting systems. Recently, improvements have been made in model resolution, process representation, parameterisation, data analysis, and computational efficiency of advanced numerical meteorological and hydrological forecasting. Early warning prediction systems have benefited equally from this'. (Najafi *et al*., 2024).

This improvement in weather forecasting systems and digital modelling programmes will drive the development of more effective early warning systems. This will significantly reduce the exposure of the population and the material damage caused by these adverse weather events.

In 2022, the United Nations created an Action Plan to develop and integrate early warning systems in all countries worldwide between 2023 and 2027. This plan envisages investments worth USD 3.1 billion over those five years, which is equivalent to just fifty pence per person per year (United Nations, 2022).

These plans are great news for countries with fewer economic resources. They will be a means of helping to minimise the damage caused by major natural disasters due to torrential rain.

If Early Warning Systems can be implemented on a large scale, it will be possible to reduce the population's exposure to areas with a higher probability of suffering a natural disaster. These systems will reduce a large number of human losses and ensure more sustainable urban development across the globe.

2.2 Sustainable urban drainage systems

When one imagines a resilient city, one will never think of a street where water flows with great virulence. However, this is what usually happens in most cities with conventional urban drainage systems.

In conventional urban environments, there are large areas of asphalt, concrete and areas with highly impermeable materials.

These types of materials cause streets to become large artificial rivers and multiply the destructive power of torrential rains.

The drainage system in conventional cities consists of a network of grates, gutters, underground pipes, storm tanks and systems designed to collect rainwater. The larger the urban area, the more these infrastructures take on pharaonic dimensions.

In many cities there are large drainage networks to collect rainwater. These systems allow the initial rainwater, which could have a significant pollutant load, to be stored. This is due to the waste that accumulates on the ground, such as pollution, fuel spills, rubbish and a large number of particles that are carried along with the rainwater.

The treatment and decontamination of this water before it is returned to river courses is one of the greatest challenges facing many cities around the world. Proper management of rainwater and its subsequent treatment are essential to ensure the protection of riverine ecosystems, both as they pass through cities and in the river basins downstream.

One solution to these major challenges arising from urban stormwater management is known as Sustainable Urban Drainage Systems. These are superficial, permeable elements, preferably vegetated, which form part of the urban-hydrological-landscape structure and precede the sanitation system. They are designed to filter, retain, transport, accumulate, reuse and infiltrate rainwater into the ground, so that they do not degrade and even restore the quality of the water they manage (Ministry for Ecological Transition and Demographic Challenge, n. d.).

> ‘Sustainable urban drainage is being implemented in many cities around the world, such as Portland, Oregon, in the United States, and Vancouver, in Canada. In Portland, more than 500 sustainable stormwater management facilities have been created, including green roofs, permeable pavements, rain gardens, and infiltration trenches. These facilities have reduced the amount of water entering conventional drainage systems and improved water quality in nearby rivers and streams’ (iAgua, n. d.).

Many of these systems are inspired by nature-based solutions and seek to draw inspiration from the behaviour of water in the natural environment and replicate it to a greater extent in urban settings. Its main objectives include improving soil permeability, increasing vegetation cover, creating controlled flood zones, and improving the quality of rainwater discharges into rivers.

Including these systems in urban planning will accelerate their implementation. Furthermore, it is a commitment to the circular economy and improving the quality of life for people living in cities.

These solutions require less investment than conventional urban drainage systems. This is because its installation is more localised and decentralised. Therefore, this investment can be managed by passing on its costs to the developers of future urban units.

Thanks to the increase in vegetation cover in cities, which has significantly increased shaded areas, this could lead to a significant reduction in surface temperature. All of this would lead to a reduction in demand for cooling in summer of approximately 92 TWh/year. This energy saving reduces CO_2 emissions by 29.9 Mt and considers that 0.325 kg of CO_2 are emitted to generate 1 kWh of European electricity (Quaranta *et al*., 2021). This energy saving is equivalent., for instance, to approximately one third of the electrical energy consumed in Spain during 2023.

These data show that increasing vegetation cover in cities will be an effective solution to the climate emergency. In addition, the CO_2 captured by vegetation-covered infrastructure will serve as a drain for this molecule, which has such a significant impact on global warming.

Addressing nature-based symbiotic solutions will drive the resolution of various challenges such as torrential rain management and extreme urban warming during the summer months. In this way, more comfortable places where people can enjoy a higher quality of life are promoted.

Therefore, opening cities' doors to Mother Nature is becoming a magnificent opportunity to address current and future climate challenges. This will encourage urban environments to adapt much better to emerging climate scenarios, providing spaces where people can connect with nature. This will create a new concept where one can live in the shelter of nature.

3 Digitalisation and water in cities

Thanks to digitalisation, it is now possible to check live waiting times for public transport, find out instant electricity consumption, unlock rental vehicles, order food from one's mobile phone, and use a host of other highly accessible tools available to the population in urban environments.

Cities are places where digitalisation is having the greatest impact, both on services and on the people who live there. More and more services are turning to digitalisation to optimise their processes and thus provide their residents with the best solutions for their daily lives.

These developments are revolutionising contemporary urban environments in many of the most technologically advanced countries. Helping to make services accessible is one of the objectives of all these tools created in the digital environment.

The urban water sector is undergoing a rapid transition towards the digitisation of its processes. These improvements will make the management of water resources and supply networks increasingly efficient. All of this will reduce the amount of water wasted during the various processes of the urban water cycle.

On this journey towards digitalisation, a large number of water operators are equipping water infrastructures with state-of-the-art technology. This will drive a new paradigm in water resource management thanks to greater control over critical parameters.

From a holistic perspective, technology will enable more efficient control of water management from its source until it is returned to the rivers. It will also help to find better solutions to new challenges, such as water scarcity and increased demand for water in cities.

Together, artificial intelligence, Internet of Things systems and automation can improve the operational efficiency of drinking water and sanitation facilities. All of this could reduce energy consumption in industrial processes related to both water purification and wastewater treatment.

The digitisation of the urban water sector is creating a favourable environment for developing highly advanced systems. This will help to improve the quality of a basic service for the population.

Thanks to the use of technology, it will be possible to achieve a greater impact on the financing of new infrastructure. This will be possible because infrastructure designed for real needs will be built through studies that analyse empirical data obtained from hydraulic systems.

3.1 Opportunities to create more efficient water infrastructure

Reducing water losses is one of the main objectives of water operators. Water scarcity is prompting efforts to focus on improving the efficiency of drinking water supply networks.

> 'Smart technologies can transform preventive maintenance activities and reduce downtime. Water leaks in drinking water supply networks amount to some 45 billion litres of drinking water per day in developing countries, which is equivalent to hydrating 180 million people' (Richards *et al*., 2023).

Improving the supply network can be achieved through various actions, such as renewal of pipes due to age or obsolete material, integration of monitoring systems (based on the internet of things), creation of digital models based on real systems and development of proactive decision-making applications.

Thanks to the digitisation of water infrastructure, increasingly sophisticated leak detection systems can be developed. This will seek to increase the efficiency of drinking water supply networks, significantly reducing water loss in their thousands of kilometres of pipes.

One of the milestones facing the urban water sector is to implement smart meters in its supply networks. Instantly monitoring both consumption in one's pipes and that supplied to end users will enable one to detect leaks in domestic networks in real time.

From the end user's point of view, energy saving projects can d be achieved in the domestic sphere. Providing users with tools that help them measure their instantaneous water consumption will encourage them to consume water much more responsibly. They will also be able to identify abnormal drinking water consumption in their domestic facilities and thus reduce unwanted losses.

Digital solutions will enable management enterprises to optimise investment in water infrastructure. These new technologies will enable action to be taken in areas that are most susceptible to accidental breakdowns.

Improving the efficiency of water infrastructure will reduce the average flow treated at drinking water treatment plants and wastewater treatment plants. This will represent significant savings in energy and treatment costs.

For all the above reasons, the digitisation of processes will be an important ally in overcoming the current challenges facing supply networks. A smart investment to drive this technological revolution in infrastructure will be the beginning of a more promising future where water resources are much better cared for.

3.2 Autonomous inspection systems

Inspecting a sewerage network gallery involves a high exposure to a multitude of diseases, flooding and even low oxygen concentrations. Many individuals who work inspecting sewerage networks around the world are exposed to these environments on a daily basis.

In towns, there are many kilometres of underground pipes that carry both drinking water and wastewater. The monitoring, maintenance and renovation of these networks are a major challenge for urban water cycle management enterprises, which devote considerable financial and human resources to these tasks.

Drinking water is usually conveyed in sealed pipes, known as pressure pipes, which transport the fluid from the main reservoirs to the taps of end consumers. Historically, inspections have been purely visual, leaving the internal condition of the pipes or any problems in the large areas where they are buried unknown.

However, urban sewerage networks carry water through pipes, galleries and infrastructure where, most of the time, the water does not occupy the entire volume of the pipe. This is known as gravity pipes. Therefore, in these infrastructures, workers periodically carry out internal visual inspections in areas that are known to be visible due to their dimensions.

Technological development and process digitalisation are enabling a major revolution in preventive and predictive maintenance in the urban water sector. It is increasingly common to use autonomous devices that enable inspection tasks to be carried out that were previously impossible, with a level of detail that was unimaginable until now.

In drinking water pipes, thanks to the digitisation of processes, there has been a significant increase in the number of sensors measuring the most important parameters. This has opened up a huge window of opportunity to develop systems for predicting operational anomalies through indirect measurements provided by all the sensors installed in the network.

In addition, autonomous devices have been tested that can be inserted into pipelines, capable of detecting potential leaks and obtaining a digital model of the actual route followed by pipes. All this without affecting the guarantee and quality of this essential service for society.

Focusing on software systems, process automation linked to the potential of artificial intelligence systems is driving a major revolution in the management of the entire urban water cycle. Increasingly efficient systems are being developed that, moreover, quickly anticipate recurring network problems.

In sewerage networks, semi-autonomous systems have been used successfully for many years. The characteristics of these networks have enabled the development of systems equipped with cameras to record the internal condition of the pipes and carry out specific internal repair work. These systems are controlled externally by a specialised technician, similar to a surgeon operating on a patient via laparoscopy.

However, these systems have significant limitations when pipes run through areas that are inaccessible to both the device and the vehicle from which they are controlled. Therefore, technological developments in recent years have enabled the development of new, fully autonomous systems that can reach areas formerly without coverage and where network maintenance personnel have never been able to access.

An example of these autonomous systems are autonomous drones, which are capable of navigating most urban sewer networks. These devices are deployed from an accessible point and travel to another point that may be several kilometres away to carry out their inspection. During this inspection, the team records the entire sewerage system in three dimensions. This makes it possible to obtain a digital twin model of the existing underground network, providing detailed information that will take operators to another dimension of management (Aguasresiduales.info, 2024).

All these autonomous devices have not been developed to replace human labour, but rather to meet pressing needs in order to improve infrastructure management. Furthermore, they have achieved a milestone, as they can inspect areas that were inaccessible with previous technology.

Digitisation is proving to be a great opportunity to raise staff safety standards in the workplace. Reducing people's exposure to particularly hazardous tasks is a guarantee of protection for workers' health.

In the future, the implementation of all these systems will be more widespread. There will be a multitude of devices circulating daily through urban water infrastructures, guaranteeing an exceptional service that is essential for the entire population living in cities.

3.3 Cybersecurity in the urban water sector

Digitisation is bringing about one of the biggest revolutions in the urban water sector in recent decades. The speed of technological penetration was slow in the beginning, but over the years it has increased and, at present, technological implementation is experiencing a high cruising speed.

Digitisation projects are a reality in all sectors of society. The emergence of applications that make life easier for both individuals and businesses is a reality. This highlights that we are facing a new revolution towards a more digital world at all levels.

However, when a movement for transformation arises, it comes with great opportunities and emerging dangers. We have already discussed the opportunities, so now we will focus on the security challenges that the world of digitalisation will face in the urban water sector.

The increased use of technology and digital solutions increases the exposure to cyber-attacks. This increased exposure requires that digitisation be preceded by proper planning of robust security systems that reduce damage in the event of any attack.

We are living in complex geopolitical times, marked by armed conflicts in Ukraine and the Gaza Strip. In recent years, there has been an increase in the number of cyber-attacks against governments and large enterprises around the world, highlighting widespread vulnerabilities in systems that store large amounts of confidential data, both personal and organisational.

The vulnerability of enterprises' cyber infrastructure to attacks can result in high economic and reputational costs. Enterprises across all sectors have experienced an increase in what are known as 'mega breaches', both in number, scale, and cost. The percentage of reports of these attacks costing more than USD one million has increased by 36% in the last three years (PwC Global, 2023).

The greater the percentage of digitisation in enterprises, the greater the budget allocated to developing cybersecurity tools should be. If digital sustainability is desired, this investment is essential for carrying out secure digitisation processes.

Investment in cybersecurity should be the cornerstone of all projects related to digitalisation. Planning system security from the outset will be key to the success and resilience of digital systems. Therefore, cybersecurity must be at the heart of enterprises' planning in this new digital era.

4 Water regeneration as a key element for economic growth

As discussed throughout this chapter, one of the most pressing problems in cities is population growth and the increase in demand for drinking water, both domestic and industrial.

Throughout human history, the growth and economic development of cities have been linked to the availability of water resources. Therefore, securing an alternative source of water resources is a path to growth for areas experiencing significant water stress issues.

In this search for alternative sources of water resources, various technologies have been developed over the years. These have become known as unconventional sources of water resources, and the most widely used technologies to date have been seawater desalination and wastewater regeneration through purification processes.

This section shall focus on evaluating the potential of treated wastewater. This resource is available in all urban centres across the globe and has great potential to mitigate water scarcity scenarios in numerous regions. 'Treated wastewater is water that, where necessary, has undergone additional or complementary treatment to bring its quality into line with its intended use' (Spain, 2007).

The most widespread uses of reclaimed water are:

- Urban: watering parks and gardens, flushing sanitary facilities, cleaning sewers and streets, etc.
- Industrial: cooling system or process and cleaning water.

- Recreational: ornamental water systems such as fountains, golf course irrigation, etc.
- Environmental: maintenance of wetlands and minimum flows or recharge of aquifers and groundwater.
- Agricultural: irrigation of pastures and crops.

However, the use of treated wastewater water is prohibited in many applications, such as:

- Human consumption (except in the event of a disaster).
- Most uses for the food industry.
- Use in hospital and similar facilities.
- Farming of filter-feeding molluscs in aquaculture.
- Bathing water.
- Use in fountains and ornamental pools with public access to the water.

The wastewater that arrives at treatment plants is taken advantage of for various uses in the urban environment, such as watering parks and gardens, street washing, vehicle cleaning, industrial water use, etc. The use of this resource offers cities located in areas with evident water stress a magnificent opportunity for growth.

Around the world's largest population centres, there are major industrial hubs that need to meet a high demand for water. Therefore, using treated wastewater to meet this demand can drive economic growth in regions suffering from significant water stress.

Many cities in inland areas face recurring water shortages, and the management of available water resources is vital to their economic development. Thanks to water regeneration, these cities will be able to reduce their consumption of drinking water for urban, industrial and agricultural uses.

Although domestic use accounts for approximately 10% of freshwater demand (UNESCO, 2024), at least half of industrial water demand could be met with treated wastewater, and even domestic demand could be met, provided that legislation allows it.

To achieve this, legislative changes would need to be made in many regions around the world, allowing for more widespread use of treated wastewater.

Furthermore, one of the greatest challenges facing the population is management through dissemination, in terms of the safety of using reclaimed water. This shows the population that this water meets the minimum quality requirements covered by applicable legislation.

For many people, it is conceptually difficult to use wastewater for everyday or domestic purposes, even if it complies with all legal health and safety requirements. This is one of the main obstacles to expanding the use of treated wastewater worldwide.

The use of treated, reused or recycled water is a strategic opportunity that many countries should consider and include in their policies in order to ensure the sustainable development of their urban environments. In doing so, they will promote safer urban, natural and social environments for their inhabitants.

4.1 Treated wastewater for human consumption

Using treated wastewater for human consumption is a survival alternative for many regions around the world. Water scarcity is prompting many cities to consider developing plans to supply drinking water to their populations using this unconventional resource. Although it was first used over sixty years ago in Windhoek, this solution has been implemented in very few regions.

In 1968, the city of Windhoek, capital of Namibia, was the first in the world to supply its population with treated wastewater suitable for human consumption. This alternative made it possible to treat wastewater, largely mitigated water scarcity in the region, and ensured greater water resilience for the city (Durán Ramírez, 2018).

> 'Due to the lack of rainfall, most rivers flowing through Namibia tend to have very low flows and are dry for many months of the year. Only during the summer months, and after experiencing intense storms typical of the season, do rivers carry a more constant flow of surface water. For this reason, most water demands are met mainly by groundwater' (Durán Ramírez, 2018).

This water situation prompted an inland city to opt for an unconventional resource as an alternative to its structural water shortage. This is a cutting-edge solution that continues to inspire the search for solutions in cities suffering from severe water stress. The city of Windhoek is a great example of how to overcome an adverse water situation.

With the turn of the millennium, Singapore and Australia ventured to promote projects that would use treated wastewater for drinking purposes. The first of these is a small country that depends mainly on water resources that are not within its territory. On the contrary, Australia is a vast country that has little annual rainfall in many regions and has suffered severe droughts, such as the one that occurred between 2000 and 2009, known as *the Millennium Drought*.

Wastewater treatment plants were built in both countries, capable of producing water of a quality suitable for human consumption. Singapore developed a project called NeWater and, since 2002, has continued to focus on increasing its water regeneration capacity. However, the Australian authorities have not yet committed to treating wastewater for human consumption.

In 2020, the Drought Emergency Plan for Catalonia was approved in Spain. This plan introduced the use of treated wastewater as an indirect source prior to its purification. To do so, a drought emergency must be declared and the reservoirs in the Ter-Llobregat basin must be below 25% of their water storage capacity (Generalitat de Catalunya, 2020).

During 2023, laws were passed in the States of Colorado and California to regenerate wastewater and supply it to the population. This was caused by the persistent droughts that both US States had been suffering for years. Furthermore, this new legislation opened up the possibility of widespread aquifer recharge.

The State of Colorado was the first in the United States of America to pass legislation that provided for the supply of treated wastewater to the population. This regulation was preliminarily approved in autumn 2022 by the Water Quality Control Commission as part of the State’s main provisions on drinking water (Colorado Department of Public Health & Environment, 2023).

Subsequently, the State of California passed a law that also provided for supplying the population with treated wastewater. Although many water management entities have used this resource for decades for irrigation, industrial uses, and aquifer recharge. This regulation sought to ensure that treated wastewater supplied to the population met all public health standards (James, 2023).

Another milestone achieved during that year was the launch of the treated wastewater system to indirectly supply the population in the Spanish region of Catalonia. This scenario led to up to 25% of the flow treated by Barcelona's main drinking water treatment plant being discharged into the Llobregat River (iAgua, 2023). This marked a turning point for the use of treated wastewater in Spain, where regulations do not allow treated wastewater to be used for human consumption; this is the first time this unconventional resource has been used to indirectly supply the population.

In order to achieve the milestone of supplying the population with treated wastewater, several barriers must be overcome, such as educating the population to raise awareness that treated wastewater is a safe resource for health and constructing new facilities to increase the availability of this resource in cities.

Treated wastewater is becoming a viable, effective, and safe solution for urban environments suffering from water shortages. Therefore, planning the construction of facilities that can mitigate their water deficit will be an important way to guarantee the supply to the population of these cities.

4.2 Singapore: a success story in water regeneration

Being one of the world's leading commercial and financial centres does not guarantee unlimited access to water resources. Singapore is heavily dependent on its neighbour (Malaysia) for water management, importing more than 30% of its drinking water from this country.

> 'The City-State is the smallest country in Southeast Asia. It has a population of around 5 million inhabitants, covers an area of approximately 720 km^2 and consists of more than 73 islands. It is one of the countries with the highest GDP per capita and has the second most important port in the world in terms of goods management' (Perero, 2016).

The City-State's drinking water supply depends mainly on the Johor River. This river is the main river in the Malaysian State of Johor. It is 123 km long and is framed by a basin of approximately 2,636 km^2. The entities that manage this water source are Syarikat Air Johor, SAJ (or Johor Water Company) and the Public Utilities Board (PUB) of Singapore.

> ‘Currently, around 30% of the water supply comes from neighbouring Malaysia under a contract that runs until 2061. another 30% comes from the 17 reservoirs that have been built, with almost no possibility of expanding their number and capacity, 10% of the water comes from desalination and the rest, around 30%, from reused water’ (Perero, 2016).

Since its expulsion from the Republic of Malaysia in 1965, the political relationship between the City-State and the country has experienced some friction, with water being a subject of dispute. Various agreements were signed that guaranteed part of the drinking water supply. Some of them are currently in force.

To understand this geopolitical conflict related to water, it is important to be aware of the water management agreements signed throughout the 20th century by the governments of Singapore and Malaysia.

The Agreements signed to date are as follows (Flora, 2021):

- 1927 Agreement. It was signed on 5th December 1927 by the Municipal Commissioners of the City of Singapore and Sultan Ibrahim II, the Sultan of Johor. Singapore was permitted to lease an area of 8.5 km^2 of land in Gunong Pulai, in the Malaysian State of Johor, for the supply of raw water. For its part, Johor could have access to treated drinking water from Singapore. This Agreement is no longer in force.
- 1961 Agreement. The Federation of Malaya signed an agreement on 1st September 1961 granting Singapore the right to draw raw water from the Pontio Reservoir and the Tebrau, Skudai and Gunung rivers. In return, Singapore was to supply Johor with 12% of the water extracted on a daily basis. This Agreement expired without renewal in 2011.
- 1962 Agreement. On 29th September 1962, an Agreement was signed allowing Singapore to draw water from the Johor River. This Agreement, which is currently in force until 2061, was revised in 1986 and 1987.
- 1965 Agreement. On 9th August 1965, the Agreement for Singapore’s separation from Malaysia was signed. This Agreement included a guarantee of compliance with the Agreements signed in 1961 and 1962. A document was submitted to the UN to ensure that neither party would breach the Agreement on water, despite their governmental friction.

- 1990 Agreement. Signed on 24th November 1990 by the Singapore Public Utilities Board and the Government of Johor, it supplements the Agreement signed in 1962. This Agreement allowed Singapore to build a dam at Sungei Linggiu to draw water from the Johor River. Singapore assumed all the costs of construction and maintenance for the project. This agreement is valid until 2061.

In August 2002, Singapore's public utility company launched a strategic project called NEWater. The main objective was to transform wastewater into a new source of water for supplying the City-State.

> 'From then until 2022, the commitment to using treated wastewater increased until it met 30% of demand. To produce this resource, Singapore built several water treatment plants, in Bedok (2002; 82,000 m^3/day), Kranji (2002; 100,030 m^3/day), Ulu Pandan (2007; 148,000 m^3/day) and Changi (2009; two plants with 228,000 m^3/day). In addition, there are plans to expand one of these plants (Kranji, with an additional 22,730 m^3 day) and build a new one (Tuas) with a capacity of 228,000 m^3/day' (Perero, 2016).

One of the major barriers faced has been raising public awareness about the safety of this resource. They have created numerous campaigns to inform the public about its safety for consumption. One of these involved distributing numerous bottles of NEWater over the last few decades in order to improve its acceptance by society.

Since its inception, a NEWater Visitor Information Centre has been built, which has won several awards. This centre has developed various educational and scientific programmes for students, open classrooms, and the creation of water ambassadors, etc. (Perero, 2016).

One of the country's objectives for 2060 will be to be able to meet 55% of water demand during that year. It should be noted that industrial water demand will increase in the coming decades, mainly due to the growth of industries in the country and their demand for water.

Singapore's determination to gain water independence from Malaysia is providing the world with a real-life example of the opportunity offered by an unconventional resource such as treated wastewater. Furthermore, this resource is available to all urban environments and guarantees a circular economy.

4.3 Treated wastewater water for cooling large data centres

A conversation with ChatGPT, consisting of twenty to fifty questions, consumes approximately five hundred millilitres of water. If the prior training of the artificial intelligence model is taken into account, consumption will rise to seven hundred thousand litres of water (Shanji *et al*, 2023).

With the emergence of artificial intelligence systems and their widespread use, the demand for water to cool data centres is expected to increase. Therefore, this new paradigm must be taken into account in planning so that alternative water sources can be found to meet this growing demand.

The digitisation and artificial intelligence models require large amounts of water to cool their data centres. The democratisation of the use of artificial intelligence algorithms is driving rapid growth in the number of users of this technology worldwide. To this end, the construction of data centres and their water consumption for cooling purposes is increasing.

Furthermore, the manufacture of the components that make up these data centres requires significant water consumption. This indicates that irresponsible use of artificial intelligence models could pose a significant risk to the global population's access to drinking water.

It is estimated that the annual water consumption for cooling Google's data centres in 2022 was 21 hm^3 (Google Sustainability, 2023). This volume of water could have supplied approximately 432 633 people for one year (INE, 2024).

In order to avoid the displacement of drinking water for the population, the question arises of using treated wastewater produced in the cities' treatment plants. This resource could be an alternative source of water for future data centres.

Using this unconventional resource will prevent the increased overexploitation of aquifers and ensure greater water availability for the population. Thanks to regeneration, the supply to the population will not be put at risk and its wastewater will provide a key resource to meet the growing needs of data centres.

This resource will provide them with independence from water stress scenarios and promote increased resource utilisation efficiency. It will also bring these facilities closer to large population centres, further optimising telecommunications networks.

If nothing is done, the growing demand for water from data centres will conflict with the population's demand for drinking water. In areas with high water stress, these tensions will lead to drastic measures that will compromise the economic and technological growth of these regions.

5 Challenges and opportunities. The urban water horizon

Urban water faces the major challenge of effectively managing the increase in demand for drinking water, linked to population growth in cities, in the coming decades. This will lead to increasing water shortages in cities, and available water sources will be unable to meet urban water demand.

The climate crisis will also put all water infrastructure in urban environments to the test and could cause severe droughts and torrential rainfall events. These challenges must be taken into account in urban planning and water management in cities worldwide.

Geopolitical scenarios with growing tensions will be a key factor that could lead to unfavourable scenarios for solving the water challenges faced by cities in many parts of the world. If global action is not taken, there will be a large number of towns with chronic water problems that will significantly limit their social and economic growth.

Opening our cities' doors to Mother Nature will significantly increase their water resilience. Implementing nature-based solutions will help build healthier environments for the people who will live in cities.

Furthermore, global financial challenges will test the adaptation of urban environments to new water scenarios. Obtaining the money to undertake the construction of the necessary water infrastructure will make adaptation considerably more difficult.

Digitisation will be an opportunity for the sector and will drive new, more efficient management models. However, it will significantly expose water infrastructure to cyber-attacks, so cybersecurity will emerge as a vital element in the sector's transformation to the new digital era.

Treated wastewater stands out as one of the key resources for tackling new urban water scenarios. This unconventional resource, available to all cities around the world, will be a vital element for regions with chronic water stress that wish to continue their social and economic development.

Another great opportunity will emerge from the transformation of people's habits in the domestic sphere. There is potential for savings linked to reducing the use of drinking water for purposes that do not require it, such as: toilet flushing, watering plants, cleaning floors, etc.

The global urban water sector is facing one of its greatest opportunities. Therefore, it must take a step forward before institutions and society to assert that it represents an essential link in the chain for generating peace and prosperity.

There is still much work to be done. Institutions must work to involve society as a key player in transforming cities' relationship with water. Without the joint efforts of institutions and societies, the emerging challenges in the urban water sector will never be overcome.

There will be no single solution to adapt to the new water scenarios. The solutions must be based on three fundamental pillars: innovation, creativity and cooperation between countries. The world must be identified as a large set of ecosystems shared by regions that must collaborate in the conservation and survival of these sources of life.

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Chapter Three

Water Management in Refugee Camps

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Abstract

Data from UNHCR indicate that around 120 million individuals worldwide were forced to flee their homes. In 2024, some 35 million individuals became refugees. 22% of the refugee population, 6.6 million individuals, live in refugee camps, which are designed as temporary solutions to provide immediate assistance and protection during specific emergencies, although they can sometimes last for years or even decades. Among the essential services provided in the organisation of refugee camps, one of the fundamental aspects is water cycle management, which guarantees the supply of drinking water, sanitation and hygiene and prevents the spread of disease. Water supply during emergencies must be carried out based on a project with clearly defined objectives, aimed at improving a situation that affects a specific group of people, a specific place and time, and limited resources. The search for nearby and available sources of water, both surface and growndwater, taking into account both quantity and quality, becomes a primary task from the very beginning of site management.

Keywords

Emergency, Refugee camp, Water supply, Sanitation.

Introduction

According to data from the United Nations High Commissioner for Refugees (UNHCR, 2022), 108.4 million people worldwide were forced to flee their homes due to persecution, conflict, violence or human rights violations. Of these, 35.5 million were refugees, 62.5 million were internally displaced, there were 5.4 million asylum seekers and 5.2 million people in need of international protection. Based on its operational data, UNHCR estimates that the number of displaced persons rose to 117.3 million in 2023 and may even have reached 120 million in 2024.

To these figures must be added the displacement caused by natural disasters, which in the last decade accounted for an average of 24 million displaced persons per year, 92% of which were caused by climate conditions, especially floods (in 2023, they caused 9.8 million displaced persons), and the rest due to geological hazards such as earthquakes.

Today, there are more refugees and internally displaced people than at any time after the Second World War.

Twenty-two per cent of the refugee population, some 6.6 million individuals, live in refugee camps. Among them, 4.5 million reside in organised and managed camps, while two million live in self-settled camps.

Refugee camps are temporary facilities built to provide immediate assistance and protection to people who have been forced to flee their homes and are seeking a safe haven (UNHCR, 2022).

They are initially designed as a short-term solution to keep the population safe during specific emergencies, but situations can drag on and cause people to live in them for years or even decades.

Initial services provided during an emergency include access to water and food, shelter, sanitation services, emergency relief items (blankets, mats, mosquito nets, clothing and personal hygiene kits), healthcare, registration services and legal assistance.

In situations of protracted displacement, these services are expanded to include education, livelihoods and materials to build more permanent housing to help people rebuild their lives and achieve self-sufficiency.

The services provided in refugee camps are often also offered to host communities. A well-organised camp should offer people the opportunity to build links with their host communities and have access to the local economy, infrastructure and services.

The UN Refugee Agency prefers alternatives to refugee camps that can offer refugees more opportunities to live independently and find employment. However, refugees living in urban areas also face significant challenges. They are often forced to live in substandard housing, such as public buildings, collective centres and other types of informal settlements.

UNHCR data from 2022 indicates that there are 420 refugee settlements and camps worldwide, spread across 126 countries, 76% of which are middle- and low-income countries.

The Kutupalong refugee settlement in the Cox's Bazar region of Bangladesh is currently the largest in the world. The settlement consists of twenty-six camps housing more than 800,000 Rohingya refugees who fled violence in Myanmar's Rakhine State, more than half of whom are children.

Other camps hosting large numbers of refugees include Kakuma, Dadaab and Hagadera in Kenya (with refugees from Somalia, South Sudan and other neighbouring countries), Zaatari and Azraq in Jordan (with Syrian refugees), Bidi Bidi in Uganda (with refugees from South Sudan) and Um Rakuba in Sudan, which is responding to the growing crisis in the Ethiopian region of Tigray. Due to their prolonged existence, mention must also be made of the Sahrawi refugee camps in Tindouf (Algeria), which since 1975 have been home to some 174,000 people living in very harsh conditions. In recent times, conflicts such as those in Palestine and Ukraine have led to a significant increase in the number of refugee camps.

Among the essential services that must be provided in emergencies, and specifically in the organisation of refugee camps, one of the fundamental aspects is water cycle management, which guarantees the supply of drinking water, both in terms of quantity and quality, as well as sanitation and hygiene, and prevents the spread of disease. This chapter focuses on this issue.

I would like to thank Miguel Martín Loeches, Antonio Bolinches and Fabio Fussi for their valuable contributions to the seminar *Water, a strategic resource in emergency situations: Reason for conflict or catalyst for cooperation?* from the Admiral Juan de Borbón Chair of Defence Studies, which have served to enrich this chapter.

1 Water in emergency situations

In humanitarian crises, water is not only a necessity, but also a right (on 28th July 2010, the United Nations General Assembly adopted a resolution recognising 'the right to safe drinking water and sanitation as a fundamental human right') and a technical challenge.

The right of human beings to have sufficient, healthy, acceptable, physically accessible and affordable water for personal and domestic use requires access to a water source, a source of energy, water treatment and technical personnel to facilitate this (UN Committee on Economic, Social and Cultural Rights, 2002; United Nations, 2010).

Water supply in emergencies must always be carried out on the basis of a project or unit of action, i.e. an intervention aimed at improving a situation identified as problematic, affecting a specific group of people, pursuing specific objectives, in a specific place, through actions aimed at achieving them, within a specific time frame and with limited resources.

Water, essential for life and health, is often unavailable in sufficient quantity or quality in emergency situations. The supply of this commodity requires immediate attention from the outset of an emergency, as it is possible to survive longer without food than without water.

The objective in these cases is to obtain sufficient quantity of water of the highest quality for refugees and to meet community needs in the most cost-effective manner.

Sometimes, achieving quantity and quality in the short term is a complex task, which is why a series of response principles have been defined (UNHCR, 2022): hence prioritise quantity, but respect quality; when selecting and planning the location, it is essential to take into account that water supply must be coordinated with measures relating to space organisation, public health and sanitation; whenever possible, water treatment should be avoided and priority given to sources of supply that do not require it; reserve mechanisms should be sought to deal with unforeseen events or an increase in the arrival of refugees; it should be borne in mind that seasonal changes can affect both the quantity and quality of water and the healthiness of the camp in the event of flooding.

When managing water in refugee camps, there are certain measures that are to be taken into consideration from the outset like calculating water requirements for drinking, hygiene and sanitation, and assessing possible nearby or available sources of supply; making an inventory of all water sources, both surface and groundwater, and assessing each one in terms of quality and productivity; protecting water sources from contamination and obtaining sufficient quantities of good quality water- water sources must be completely separated from sanitation facilities and other possible sources of contamination-; improving access to supplies and build supply points and a storage and distribution system to distribute sufficient quantities of good quality water, including a reserve supply; carrying out periodic water quality analyses, etc.

If the available water sources are inadequate, measures must be taken to find others and, if necessary, to transport the water to the site.

Given that it is difficult to predict the lifespan of a refugee camp, it is best to plan for long-term cost-effectiveness.

Local authorities should participate and be involved in the assessment, as it is essential to know the terrain, local conditions and to bear in mind that rivalry may arise between refugees and the local population over water supply resources.

The technology and equipment used must be simple, reliable, appropriate and well known in the country. Refugees should be involved, their skills utilised and trained to take responsibility for the operation and maintenance of the system.

When assessing water resources, an analysis of the terrain should be included, bearing in mind that there may be advantages (gravity distribution can be exploited if the source is topographically elevated) and disadvantages (pumps may be required if the water source is located at a lower elevation than the camp). It is additionally an important consideration in terms of potential flooding problems at the site. Although decisions must be made quickly under the pressure of dealing with a humanitarian emergency, it is customary to choose areas with slight slopes (minimum gradient of 2%) for settlement in order to prevent water accumulation, thus promoting natural drainage and protecting the area from flooding.

Among the most important aspects to be taken into consideration is the family of six to eight individuals as a distribution unit, for which internal enclosures must be provided. The space requirements should be approximately 30 to 45 m^2 per person, of which 3.5 to 4.5 m^2 per person should be covered.

Fire prevention plans must be in place, such as firebreaks measuring thirty metres for every three hundred metres of construction and a minimum of two metres (preferably twice the height of the structure) between accommodation units. Flood prevention plans must also be in place.

Other criteria for site selection include good access (roads, ports, airports) and adequate security conditions.

1.1 How to initiate an intervention: the use of questionnaires

Before starting the project of building a refugee camp, it is necessary to investigate the initial conditions in a quick and organised manner. The first step should be to define water, hygiene and sanitation needs, by experienced and well-trained personnel. Efforts should be made to obtain available information on the situation, including determining the risks to public health, water supply possibilities, basic sanitation needs and deficiencies, and the hygiene circumstances and customs of the affected population. This information will form part of an initial action plan to be used by those responsible for seeking funding.

To obtain this primary information, questionnaires are conducted to collect a wide variety of data (Sphere Association, 2018; Médecins Sans Frontières, 2010):

- Geographical information (topographical, geographical, hydrological and demographic maps, satellite or aerial photographs).
- Climate conditions (temperature, precipitation, winds, etc.).
- Political and social organisation.
- Regional development and activity (existence of industry, agriculture, natural resources, etc.).
- Existing emergency plans (from the government, NGOs, agencies, and other actors).
- Other humanitarian actors working in the field (assess their capabilities, available materials and previous experience).
- Regional data and observations (vegetation, water sources, settlements, roads, vulnerability to natural disasters, security, etc.).

– Information on existing settlements (population density, area profile and drainage, sanitation infrastructure, etc.).
– Water requirements (people, livestock, health centres, infrastructure).
– Water container requirements (possibilities for transporting and storing water).
– Basic sanitation infrastructure requirements.
– Logistics and locally available resources (materials, human resources, access for loading and transport, local construction techniques, local treatment methods, etc.).
– Physical data on water sources (name of source, type, location, water table, design and dimensions, estimated flow rate, water quality [turbidity, temperature, pH, etc.], risk of contamination).
– Legal, safety and socio-cultural aspects (owner of the source, land titles, prior agreements for its use, fees, access, safety, treatment permits, etc.).

Under international law, a declaration of emergency or a request for assistance from the local government is required in order to initiate interventions.

Information can be obtained directly or indirectly (López and Schiffer, 2012). Direct sources include personal observations, taking notes and photographs; aerial inspection by manned flights, use of drones or observation from elevated positions; observations made during walks, randomly crossing sectors of areas or neighbourhoods (cross-sectional walks); discussions and interviews (structured, with questionnaires, or improvised) with special interest groups that handle key information, such as women, the elderly, local authorities, children, teachers, health personnel, etc.; and measurements, analyses, tests, or counts (water analysis, excavations to detect the water table and soil composition, areas of open defecation, etc.).

Indirect sources are based on documents, reports and maps that existed prior to the disaster, such as vulnerability studies, project reports, assessments by counterparts, etc.; contingency plans, EPP (Emergency Preparedness Plan); information on the Internet (such as disaster response pages), press, television; situation reports or rapid assessment reports already produced by other organisations or agencies; reports and data transmitted at WASH

Cluster (Water Sanitation Hygiene, led by UNICEF) meetings, ministries, agencies, etc.

Rapid assessment questionnaires require as comprehensive a list of contact persons as possible and a sketch of the location/camp of displaced persons, including the approximate location and distance from water sources, latrines or defecation areas, health posts, nutrition centres and other relevant structures.

The items to be analysed in this preliminary study must consider general aspects and others related to water supply, sanitation (excreta disposal, vector-borne diseases, solid waste disposal, drainage and sewers) or hygiene promotion.

Among the general aspects, it is important to consider the number and location of those affected, possible displacement, factors relating to the safety of both those affected and those providing assistance, which water- and sanitation-related diseases may pose a threat, who should be consulted, who is vulnerable, and what safety risks women and adolescents are exposed to.

With regard to aspects related to water supply, it is necessary to know the current source of water and the amount available per person per day, how often (daily or weekly) the water is distributed, whether it is sufficient to meet short—and long—term needs, how far away the water collection points are and whether they are safe, and whether users have containers of the appropriate size and type for collecting water. It is also important to know whether the water source is contaminated or at risk of contamination, and whether treatment or disinfection of the water is necessary and, if so, what type would be required. Likewise, it is necessary to ascertain whether there are other sources of water nearby and whether there are any obstacles to the use of the available sources. If water sources are insufficient, the possibility of relocating the population to another location or storing water in tanks should be investigated. It is also necessary to know which institution is responsible for the water system and for repairing it if it fails, the cause of the failure, whether or not there are plans to restore it to working order, when and by whom, as well as the possible cost of repair and the estimated time required.

Sanitation-related aspects (excreta disposal, vector-borne diseases, solid waste disposal, drainage and sewers) are extremely important in the design of a refugee camp.

With regard to excreta disposal, questionnaires should ask about current defecation practices, whether this is done in the open, whether there is a designated area and, if so, whether it is safe. Whether facilities exist, whether they are used, whether they are adequate or function well, and whether it is possible to expand or adapt them. It is also important to know whether defecation can pose a threat to water sources, living areas or human health. On the other hand, it is necessary to know whether the population is familiar with the construction and use of latrines or whether individuals are prepared to use latrines, open-air sites, ditches, etc., and whether there is sufficient space for open-air defecation areas, pit latrines, etc. Current beliefs and practices, including gender-specific practices, should also be considered.

On another level, it is necessary to know the slope of the terrain, the depth of the water table, and whether the soil characteristics are suitable for on-site excreta disposal. When designing latrines, consideration must be given to the materials available locally.

Regarding hygiene, consideration should be given to whether current procedures for excreta disposal encourage the presence of vectors, whether individuals have access to soap and water for hand washing after defecation, whether materials or water are available for anal hygiene, and how women are to deal with menstruation-related issues.

With regard to vector-borne diseases, the risks and severity of these diseases should be investigated; whether the risks are high; whether there are possibilities for individual protection, especially for individuals exposed to a higher risk; whether it is possible to modify the local environment (through drainage works, clearing, excrement disposal, waste disposal, etc.) to prevent the reproduction of vectors; whether it is necessary to combat vectors by chemical means and whether there are programmes, regulations and resources for vector control.

About solid waste disposal, we must ask ourselves whether it constitutes a problem, how it is to be disposed of, what type and quantity is produced, and whether it is possible to dispose of it on site or whether it must be collected and disposed of off-site. It is also important to know whether there are medical facilities and practices that produce waste, how it is disposed of, and who is responsible.

Furthermore, it is necessary to determine whether flooding is a problem in the area; what the situation is like, how existing drainage systems work and are maintained; whether there are drainage problems, such as flooding of shelters and latrines, vector breeding sites, contaminated water that pollutes living areas or water sources; and whether individuals have the means to protect their shelters and latrines from local flooding.

Concerning data on hygiene promotion, consideration should be given to the water and sanitation practices that the population was accustomed to before the disaster, which practices are harmful to health, who engages in them and why, who continues to have positive hygiene habits, what enables them to maintain these habits and what motivates them; what are the advantages and disadvantages of a proposed change in habits; what are the formal and informal channels of communication and dissemination (community health workers, traditional birth attendants and healers, clubs, cooperatives, churches, mosques, etc.); whether there is access to the media in the area (radio, television, video, newspapers), what media or non-governmental organisations (NGOs) are in the area, which sectors of the population should be targeted (women, mothers, children, community leaders, community kitchen staff, etc.), what kind of dissemination system would work in this context (volunteers, health clubs, committees) to ensure immediate and medium-term mobilisation; what needs to be learned by staff and volunteers involved in hygiene promotion, what non-food items are available and which ones meet the most urgent preferences and needs; Finally, how effective are hygiene practices in health facilities (particularly important in the event of epidemics)?

2 Drinking water supply: quantity

The assessment of water resources for human consumption aims to determine the availability of water, both in terms of quantity and quality, in relation to demand.

The assessment of the water supply should identify potential water sources, and it is important to conduct an immediate, on-site assessment of local water resources based on needs.

What is the amount of water required, the demand?

Water supplies in the construction of a refugee camp vary depending on the situations that need to be addressed.

The minimum survival allowance in the initial phase of an emergency is considered to be 5-7 litres per person per day, although this should be increased as soon as possible to 15-20 litres per person per day when the situation becomes less critical (table 1).

Community needs and reserve capacity in anticipation of new arrivals should be added to these figures. On the other hand, minimum water requirements increase with ambient temperature, physical exercise, or social and cultural norms (table 2). It should be noted that the minimum amount of water recommended by the WHO is 100 litres per person per day.

Population needs (litres per person per day)				
AGENCY	**Sphere**	**UNHCR**	**WHO/MSF**	**Oxfam**
Acute phase	15	7	5	9
Recommended	15	15	15	15-20

Table 1

Basic water requirements for human survival (Sphere Association, 2018)		
Requirements to ensure survival: water consumption (for drinking and use with food)	2.5-3 litres per day	Depends on climate and individual physiology
Basic hygiene practices	2-6 litres per day	Depends on social and cultural norms
Basic cooking requirements	3-6 litres per day	Depends on type of food, social and cultural norms
Basic requirements: total amount of water	7.5-15 litres per day	

Table 2

When supplying healthcare centres, requirements increase to 40-60 litres per patient per day, although for hospital use, supplies should guarantee around 200 litres per inhabitant per day (table 3).

Service requirements (litres per person per day)	
Health posts	5
Health centres	40-60
Hospitals (laundry)	220-300
Nutritional centres	20-30
School with facilities	10-15
Large livestock	20-30
Small livestock	5

Table 3

If there are animals at the camp, in the case of cattle, thirty litres per day per head are required (table 3).

In addition, there are usually other collective services such as watering vegetable gardens and crops planted by refugees or building camp infrastructure that requires water. The better the camp conditions, the greater the water requirements and consumption.

Water availability is also a determining factor in the choice of sanitation systems. Pit latrine systems do not require water, but shower facilities, laundry facilities, and flush toilets do.

Among the recommendations of the UN programme, Water for Promotion and Communication within the framework of the Decade (UNW-DPAC) (United Nations, 2024), it is indicated that the maximum distance from any home to the nearest water supply point is to be no more than one thousand metres, and that the time required to collect water at a supply point is not to exceed thirty minutes. In addition, there must be at least one water point for every two hundred and fifty individuals (table 4).

Access/distance and quantity of water	
Maximum distance to water source	50 m
One water point for every	250 individuals
Minimum flow rate at the water point	0.125 litres/second

Table 4

2.1 Sources of water supply

The main natural sources of fresh water are surface water, groundwater, and rainwater. The latter two are usually of better quality than water from rivers, lakes or reservoirs, and should be used whenever possible.

When choosing between several possible sources of supply in an emergency situation, aspects such as the speed with which the supply can be put into service must be taken into account; the volume of water it provides; the security of the supply; water purity, contamination risks and ease of treatment; the rights and well-being of the local population; the simplicity of the technology and ease of maintenance; and cost (Sphere Association, 2018).

Surface water sources require less energy, but the amount available throughout the year can vary due to seasonality, and they are exposed to contamination. Groundwater sources require more energy the deeper they are, but they are more stable in terms of quantity as they are less subject to seasonal variations and require less treatment.

Surface water from streams, rivers, ponds, lakes, reservoirs and shallow wells is rarely safe to drink. It usually contains high levels of turbidity and is likely to be microbiologically contaminated. Therefore, treatment measures are often necessary before it can be used directly. These measures can be difficult to plan and implement during most refugee-related emergencies. Despite this, in many cases, the supply comes from surface sources because emergency interventions require large quantities of water to be supplied in the shortest possible time, and obtaining groundwater requires a long time.

Rainwater can be collected using simple systems, under roofs and gutters. It can only be used as a primary source of supply in areas with regular rainfall and facilities for household storage, so it is not usually a good solution in most emergencies, although it can be a useful supplement for individual consumption at times when other types of water are abundant but unsafe.

The use of groundwater is almost always the best solution, as it is usually the most cost-effective way to quickly obtain the necessary quantity and the best quality. However, the decision to use it for long-term needs should be made after a detailed assessment of aquifers and factors related to water recharge, flow, and discharge.

In contrast to surface water, which is often polluted, groundwater is filtered by the soil and rocks that make up the aquifers in which it is stored, and from which it is extracted.

Springs are the best source of groundwater supply, and it is essential to protect them from contamination. If it is not possible to meet demand with springs, the best option will be to extract groundwater through tunnels or wells, by digging or drilling into the ground. The method chosen will depend, above all, on the depth of the water table, the type of rock and the availability of the necessary equipment. Thanks to specialised drilling machinery, it is now possible to extract groundwater from very deep underground, protected from surface contamination.

Without a proper study of groundwater resources, there is no guarantee that new wells or boreholes will produce the necessary quantity or desired quality of water. Furthermore, this can be expensive. A hydrogeological study must be carried out before undertaking a drilling plan (figure 1). Such hydrogeological exploration should enable the location of aquifers from which water can be obtained in sufficient quantity and of adequate quality for the intended purpose.

Figure 1. Supply from a well in the Sahrawi refugee camps in Tindouf (Algeria). Own image

Hydrogeological exploration of a region usually begins with unconsolidated deposits such as gravel or sand, which are easy to excavate and drill and essential in emergencies. Given that these materials typically fill depressed areas, the water table is usually shallow, requiring minimal pumping elevation and thus saving energy costs. These materials are usually easily replenished from rivers and lakes, have good storage capacity and high permeability, although they are also more vulnerable to contamination.

The capacity to store and transmit water from aquifers depends on the type of lithology or rock that forms them, ranging from sand or gravel to fractured rock. The sizes of aquifers also vary, ranging from a few hectares to thousands of square kilometres. Another aspect is the depth at which the aquifer is found, ranging from very shallow levels to hundreds of metres, and whether it is covered by impermeable rock materials.

Water from shallower wells (around five metres deep) is to be considered surface water and may be contaminated, meaning that it needs to be treated. Most traditional dug wells extract water from shallow aquifers.

Wells deeper than ten metres usually require a pump (manual or motorised) to raise the water.

In all cases, a well must be constructed with a sanitary seal and a cover to prevent contamination entering from the surface.

The quantity and quality of water from a well must be ensured in the long term through a comprehensive project that includes proper construction and maintenance (Médecins Sans Frontières, 2010).

Before digging a well to supply water in an emergency, the natural recharge capacity of the aquifer must be calculated to ensure sustainable use of the resource. In many cases, the construction of a well can attract other users, thereby increasing the population that has access to water. At other times, providing water for livestock through a well can overexploit the surrounding pastures, and wells for crop irrigation can reduce the water available for natural vegetation.

Furthermore, the construction of a new well can alter how time is used in a community and create changes or conflicts of power, influencing the roles and tasks of women, girls, and boys.

Wells should not be located in an area where there is a risk of contamination from latrines or sewage. Faecal matter, which contains parasites, bacteria or viruses, can seep through the soil, reach the water table and be carried in groundwater to the well. Although it depends greatly on the type of soil and aquifer, a minimum distance of thirty metres between latrines and supply wells is recommended (Sphere Association, 2018).

In the case of chemical contamination, which can travel greater distances, it also depends on the type of soil and rock, but it is recommended to maintain a distance more than seventy metres from the source of contamination to the well, monitor possible sources of contamination, and carry out physicochemical checks on the water.

In urban and suburban areas or in camps, it can be very difficult to maintain the minimum distances recommended by regulations, so it is sometimes easier to bring water in from other places.

Possible natural/mineral contamination (salts, sulphate, fluoride, arsenic, etc.) must also be taken into account.

3 Drinking water supply: quality

What should the water quality be like in a refugee camp? To preserve public health, it is better to have abundant, reasonably pure water than a small amount of very pure water.

The water must be safe to drink, as refugees will drink any water that tastes and looks acceptable, unwittingly exposing themselves to the dangers of chemical residues and microorganisms.

The water should have a pleasant taste and be of sufficient quality to be drunk and used in food preparation or for personal hygiene without posing a health risk. Quality is assessed based on chemical and microbiological composition (WHO, 2022).

In terms of chemical composition, water can be contaminated by chemical residues or heavy metals from sewage effluents, industrial complexes, mining activities or pesticides from intensive agriculture. Many chemical components in water are harmful to health after prolonged consumption. However, in emergencies, it is preferable to have water available, even if it significantly exceeds the established parameters, rather than restricting access to it.

In terms of microbiological content, during emergencies, diseases related to water, sanitation and hygiene are common (López and Schiffer, 2012): diarrhoea, typhoid fever, cholera, polio, giardiasis, amoebiasis, hepatitis A and E, shigella, bacterial dysentery, meningitis, salmonellosis; skin diseases such as scabies, mycosis, eye infections (trachoma, conjunctivitis), lice; or transmitted by parasites (schistosomiasis [Bilharziosis], Guinea worm, intestinal parasitosis) or by insect bites such as fleas, mosquitoes (malaria, yellow fever, dengue, filariasis) or flies (sleeping sickness, trypanosomiasis, lymphatic filariasis).

The most serious threat is contamination caused by urine and faeces (human or animal) present in wastewater. The greatest risk associated with consuming contaminated water is the spread of diarrhoea, dysentery, and infectious hepatitis. The World Health Organisation estimates that two million deaths occur every year due to waterborne diseases, most of them in children under five years of age (WHO, 2022) (table 5).

It should be borne in mind that, once water has been contaminated, it is difficult to purify it quickly in emergency conditions and that many of these agents are very persistent in water. The elimination ranges in water at 99.9% vary between 7-8 days for coliform bacteria, 10-50 days for *E. coli*, and up to 275 days for *S. typhimurium*.

New sources of water supply must be tested bacteriologically before use, and existing sources must be monitored regularly, so that they can be retested immediately after any outbreak of disease that could be caused by poor-quality water. Due to possible microbiological contamination, it must be determined that no faecal coliforms (more than 99% of which are *E. coli*) are present.

PATHOGENIC MICROORGANISMS IN WATER	
Disease	**Agent**
Bacterial origin	
Typhoid and paratyphoid fevers	*Salmonella typhi* *Salmonella* *Paratyphi A y B*
Bacillary dysentery	*Shigella*
Cholera	*Vibrio cholerae*
Acute gastroenteritis and diarrhoea	*Escherichia coli EN* *Campylobacter* Enterocolitis-causing *Yersinia* *Salmonella* species *Shigella* species
Viral origin	
Hepatitis A and E	Hepatitis A and E viruses
Polio	Polio virus
Acute gastroenteritis and diarrhoea	Norwalk Virus Rotavirus Astrovirus Calicivirus Enterovirus Adenovirus Reovirus
Parasitic origin	
Amoebic dysentery	*Entamoeba histolytica* *Giardia lamblia* *Cryptosporidium*

Table 5

Refugees will normally use the nearest water source, whether surface or groundwater, regardless of its quality. Whatever the source of supply, immediate measures must be taken to prevent contamination by faeces. It is also necessary to observe whether there are any nearby activities that could indicate possible water contamination, to implement measures to prevent water contamination after it leaves the distribution point, during transport or storage at home, and to encourage refugees to drink water from safe sources and not to use others that could be contaminated.

In the case of surface water, the intake should be located upstream from the settlement or camp, and a special area should be reserved for this purpose. Further downstream, an area should be designated for washing, and finally, downstream from the site, livestock should be allowed to drink. Part of the riverbank will need to be fenced off, and attention must be paid to any potential hazards that may be present.

In the case of wells or springs, they must be fenced off, covered and monitored. Water should not be drawn using individual containers that could contaminate the supply source.

Water disinfection is necessary to prevent infections of microbiological origin and to eliminate pathogens such as bacteria (*E. coli*, *Salmonella typhi*, *Shigella*, *Vibrio cholerae*), viruses (Poliovirus, Rotavirus), protozoa (Giardia) and parasites.

The risk of water contamination is usually measured in Nephelometric Turbidity Units (NTU), which must be less than 5 NTU. Turbidity, caused by the presence of particles in the water, indicates a higher probability of microbiological contamination. Therefore, turbid water must be treated to reduce its turbidity using filters or by flocculation and decantation. It is also recommended that the pH does not exceed a value of 8.

Water disinfection can be carried out using various methods: by oxidation, using chlorine; by sodium hypochlorite; or by chlorine gas.

Disinfection by oxidation, using chlorine, requires a dose of 1 to 5 g/m^3 water. The amount of chlorine that leaves a residual of 0.2 to 0.5 g/m^3 (or up to 1 g/m^3, if cholera is present) should be chosen and this residual should be analysed several times a day at the distribution point. These figures allow us to assume 0 *E-coli* in 100 ml.

Disinfection with sodium hypochlorite (liquid) is equivalent to 10-15% chlorine equivalent; the installation is cheaper (it uses dosing pumps), the volume of liquid to be treated is much greater, and it loses its effectiveness more quickly during storage.

Chlorine gas disinfection is equivalent to 100% chlorine equivalent; the operating cost is lower, but it requires more infrastructure and technology and is more dangerous.

In cases where centralised supplies are not available, treatment must be carried out at home.

In all cases, residues of chemicals used in the treatment process (such as coagulants/flocculants) must always be analysed to ensure that the maximum limits set by the WHO are respected.

4 Sanitation and hygiene

One of the main problems in refugee camps is the management of sanitation and hygiene.

The danger posed by human and animal excrement to the health of the camps, causing contamination of the soil and groundwater, has already been discussed. The construction of latrines and good drainage systems that prevent this contamination allows the transmission vectors to be controlled. Other aspects to consider are the handling of corpses and the control of other sources of contamination, such as rubbish dumps, among others (Médecins Sans Frontières, 2010; Sphere Association, 2018).

Regarding sanitation for the disposal of wastewater, it is advisable to build latrines in areas far from sources of drinking water, although they should also be built as close as possible to the areas where refugees are located, in order to encourage their use.

Human waste disposal in refugee camps is usually carried out through infiltration pits or latrines and septic tanks, and it is recommended that there be at least one toilet for every twenty individuals.

The search for solutions and designs with technical expertise, carried out by professionals, are key to sanitation in emergencies. It is very important in this work not to lose sight of solutions that guarantee individuals privacy and dignity.

When disposing of excreta in emergencies, aspects such as the ease of hand washing should always be considered, as well as an appropriate and functional design for children, men and women, the elderly and people with disabilities, maintenance of latrines, their cleaning and hygiene education related to them, whenever possible, the use of local materials and appropriate technologies; that individuals feel ownership and responsibility for their latrines; and the participation of future individuals in all steps of the process, from design to construction.

Many types of subsoil act as filters, which, combined with the bacterial and microbiological activity of the soil itself and the passage of time, eliminate most pathogens before they can travel long distances through groundwater flow.

To ensure that leachate from a latrine does not pose a threat to public health, there must be a minimum distance of thirty metres between a latrine and a groundwater source and a minimum distance of 1.5 metres vertically between the bottom of the latrine pit and the water table, in order to ensure good filtration through the unsaturated zone and the action of soil microorganisms on the infiltrated faecal matter; once the infiltrations have passed through this filter, they join the groundwater flow, take the same direction and travel (depending on the type of soil and rock) about seven to twenty metres before the biological contamination has been diluted and completely disappeared from the subsoil.

These distances are usually sufficient, except in highly transmissive rocks where water circulates very quickly. In these situations, the distance to the water source should be increased considerably.

The latrine should always be located at a lower elevation and against the direction of flow of an groundwater source (well or spring).

Depending on the depth of the groundwater table, latrines may be located above or below it.

If they remain above, in the unsaturated zone, in the absence of significant groundwater flow, with a very low hydraulic gradient, the spread of contamination is limited and confined to a depth of two to three metres, with almost no lateral spread. In the case of heavy rainfall on highly permeable land, the spread of contamination may be more significant. The unsaturated zone tends to favour the attenuation of microorganisms through filtration, adsorption or dilution. The risk of these reaching the water table and, therefore, groundwater, with unacceptable concentrations, depends largely on the characteristics of the rock material. This presents a low risk in areas consisting of fine sand and clay, a medium risk in areas with medium sand or altered bedrock, and a high risk when coarse sand, gravel, sandstone, limestone and fractured rock are present.

If the depth of the latrine reaches or stands below the water table, i.e. if it is found in the saturated zone and the groundwater flow is continuous, for moderate groundwater flow rates (1 to 3 m/day), the WHO proposes a maximum contamination propagation distance of eleven metres in the direction of flow. It is recommended that the drainage network have a slope of approximately 1%.

In terms of hygiene, one shower for every twenty-five people is recommended, as well as the distribution of toiletries such as soap, toothbrushes and toothpaste, towels, etc.

Information sessions in schools, for women and heads of households are also essential to raise awareness of the importance of practising good hygiene to prevent the spread of disease. Correct use of the entire system is essential to prevent contamination, from water collection, transport, storage and disinfection (chlorination, boiling, filtration) to consumption.

4.1 Vector control

Controlling the vectors that cause disease transmission involves reducing their population, which requires an understanding of their life cycle, population dynamics, and the epidemiology of the transmitted disease.

Vectors such as flies and mosquitoes, which are partly responsible for the transmission of infections, malaria and diarrhoeal diseases, often breed in areas where there is excrement or stagnant sewage. Up to ten thousand flies can reproduce in one kilogram of excrement, and millions of mosquitoes can breed in sewage or stagnant water (Sphere Association, 2018).

Vector control requires preventing reproduction, for which traps and other means are used, such as covering latrines, ventilated pit latrines (VIP), covering faeces and rubbish with soil, cleaning and hygienic conditions, draining stagnant water, repellents, etc.

The most common measure in humanitarian action for protection against vectors such as flies or mosquitoes, especially for particularly vulnerable people, is the distribution of mosquito nets impregnated with long-lasting insecticides, regulated by the WHO.

Active control is also carried out by fumigating or spraying chemical insecticides or pesticides. This task requires trained, specialised and properly equipped personnel who know how to handle toxic material, are familiar with the frequency of its use and can identify whether the vector is developing resistance to the chemical product. In emergency situations, it is common to work with experts from the local health ministry.

In this task, it is important to use products and protocols that follow WHO recommendations, with an international register of original packaging, indicating on the label the active ingredient, concentration, mixing and application instructions, and measures to be taken in case of accidents (Sphere Association, 2018).

The storage and transport of fumigation products (chemicals and tools) are also regulated by WHO guidelines and must remain in their original packaging, in secure locations with restricted access, cool, dark and well ventilated. They should never be stored near fuel or food.

4.2 Drainage

As previously mentioned, one of the most serious problems that can occur in refugee camps is flooding or waterlogging, which can cause property loss and force individuals to abandon their homes. Floods can affect water, hygiene and sanitation infrastructure and destroy latrines, facilitating the infiltration of sewage and excreta and contaminating drinking water systems.

To prevent flooding or mitigate its effects once it has occurred, it is essential to provide good drainage systems to remove excess water by clearing the way for stagnant liquids so that they can be evacuated by gravity.

All areas around dwellings, water supply points, washing facilities, showers and sanitation facilities must be well drained and free of standing water.

There are several types of water, with varying degrees of contamination, that must be drained from refugee camps, especially after flooding: water used for washing clothes, personal hygiene, splashed at distribution points, etc.; water accumulated on the surface after or during rainfall (rainwater or torrential water); water accumulated on the surface or in shallow layers of the ground; water pooled as a result of poorly permeable soils, very flat terrain with no natural slope, or in places with blocked drainage.

The type of drainage is decided based on soil permeability, slope and topography, vegetation, population density, and rainfall intensity.

Rainwater can be drained above or below the vegetation or ground surface into ditches and, from there, be led to collectors. To evacuate greywater, infiltration wells are used until deep areas of the ground. In this case, care must be taken to prevent groundwater contamination (Sphere Association, 2018).

It is advisable to lead drainage water through groundwater pipes, which require maintenance, although in the initial phase of emergency situations it can be difficult to rely on them.

Surface water drainage in rural areas is usually carried out in open channels, either earthen, grass-covered, or concrete, which follow the slope and natural waterways. Small ditches flow into larger collectors towards lower elevations. Open drains should never be used for sewage and drains for used water should not be mixed with those for surface water accumulated from rainfall.

4.3 Handling of corpses

Another aspect to consider after natural disasters is the risk of epidemics due to the presence of corpses (Sphere Association, 2018).

When this occurs, priority should be given to the living over the dead: identifying and registering bodies, providing appropriate mortuary services, avoiding burials of unidentified bodies in mass graves, and respecting the religious/cultural wishes and customs of families.

In the case of people who have died from infectious diseases such as cholera, haemorrhagic fever (Ebola, Marburg), typhus or plague, in situations of epidemics involving the handling of many corpses, every effort must be made to prevent the spread of the disease and serious and strict measures must be taken to prevent future contamination.

4.4 Other sources of pollution

When choosing camp locations, consideration should be given to pre-existing activities that may constitute sources of pollution, such as agricultural and livestock farming, industrial and mining activities, or landfills and wastewater from towns and settlements.

5 Preparation of a project for the construction of a camp

As previously mentioned, water management in emergencies must be carried out based on a project with specific objectives to improve a situation that affects specific individuals, in a specific place, at a specific time and with limited resources.

Each organisation sets performance standards with indicators specific to each project.

There are also the standards of the Sphere Project, the Humanitarian Charter that sets out the minimum standards for humanitarian response. It deals with the principles of protection, the essential standards for water supply, sanitation and hygiene promotion, food security and nutrition, shelter, human settlements and non-food items, health actions and codes of conduct.

Furthermore, the quality guidelines of the World Health Organisation (WHO, 2022) must be followed.

5.1 Phases of a project

The project to build a refugee camp is carried out in several phases.

Firstly, the needs and objectives that have been previously identified must be defined using indicators. A preliminary design is drawn up, and a tender competition is held.

The next phase is the preparation of the contract, for which all parties are to be involved, and the framework and purpose of the contract must be defined. The working materials must be listed and the budget established (Bill of Quantities, BOQ). This allows costs to be quantified and interim payments to be defined. To do this, the items, unit price, total price per item, and total budget price are listed. Additionally, it is necessary to establish a time frame for the actions. It is also important to define how payments will be made, whether by bank transfer or in cash, and whether there will be interim payments. Penalties should also be established, if necessary, and arbitration in the event of non-compliance by any party. Contract modifications may be made throughout the duration of the project.

It is important to carry out interim inspections and one at the end of the contract. Even after the project has been completed, post-project inspections must also be carried out after a certain period. The final report should reflect the outcome of the experience.

5.2 Project characteristics

The actors involved in the implementation of any project of this magnitude are very diverse and must be firmly supported by legal means: from the organisation itself (which must have statutes), donors (through funding agreements), local authorities (through memoranda of understanding, which define the framework for negotiations between consortium partners), local counterparts (agreements), contractors and suppliers (contracts), and beneficiaries. International organisations must always work with NGOs and local authorities within a governance framework.

With regard to logistics, it is ideal for both contractors and suppliers to use the local market in order to provide greater assurance of long-term maintenance and to promote the local economy (clauses can be included in projects to increase wealth distribution). The international market should only be used in special cases and always in accordance with customs agreements. For the acquisition of specialised products (such as Oxfam tanks, chlorination tablets, portable motor pumps, etc.) or rapid response needs (emergency stocks), the delegation´s warehouses or even the organisation’s headquarters can be relied on.

In the early stages of an emergency or when the water quality is not suitable for drinking, the most useful and quickest solution is to distribute bottles, which is subject to market availability.

Another method of water distribution, only valid in the early stages of an emergency, is water trucking or distribution by tanker lorries, for which a maximum volume of 15 m^3 is recommended.

Once the camp is set up, a distribution network is required, consisting of a water source, a pumping unit (which requires a power source), a storage system, pipes, taps and individual containers.

5.2.1 The water source

The importance of correctly selecting the water source or drilling wells where necessary has already been discussed in section 3.

In the case of groundwater, once the new well has been constructed (figure 2), there are a number of important aspects to consider in order to protect and maintain water quality.

Figure 2. Supply from a well in the Sahrawi refugee camps in Tindouf (Algeria). Own image

Firstly, to protect the quality of the well water and prevent the infiltration of contaminated surface water, a concrete sanitary platform must be built (with a height of one metre for wells without a hand pump and a lower height for those with a pump) and a sanitary seal must be installed in the well. It is advisable to construct a good drainage system to remove water splashed around the well, using a channel with a minimum slope of 5% directed towards an infiltration pit. The durability of the infrastructure depends on the quality of the materials used for the concrete. It is essential to use the correct mixtures, high-quality cement, water, gravel and clean sand, free of salts and with the appropriate grain size (Davis and Lambert, 2002).

Depending on the context, the well should be fenced off to prevent animals from entering the clean area.

When previously dug wells are available for use, the first step to consider is their rehabilitation and disinfection. The well is emptied, the material at the bottom is removed, and the walls are cleaned of dirt, roots, algae, and encrustations. After cleaning and natural recharge, the water should have less than 5 NTU. If not, repeat the process several times and clean the walls with a chlorine solution until the pH is between 6 and 7.8 for effective disinfection with chlorine. The residual chlorine in the water once the well has been refilled must not exceed 0.6 mg/litre.

During the process, which may take several days, no water should be extracted from the well. It should be noted that regular chlorination is independent of well disinfection.

It is important to bear in mind that cleaning alone does not eradicate the source of contamination, so it must be eliminated or, failing that, the use of the well must be restricted.

In the case of surface water bodies, after selecting the water source, a pumping system must be installed, a location for treatment must be found, and distribution must be adapted. To do this, the topography of the site, the different levels and distances must be measured and analysed to check whether there is sufficient space available for the installation of the materials. Calculate the type of pump required, the quantity and type of pipes needed to assemble the system (Davis and Lambert, 2002).

The first step is to protect the water source from contamination so that it can be used throughout the emergency period. To do this, it is beneficial for individuals to be informed about the importance of protecting water sources and fencing them off if necessary. Individuals should be prevented from entering the source and contaminating it with their feet, clothing or containers (Sphere Association, 2018).

It is important to note that surface water should be taken as far away from the shore as possible in order to avoid potential sources of contamination. In rivers and running water, the sampling point should be located upstream of the site, before points of contamination such as drain inlets, animal drinking troughs, places for washing clothes or regular cleaning.

Care must be taken to ensure that no damage or changes occur to the bank where the intake is installed, so it is necessary to analyse whether the site has a history of previous flooding or erosion. In the case of fast-flowing rivers, it is important to find places where a jetty can be installed where the current is gentle, to avoid the suction of sediment or floating particles or the risk of the current dragging the suction line.

5.2.2 The pumping unit

For the extraction of groundwater, water pumps are required to convert mechanical energy into hydraulic energy (Davis and Lambert, 2002).

Its main design parameters are flow rate, volume obtained in a given time (m^3/s) and pumping pressure, measured in metres of water column (m).

There are manual pumps with low initial costs, low maintenance, low flow rates and low pressure (such as the INDIA MARK II); and automatic pumps, powered by electric motors (single-phase for low power or three-phase) or fuel engines. In all cases, sizing is very important.

Power generators (with air, oil, fuel and battery filters) are also required.

In surface waters, just as important as the correct installation of the pumping station (and the selection of the location for its installation) is the suitability of the water intake. To prevent, from the outset, organic matter (leaves, plants, insects, aquatic animal life, large algae) and part of the suspended matter floating in surface water bodies (clay, sediment, algae, zooplankton) from being sucked into a system's water intake, and also to prevent the suction of sludge and sediment from the bottom, raw water intake is to be planned in a clean area, about 40 cm below the surface (Sphere Association, 2018).

The pump is installed and secured in a safe location away from potential flooding, but as close as possible to the body of water, so that the maximum suction height of seven metres between the pump and the water surface is maintained. The suction pipe must be equipped with a non-return valve at its base, which allows water to enter but prevents it from escaping back out through the suction side of the line. A grid is placed in front of this valve to prevent large objects such as leaves, plants or stones from entering.

Measures must be taken to avoid contaminating the source with lubricants or fuels from the motor pump and to keep the installation site clean.

Motor pumps are designed for specific pipe diameters. The suction line must not have a diameter smaller than that of the pump, although pipes with a larger diameter may be connected to the outlet. In semi-permanent installations, the pump and pipes must be fixed to a platform to prevent vibrations and damage, and the pump must be protected from rain and sun with a well-ventilated enclosure that ensures its cooling.

In areas where there are abundant suspended solids in surface waters, pre-filtering can be carried out by digging a shallow well that collects water infiltrating from the surface water body. Depending on the permeability of the soil, a gallery filled with gravel and sand can be constructed between the body of water and the well to facilitate filtration.

Pumping systems in surface water are generally powered by combustion engine pumps (petrol or diesel).

The most common pumps have a discharge flow rate of between 25 and 35 m^3/hour, with a maximum discharge height of around 28 to 38 metres and a maximum suction height of seven metres.

Due to their weight, ease of transport, efficiency (flow rate and discharge height), simplicity and durability, rotodynamic or centrifugal pumps coupled to a fuel engine are used. Sometimes, rotodynamic pumps with single-stage or multi-stage electric motors are also used, which require a generator for their power supply.

5.2.3 The storage system

Once the water has been obtained, structures are required for its storage. These can be of different types (figures 3 and 4): metal and polyethylene tanks (1.2 or 5 m^3), which can be purchased

Figure 3. Water tanks in the Sahrawi refugee camps in Tindouf (Algeria). Own image

Figure 4. Water tank in the Sahrawi refugee camps in Tindouf (Algeria). Own image

from humanitarian organisations' warehouses and local markets; bladders and onion tanks (15 to 25 m^3) (figure 5); Oxfam tanks (up to 100 m^3), which are normally in stock in humanitarian organisations' warehouses, can be put into operation quickly and usually hold a day's consumption; and reinforced concrete and metal tanks, which allow for the storage of large volumes, are

Figure 5. Individual water containers in the Sahrawi refugee camps in Tindouf (Algeria). Own image

usually located above ground, at ground level or groundwater, are installed according to the setting time of the concrete and must be kept clean inside.

5.2.4 Water distribution: pipes and taps

The next aspect to consider is water transport, which, depending on the location of the source, will be by gravity or by pumping. It is also time to select the location for the treatment area (Sphere Association, 2018).

With regard to distribution pipes, aspects such as the type of material (stainless steel, polyethylene, etc.), the diameter (mm or inches) and the permissible internal pressure (bar) are to be taken into account. It should be sized for an average velocity between 0.5 and 1.5 m^3/s in order to prevent the accumulation of solids and excessive pressure losses.

In order for everyone to have equal access to piped drinking water, distribution points must be created and maintained no more than five hundred metres from their homes.

There must be at least one tap with a flow rate of 7.5 l/min for every two hundred and fifty people.

Prefabricated distribution ramps are commonly used, each with six taps, and are installed on a firm, well-drained platform.

5.2.5 Community water treatment

In emergency situations, water of varying quality and levels of contamination or turbidity is often available, so water treatment systems must be prepared to treat it effectively and safely. They must be simple to assemble and operate, economically acceptable, robust and resistant, transportable, and capable of producing sufficient quantities for the population to be supplied (House and Reed, 1997).

The choice of treatment also depends on factors such as the type of emergency (flooding, earthquake destruction, displacement, etc.), the affected population (number of people affected, religion, customs, demographic data, etc.), the availability of water at the site and in the region (sources affected by the disaster, access to sources, drought situation, etc.), or locally accessible materials and tools (national standards, available emergency treatment facilities).

It is also very important to know the demand for water and the human resources (local and expatriate) available to set up and operate the treatment plant, as well as their previous experience.

Planned needs must be met and a significant improvement in water quality must be verified under WHO/Sphere standards, as well as the system being potentially viable and its complexity appropriate to the situation. The maintenance required by the chosen system must also be guaranteed (and equipment consumables must be secured for the duration of operation). The purchase and operating costs of the equipment (euros/litre) must be affordable for the organisation. Similarly, speed and the time required to get the equipment up and running are essential.

For surface water, the simplest, least expensive treatment system suitable for many circumstances should incorporate pre-treatment (infiltration gallery) at the water intake and be capable of injecting and mixing the flocculant/coagulant into the water at the correct dose, handle raw water with high turbidity and reduce it to less than 5 NTU, separate the clarified water from the settled sludge and carry out chlorine disinfection in another tank.

This process can be carried out with relatively simple and accessible materials such as deployable tanks, motor pumps, pipes, and buckets (BATCH system).

In more complex conditions where the use of BATCH systems is not possible (material, accessible space or available time), more purified water is required or there will be concerns of non-biological contamination. The use of compact, mobile water purification plants should be considered.

Once the raw water has been clarified to below 5 NTU and disinfected with chlorine, the entire facility is up and running, and water is coming out of the taps, a final water quality analysis must be carried out on the ramp before opening it to the public. This process must be repeated after each change in treatment (each batch or batch of water) and at least once a day.

If the turbidity tube test indicates less than 5 NTU and the Free Residual Chlorine (FRC) reaches a minimum of 0.5 mg/l, it can be assumed that all pathogens have been oxidised and the water is bacteriologically safe.

At a more advanced stage of the intervention, and as soon as possible, bacteriological analyses should be implemented. Various field kits are valid, with quantitative (how many *E. coli* are present in 100 ml) and non-quantitative results (Colilert tubes that indicate the presence or absence of *E. coli*, without specifying the number). Given that WHO regulations stipulate that there should be zero faecal coliforms (the international indicator is *E. coli* bacteria) in 100 ml of water, non-quantitative tests are simpler and more feasible. Samples can also be analysed at a nearby laboratory for a complete analysis.

As for physical parameters, temperature, turbidity, conductivity and pH can be easily monitored during an emergency intervention using field kits. The water temperature may indicate improper storage or handling and cause a bad taste when combined with chlorine. Conductivity can indicate the presence of salts and minerals and, in extreme cases, also influence flavour. These parameters must be measured before treatment and repeated at the distribution point, although the same regularity as with bacteriological analyses is not necessary.

The products used in the treatment (coagulants, flocculants, etc.) must also be analysed using different tests and zinc tests must be carried out if rainwater is collected from zinc roofs, as well as nitrate and nitrite analyses in water that may be contaminated by fertilisers or slurry.

5.2.6 Home treatment

Water treatment or purification at the household level was incorporated into the emergency protocol after observing that contamination occurs between the source and consumption at home. Safe water treatment and storage at home allows consumers to control the quality of their drinking water and participate in its purification (Sphere Association, 2018).

It should be noted that even if drinking water is clear, without turbidity (< 5 NTU) and without biological contamination (0 coliforms/100 ml), it can become contaminated before consumption in the transport container, by hands, at the place of storage at home, in the kitchen or in the glass used for drinking.

Household treatment must be capable of eliminating pathogens (bacteria, viruses, eggs, cysts) from drinking water; be simple, easy to understand, manageable and easy to clean; be affordable and have affordable replacement parts; keep water safe (it must be covered and able to be drawn without contamination); be acceptable to users in terms of their culture, religion, tastes and customs; materials must provide adequate information for use and maintenance.

In emergency situations, it is recommended to use a safe container, treat the water with combined flocculation and chlorination products, use ceramic filters (‘candle’ or ‘pot’ type) and chlorinate with tablets. Other more complex systems are not recommended in emergencies.

5.2.7 Water containers for safe transport and storage at home

In many cases, microbiological contamination comes from the containers used for storage and transport, and removal from the container (with dirty hands or glasses) is the cause of contamination. Therefore, containers must be equipped with a valve, be easy to clean and cleaned regularly, be made of a resistant and clear material (so that dirt is visible), be long-lasting, have a lid, be affordable, have adequate capacity (10-20 litres), and be economical to transport and distribute.

The Oxfam Bucket embodies these qualities. Every household should have at least two of these containers (one for transport and one for storage).

For turbid water, the use of combined flocculation and chlorination products is recommended, as turbidity affects the effectiveness of chlorination. There are various combined products in ten- and twenty-litre sachets, which are used by different agencies and NGOs, and carry out the process of coagulation-flocculation and precipitation combined with chemical disinfection using germicidal agents.

When clear water is available (< 5 NTU), it can be chlorinated at home using sachets or tablets, powders or granules of disinfectants without flocculants to treat between one and five hundred litres.

To improve water clarity by removing bacteria, some viruses, parasite eggs, cysts and solid particles, effective ceramic filters are available. Some have cylindrical filtration elements ('candle' type), which are a simple method that works by gravity. These filters are expensive and ceramic spark plugs can break during transport. Filtration elements are available in very few places, and most households cannot afford to purchase replacement parts.

There are also 'pot' type home filters, which consist of a pot-shaped ceramic filter, a receiving bucket, and a lid. The receiver can be made of plastic, ceramic or stainless steel. The filter is made of porous ceramic, clay mixed with rice husks or sawdust. These filters require little maintenance, can be produced locally or nationally, and in many cases are a more economical option than chlorination or other types of filtrations.

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Chapter Four

Integrated Water Management in Military Camps

Jaime Lancho Cenamor

Abstract

Integrated water management (IWM) in military camps is a factor that greatly influences the choice of location and contributes to the success of the design, execution and subsequent occupation by Force.

Water supply includes the collection, conveyance, treatment, storage and distribution of water intended for consumption, while sanitation covers the required actions for the disposal of wastewater, whether it be the conveyance and treatment of white, grey and sewage water, or its temporary storage in septic tanks and subsequent removal by specialised companies.

Keywords

Integrated water management, IWM, Military camp, Sanitation.

Introduction

Integrated water management (IWM) in military camps is a factor that greatly influences the choice of location and contributes to the success of the design, execution and subsequent occupation by force.

Throughout history, water has been one of the key factors in the location and construction of camps, fortifications and castles, of which there are countless examples, such as the siege of Masada in Judea by Rome, the cisterns built in hundreds of castles in Spain, the instructions given by Sancho de Londoño in his *Discurso sobre la forma de reducir la Disciplina Militar a su mejor y antiguo estado* (*Discourse on the Way to Return Military Discipline to its Former, Better State*) and the references to the importance and use of water that appear in Lieutenant Colonel Ferraz's *Tratado de Castrametación o Arte de Campar* (*Treatise on Castrametation or the Art of Camping*) in 1800.

Figure 1. Arab cistern in Cáceres [online]. Source: http://museodecaceres.juntaex.es/web/view/portal/index/standardPage.php?id=62 [Accessed: 2026]

For this reason, it is important to take this factor into account when conducting reconnaissance of the area prior to deployment. The engineering officer who is part of this reconnaissance must be qualified to advise the Command appropriately on the suitability of the proposed locations from a water perspective. 'It is important to remember the maxim "without water there is no life"'.

Once the decision on the location of the camp has been made, the engineering officer tasked with designing the entire IWM system must approach it from a global perspective. The most convenient starting point is to carry out an inventory of water resources in the area, which includes surface, underground and atmospheric resources, although the latter can only be used under special conditions, near the coast and with high relative humidity.

This inventory must consider both quantity and quality; and it is essential for both aspects to gather as much information as possible regarding human activities in the area. It is essential to determine the water resources used by the local population and quantify the daily amount of water needed, as well as the activities carried out that may be a source of water pollution (agricultural, livestock, industrial or human), followed by the opportunities to collect collection and finally dispose of wastewater in terms of the quantity and quality of the effluent.

1 Concept of IWM

IWM consists of the following phases:

- Catchment
- Conveyance
- Treatment
- Storage
- Distribution
- Sanitation

These phases can be grouped into two main processes: supply and sanitation.

Supply includes the collection, conveyance, treatment, storage and distribution of water for consumption, while sanitation covers the actions necessary for the disposal of wastewater; whether it be the conveyance and treatment of white, grey and sewage water or its temporary storage in septic tanks and subsequent removal by specialised companies that have tanks equipped with suction pumps, as well as the sludge resulting from wastewater treatment.

In order to create a successful design and optimise IWM, a number of factors must be taken into account, starting with the correct location of the camp, which is discussed in point 3. Once a location with sufficient water for our needs has been decided upon, we must tackle the design of the entire water system. This must be done from a broad perspective and with an overview, and then we must go into detail on each of the elements that comprise it.

This means avoiding oversizing certain elements that could then cause funnels in some cases and bottlenecks in others, which would be unable to cope with the flow received, making the whole system vulnerable and inefficient.

If more water is collected and distributed than can be adequately disposed of and treated in the Wastewater Treatment Plant (WWTP), corrective measures will obviously have to be taken. These measures will normally be difficult to implement once the camp is occupied and operational, as well as being expensive and inconvenient for the personnel occupying it.

As a first approximation, the water supply decided upon by the command should be available for the personnel who will occupy the camp. This allocation will, *a priori*, be around 150 litres per person per day, according to *ATP-104 Water Production, Storage and Distribution* (NATO, n. d.), but it can vary greatly depending on a multitude of factors such as the weather, troop morale and a long list of other possibilities.

ATP 104 proposal for cold weather:

Types of Use	Phase		Qualitative Water Characterization
	Arrival in Theater	Full Ops in Theater	
Drinking and summary ablutions	15	15	Potable
Kitchen	10	10	Potable
Showers	20	40	Potable
Laundry	10	10	Potable
WC	10	10	Technical
Cleaning Premises	10	10	Technical
Cleaning Equipment	-	50	Technical
TOTAL	75	145	

Figure 2. Water requirements per person for cold weather

Once this data has been defined, the hydropneumatic pumps can be sized to deliver the necessary daily amount of water, as well as the precise conveyance system to carry it to the reservoirs and from there to the distribution and consumption points.

These reservoirs are also sized based on the amount of water needed for a day's supply, 'C', which can be increased depending on the reserve water that is decided to be stored, normally between C and C/3, and the water for firefighting if it is obtained from the same water source. In the case of the most common camps—fewer than 5,000 persons—3,500 litres are calculated.

With this consumption data, together with the quality of the water at the entrance to the reservoirs, the size of the water treatment plant required to treat the specified amount of water on a daily basis is determined. The most common case is to use the water purifiers provided by the water treatment centre, currently SETA (Spanish Water Treatment Company), and to understand their capabilities depending on the type of raw water to be treated, but the possibility of using civilian water purifiers purchased in the area of operations (AO) should not be ruled out, if necessary. It is very important to know the potential contaminants that may be found in the water in order to properly design the necessary purification stages, thereby preventing others from reducing performance or adding unnecessary reagents to the water that will later be consumed.

The next step would be to design the distribution network, capable of carrying water to the necessary consumption points in the camp and attempting to do so as efficiently as possible, grouping large consumers together, optimising the location of ablution containers according to the needs and convenience of personnel, and ensuring that, in the event of a breakdown or breakage, it can be isolated and the water supply can be sent through another branch of the network using mesh networks.

At this point, we must decide how to use rainwater and what to do with greywater. If rainwater is to be collected, a specific network must be designed and, depending on its intended use, it must be stored and treated appropriately.

The optimal solution for rainwater harvesting involves collecting it in *recovery ponds*—ponds in permeable soil that collect rainwater and facilitate its infiltration into the ground—. The advantages of this solution are unlimited storage capacity in the aquifer, filtration and treatment of water by the land itself, which eliminates the health risks of stagnant water. This solution is only feasible if the terrain is suitable: ideally, alluvial deposits with a water table that is not too close to the surface (> 3 m).

Depending on their use, the rainwater harvesting network that influences the camp's drainage system is designed. Water collected for consumption must be stored and treated in the same way as water collected from the supply aquifer, while water collected for technical use must be stored and treated separately and always clearly labelled.

If rainwater is collected, yet not used for drinking and consumption, but rather for technical purposes, it must be treated specifically and stored in tanks that are clearly differentiated from those used for drinking water and properly labelled. This network must be completely separate from the drinking water network and must always run below it in shared sections.

Technical water is defined as water that undergoes mechanical filtration and shock chlorination but is not made potable; it can be used for various purposes, but not for human consumption, food preparation, laundry or personal hygiene.

In a worst-case scenario, if rainwater is not collected, drainage must be anticipated, and if it is going to end up in a combined sewer system together with black and greywater, this must be taken into account when sizing the WWTP.

Greywater can be combined with sewage in combined sewer systems, in which case both must be taken into account when sizing the WWTP, or it can be combined with rainwater when this is to be used as technical water. With the current design of the ablution containers used by water treatment centres, grey and sewage water from these containers flow through unitary networks and receive the same treatment, but this is not the case for greywater from kitchens and laundries, which can be treated as technical water together with rainwater.

Depending on water scarcity in the area and the budget, among other factors, a system should be chosen to optimise water use and not make construction prohibitively expensive. If in doubt, the more rainwater that is harnessed and the more greywater that is reused, the more efficient and environmentally friendly the installation will be, and the less negative impact there will be on the environment and, therefore, on the local population, thus minimising the water footprint.

All swage is to be treated in the WWTP, which shall be sized taking into account the grey and white water involved. As a first approximation, it should be assumed that 85% of the water supply goes to the drainage network.

2 Criteria for camp site selection

During the preliminary reconnaissance for site selection, a multitude of factors must be taken into account in order to properly advise the commander on the best location from a IWM perspective, which must necessarily be coordinated with tactical, security, and any other requirements that may influence the suitability of establishing the camp at a specific location.

Regardless of the deployment area, a series of actions must be carried out prior to deployment in order to gather as much information as possible, so as to have an overview of what is expected from the advice on the IWM aspect.

It is necessary to ascertain, as far as possible, the commander's ideas regarding the overall mission of the Force, the capacity of the camp, the duration of the deployment, its geographical location, the security situation in the area, etc.

To this end, this means that information shall be gathered by all possible means, including open sources, which will be duly verified.

In any case, it is essential to know:

- Geographical area of deployment and its topography.
- Climatology, with special attention to temperatures, rainfall, and storms.
- Estimated length of stay at the camp.
- Number of expected occupants of the camp.
- Hydrology of the area.
- Water quality in the area.
- Existing hydraulic infrastructure and its condition.
- Water sector companies in the Area of Responsibility (AOR), both local and contracted companies that may operate in the area.
- Security situation and public sentiment regarding the Force.

– Likely impact on nearby populations that our exploitation of the area's aquifers could have.
– Industrial, agricultural or livestock activity carried out in the vicinity of the base and its potential for pollution.
– Other information that could influence the proposed location.

With these premises regarding water, it will be possible to optimise the time available for reconnaissance in the area, which will always be limited.

Each proposed information requirement shall be analysed in order to specify the data to be collected in each case.

Figure 3. Gran Capitán Base [online]. Source: https://www.bolsamania.com/noticias/politica/el-jemad-visita-las-tropas-espanolas-desplegadas-en-turquia-afganistan-e-irak--2753266.html [Accessed: 2026]

2.1 Geographical area of deployment and its topography

By request to the Army Geographical Centre (CEGET), maps of the area at different scales are to be collected for study.

They should be expanded with aerial photographs obtained both through official channels and from open sources.

If it is possible to obtain information on specific points using UAVs, drones, etc., this should be exploited in order to gain detailed knowledge of the area.

The aim is to gain a clear idea of the appearance of the area, including its relief, watercourses and bodies of water, nearby population centres, etc.

Special attention must be paid to toponymy, as they will provide additional information about the possible existence of springs, water sources, etc. To this end, the support of duly accredited translators will be necessary in cases where the legends and indications on the maps are written in languages with which the technician undertaking the task is unfamiliar.

If possible, geological maps are to be located, which will be of great help in detecting underground water masses for possible catchments, while also providing information to predict the depth of the water table, to be determined during the reconnaissance and which should be at least 3.5 metres below the surface of the ground.

It is common in developing countries for the local population to live above significant deep aquifers that have not been exploited due to a lack of infrastructure or energy sources to extract the water. Therefore, they settle for exploiting lower-quality surface aquifers. The study and assessment of groundwater is a complex task that requires experts in underground hydrology.

Among the factors to be taken into account is the slope of the terrain. Plains should be avoided due to the difficulty they pose for the camp's necessary rainwater drainage network. Choosing a site with a slight average slope of around 3%, and below 5%, facilitates this drainage, as well as simplifying the design of the distribution and drainage networks. Special attention must be paid to flood plains, which should be avoided at all costs due to the obvious drawbacks they present.

It is also necessary to study the ease of evacuation of treated rainwater and wastewater to watercourses, ravines and appropriate points that do not cause conflicts with the host nation, hereinafter referred to as HNS.

2.2 Climatology, with special attention to temperatures, rainfall and storms

Maximum temperatures will influence the need for water supplies for deployed personnel. The higher the temperature, the greater the need for water per person per day. It is important to try not to lower the ratio unless it is essential, due to the impact this action has on troop morale.

The ATP-104 indicates the equipment to be considered depending on the climate, whether hot or cold. It should not be forgotten that the temperature of drinking water is a very important factor in its quality and that, above 20 °C, the risk of unwanted micro-organisms proliferating increases and it becomes less palatable for personnel, who should be offered drinking water at a temperature as constant as possible between 5 and 15 °C, whenever possible.

Maximum and minimum temperatures will influence the protection required for regulating tanks and the distribution network. High temperatures cause water reserves in tanks to evaporate, so it is also advisable to protect them with at least sheds or shade structures.

The risk of frost can cause pipes to burst, so it may be necessary to bury pipes at a depth of more than 60 cm and also to thermally insulate tanks.

These circumstances could even warrant the use of buried or semi-buried tanks instead of the surface tanks provided by the water treatment centre.

As for rainfall, it is necessary to study it to determine whether it is constant or seasonal, since if the intention is to exploit rainwater resources for supply, it is essential to know the distribution of rainfall.

For smooth surfaces (roofs or esplanades), all rainfall below 3 mm should be disregarded, and for earth surfaces or those with vegetation cover, rainfall below 10 mm should be disregarded. The isohyet map of the area must also be studied in order to calculate the dimensions of the drainage systems for the camp roads, the necessary perimeter ring road for safety, the pumping systems for the roads and heliport, as well as the existing esplanades.

In this case it may be advisable, if containers are used in the camp, to design and implement of a system of gutters and downspouts with drains to collect rainwater and store it in water tanks for later use as fire reserves, vehicle washing, irrigation and hosing down of roads and esplanades if necessary, and even irrigation of gardens and green areas in permanent and semi-permanent camps.

These calculations shall account for the Technical Building Code (CTE, in Spanish).

The study of occasional storms and downpours may suggest searching for nearby underground caves or constructing a storm reservoir to conveniently evacuate and store excess water. The possible treatment of water and its release into the area's hydraulic system will be borne in mind to prevent the proliferation of insects due to the possible nuisance and diseases that could affect the personnel occupying the camp, and the refilling rafts described above in Section 1 will be used.

All tanks must be protected from the elements by vertical and horizontal shielding to minimise the impact of solar radiation, temperature gradients and the possibility of water contamination by suspended particles. This protection can initially be provided by modular collective shelters, which can then be improved upon later.

2.3 Estimated duration of the camp

Depending on the length of occupancy, the camp infrastructure will be refined and become more complex, moving from an initial setup with tents and chemical toilets with minimal water services such as food and showers, considered essential in temporary camps, to permanent and semi-permanent designs that include complete supply and sanitation networks with laundry services, a cooperative, gardens, etc. ATP-104 indicates the appropriate provision for entry into AO and subsequently during the course of operations.

In cases where camps evolve due to increased occupancy time and, consequently, their design changes, it is necessary to anticipate changes in the amount of water that must be stored in the regulation tanks, the transition from chemical toilets to ablution containers connected to septic tanks or sanitation networks, as well as the drinking water distribution and treatment capacities at the WWTP in order to avoid bottlenecks that could cause the IWM network to collapse.

In these dynamically evolving camps, consideration should be given to the possibility of using rainwater and greywater, with the consequent construction of dedicated networks and tanks with specific treatment for use as technical water, both in the installation of firefighting tanks and for irrigation, vehicle washing, etc.

To achieve this, it is very important, from the early stages of construction of the base, to differentiate between the sewage network (including grease and other contaminants) and those that only carry traces of detergents (personal hygiene).

2.4 Number of people who will occupy the camp

The number of people occupying the camp is decisive in designing the entire system.

When determining the size, it is necessary to consider not only the anticipated force, but also possible temporary reinforcements (Afghanistan election bonus) and passers-by.

The calculations will be based on the minimum stipulated by ATP-104, although in times of restriction this may be reduced to a minimum of twenty-five litres of drinking water per person per day, plus a variable minimum of technical water, a production of around fifty litres of sewage per person per day, and a ratio of one toilet and one shower for every ten people.

The situation will vary, so this data will also vary in one direction or another, meaning that the situation at the Cervantes Base in Lebanon (no restrictions) may occur, or water consumption control measures (COP, s in certain situations) may be taken to extremes.

The Logistics Units (ULOGs) deployed in AO will also have the amount of bottled water in their warehouses and isothermal containers defined by the Logistics Procedures (PROLs), based on the number of people staying in the camp and the reserve marked in days of supply (DOS). It is usually estimated at seven reserve DOS, although this may vary depending on the situation.

The number of people in the camp also determines the number of shelters, which may be equipped with bottled water for the expected number of occupants for a specific period of time to be determined in the PROL. This amount of stored water must be periodically checked and replaced when its best-before date approaches.

2.5 Hydrology of the area

The hydrology of the area is another determining factor when choosing a location.

The best option is for the water collection point for consumption to be located inside the camp, due to the logistical constraints involved in transporting water and the vulnerability this poses to staff safety during journeys, as they are easily identifiable by potential hostile elements, as well as the possibility of sabotage at the collection point itself.

Another good option is to connect to the local drinking water distribution network and channel sewage into the public sanitation system, but this will not be the most common case.

In any case, a minimum storage capacity must always be guaranteed within the base defined in the PROL.

2.6 Water quality in the area

The quality of drinking water must comply with the conditions of STANAG 2136. The health service (pharmacy) is responsible for checking these quality standards and is the only body authorised to carry out water potability analyses.

However, in the preliminary study, water bodies and rivers with obvious signs of contamination should be avoided as far as possible, as should areas downstream from polluting industries that discharge wastewater into the watercourse or water body, agricultural and livestock farms in the same conditions, and other possible cases of water contamination.

However, pollution *per se* is not an impediment to the use of water resources. The key is to know what activities have been carried out in the area and, based on this information, request that water analyses include sampling of parameters that indicate the presence of these pollutants.

Once the contaminants present have been identified, the risk and cost-effectiveness of the processes for removing these contaminants from the water must be assessed, and the solution weighed up against other supply alternatives.

One of the first analyses to be carried out is that of the organoleptic qualities of the water and its turbidity, as well as the presence of poisons and heavy metals, which can provide us with important data on the possibilities of consuming the water under study.

A valuable guide for study is STANAG 2885 on emergency water supply.

2.7 Existing infrastructure and its condition

Local supply and drainage networks should be the priority for water supply and drainage in military camps, together with collection within the camp itself.

According to STANAG 2885:

'The water requirements of the armed forces are normally met by public water supply systems'. In the event of an interruption to the normal water supply and to the water supply prepared for defence purposes, which is independent of public systems, the Armed Forces must be able, if they wish to maintain their operational capacity, to meet their drinking and technical water needs through an emergency supply provided by their own means.

For this reason, the local water supply and drainage infrastructure for military camps will be assessed, without losing sight of the quality of the water supplied and drained.

Whenever possible, these networks shall be used for reasons of economy of means and commissioning time; however, the following precautions shall be maintained:

- Use of buffer tanks with emergency reserve capacity to be assessed according to the situation, with a recommended capacity of seven days in a COP.
- Regular checks on the quality of the water supply, with more frequent and random checks the higher the threat.
- Regular checks on the quality of wastewater leaving the camp on its way to the WWTP and on the effluent from the WWTP into the environment.

Normally, a contaminant is not detected unless the water sample is subjected to specific analysis for that contaminant. For this reason, it is necessary to pay attention to water parameters that indicate the presence of anomalies:

- Ionic balance: if there is a difference between the sum of anions and cations (equivalents), the water contains a contaminant that has not been sampled.
- pH: values below 6.5 or above 7.5 should raise suspicion.
- Electrical conductivity or dry residue: increases or sudden variation of its value.

The supply of water to the camps from the local network will normally be carried out using standard high-density polyethylene pipe suitable for food use, of a calibre appropriate to the flow rate required based on the calculated water demand and, preferably, with a free surface. If the layout of the terrain does not allow it, pumping will be used.

2.8 Water sector companies in the Area of Responsibility (AOR)

The existence of companies or the possibility of contracting them, both national and from the organisation on which one depends (NATO, UN, etc.) and from the HNS, is another point to be studied.

It is relatively common to outsource certain services depending on the situation. These services include the supply and maintenance of water treatment plants, so that they can be operated by military personnel or by the contracted company itself.

It is also possible to contract wastewater treatment plants under the same maintenance and operating conditions as drinking water treatment plants.

In other cases, you can hire the services of companies with septic tank suction and emptying equipment, if this is the system used for wastewater disposal. In this case, it is necessary to verify, whenever possible, that the company treats wastewater appropriately in accordance with existing HNS legislation. In the absence of such legislation, national legislation or that published by the international organisation shall be adopted.

This system presents vulnerabilities in camp security, so it should be used with caution, and access control measures should be tightened.

The ULOGs and Base Support Units (UABAs) will be responsible for controlling these services, each within its area of competence, after they have been put into operation by the UAD (Deployment Support Unit) established at the camp.

It should be noted that, currently, the Temporary Join Ventures (Union Temporal de Empresas - UTE, Spanish) that are usually contracted in AO to provide food services supply Class 1 resources. C-class resources, including bottled water served in canteens and water stored, bottled and palletised in designated areas at ULOGs deployed in AO and in shelter provisions.

2.9 Security situation and public sentiment regarding the Force

The situation will determine the degree of threat and will consequently affect the design of our facilities, including the IWM system. Depending on the threat, it may be necessary to install vertical and horizontal protection in our storage facilities using Hesco Bastion systems, T-walls, reinforced concrete walls and horizontal covers, which can be made of various prefabricated materials, reinforced concrete, etc.

In any alert situation, the water treatment plant will be fenced off, and additional security measures will be in place, with access restricted exclusively to authorised personnel, such as plant operators, sampling staff, etc.

The WWTP must also be monitored and fenced off, as it is another sensitive point in the system that is susceptible to sabotage, allowing access only to authorised persons.

Regarding the perimeter security of the camp, it is essential to plan the drainage points for runoff so that they do not become weak points in the defence. For this purpose, several small-diameter pipes will be used rather than a single large one, and siphon devices will be installed to make it difficult for intruders to pass through them.

It must also be ensured that, in the event of a pipe break, sewage and greywater flow by gravity outside the campsite, taking the precautions described above.

2.10 Likely impact on nearby populations of our exploitation of aquifers in the area

The exploitation of local aquifers by the Force may affect nearby populations, so this must be considered when choosing the location, ensuring that water consumption does not cause shortages in these populations and that effluent from the WWTP does not contaminate other aquifers used by the local population.

We must not forget water for livestock or irrigation, as its use can be seasonal and very critical, endangering the harvest or the lives of animals.

2.11 Other information that could influence the proposed location

This includes all circumstances that could affect the location in one way or another, such as possible civil-military cooperation

(CIMIC) support, supplying areas with water shortages, repairing wells shared by the Force and the population, etc.

3 Water supply to military camps

Water supply consists of the following phases.

- Catchment
- Conveyance
- Treatment
- Storage
- Distribution

A sequence of phases will be developed to serve as a guide for the engineering officer who must design the system, without delving into the calculations, but instead providing simple computer tools to perform them that have been developed by various officers of the branch and have proven effective both domestically and in operations.

3.1 Catchment

Water for consumption can be collected in the following ways:

- Surface water collection
- Groundwater abstraction
- Rainwater harvesting
- Atmospheric water harvesting - condensation of ambient humidity
- Seawater and brackish water collection
- Use of the local water network

Each of the above methods can be used in combination with the others as needed, so that, depending on the circumstances, any of them can be used for a specific purpose.

The most desirable case is the use of the local network, through an exclusive connection to the camp combined with collection within it. In this case, the quality and quantity of the water must also be verified to guarantee supply.

Surface water collection from flowing sources such as rivers and canals should be carried out upstream of towns and other possible sources of pollution, whenever possible, unless low flow rates make it necessary to locate the intake downstream of the town in order to avoid complaints, even at the cost of poorer water quality.

Analyses prior to the installation of the collection equipment are mandatory to avoid starting to assemble the collection installation until it has been verified that the water is suitable for consumption treatment, thereby avoiding wasted time and unsuccessful assemblies.

In surface waters without current, the preliminary analyses are carried out in the same way, and the samples are taken at mid-height without resting on the bottom where possible contaminants may have settled. Initially, a suction hose can be installed with the shower head attached to a float anchored to the shore so that it is placed at a sufficient distance from the shore and at medium height. Subsequently, intake towers and pipes can be installed to optimise the installation.

Groundwater is collected using various types of wells, which can be horizontal or vertical.

Horizontal wells are uncommon and are divided into galleries and drains. In both cases, the water is collected by gravity in a collection well from which the pumping begins. It is a rare system.

The much more common vertical wells are constructed by drilling vertically into the aquifer and installing the appropriate motor pump unit for its exploitation. Excavation is always below the water table and can be constructed using reinforced concrete pipes, bricks, metal pipes or PVC.

There are various procedures for their construction, such as percussion and rotary drills.

If the well needs to be built and no existing well in the area can be used, the area must be studied in order to carry out test drilling, based on geological maps, place names and the knowledge of local inhabitants, as well as the various methods of searching for water that can be hired if necessary.

Where possible, avoid constructing wells in shallow aquifers that are being exploited by the local population, as this can cause a drop in the water table, with consequences for nearby water catchments. When there are shallow aquifers, it is common for other deep aquifers to appear with hydraulic behaviour independ-

Figure 4. Rotary drilling machine. Source: Hard Rock Drilling - Perforaciones para Obras Civiles [online]. Available at: https://www.hrd.cl/index.php/category/pozos-de-agua/ [Accessed on: 2026]

ent of the shallow aquifer and, therefore, without impact on the local population.

Rainwater harvesting should be promoted, given that, until now, it has not been widely used in military camps despite its potential depending on the location, mainly due to the complexity involved, as mentioned above. Basically, these are water collection areas, pipelines and cistern tanks.

When calculating the total usable area of the camp, the following elements must be taken into consideration:

- Roof surfaces of buildings, as well as sheds and roofs.
- Esplanades, heliports and roads.
- Drainage system for the entire camp.

In all cases, a system is planned to discharge the first waters that carry contaminating materials, and then to use the rest of the precipitation up to the maximum height of the spillways, from which point the rest of the water will be evacuated from the camp through the drainage system to rivers, marshes or the storm reservoir, if one has been built.

The precipitation collected by the roofs is calculated to size the gutters, downpipes and drains using the procedure described in the Technical Building Code in Basic Document DB-HS5.

It is also interesting to consult the CTE DB-HS1 document, section 3.4 of which describes construction solutions for roofs to promote drainage.

The esplanades act as collection areas or threshing floors. They can be made of concrete, gravel, or at least tolerable soil, but they should always have a slope or camber of less than 5% depending on the topography of the camp, and the best solution should be sought so that they drain in the right directions carry the water through gutters or pipes to the cisterns if it is to be used, or to the general drainage system if it is to be discharged to suitable areas downstream of the camp.

Heliports shall have a floor that is at least tolerable, with a minimum thickness of 50 cm and a slope of just under 3% to facilitate drainage. Water shall be drained in the same way as on esplanades.

Gutters will be built along the roadsides to collect water by gravity, channelling it parallel to the road towards cisterns or the general drainage system.

The general drainage system for the camp as a whole will also include the perimeter patrol track, which will preferably be made of gravel or reinforced concrete.

This system will collect rainfall upstream and allow excess rainfall that cannot be utilised to be discharged through multiple narrow, siphoned pipe outlets for safety reasons. This drainage system must be dimensioned to allow for the evacuation of the maximum expected inflow and has a return period of twenty-five years.

Atmospheric water harvesting through condensation must be taken into account when the ambient humidity remains above 80% for most of the year.

Seawater and brackish water is collected when it is not possible to use the local network or surface or groundwater, and rainwater is insufficient.

This system requires special water treatment plants with a desalination function, usually reverse osmosis. At present, SETA water treatment plants have this capability, but it should be noted that the daily flow of water produced is significantly reduced, even by half, compared to the use of raw fresh water. This should be considered when calculating water and water treatment plant requirements so as not to create a bottleneck in the IWM chain. We recommend you consult the SETA water purifier manual for more information its features and capabilities.

Figure 5. SETA water treatment plant. Source: Refresher course on water purification for sappers from BRI II - Army (defensa.gob.es)

Figure 6. Mobile water purifier [online]. Source: Potabilizadoras Móviles archivos – SETAPHT. Available at: https://www.setapht.com/potabilizadoras/potabilizadoras-moviles/ [Accessed on: 2026]

Other types of desalination plants that use evaporation and subsequent salt addition are also available on the market, but they are uneconomical due to the high amount of energy they require and their low efficiency.

If the method used for water collection is saltwater and brackish water, consideration must be given to the disposal of the brine produced, which must be carried out in suitable locations so as not to alter the environmental conditions of the area.

3.2 Conveyance

The water is conveyed from the collection point to the treatment and storage point through pipes of the appropriate diameter, depending on the flow rate required for the camp. It may also be necessary to transport untreated water in tanker vehicles, but this solution should always be considered temporary until piped water can be used.

It is desirable that the journey be as short as possible to minimise costs and risks, as well as the possibility of losses, contamination and breakdowns.

If it is possible to transport water by gravity regulated by pressure groups, this system should be used due to its simplicity. Pressure groups prevent overpressure in the network and guarantee the flow required by the user; however, they require positive pressure at the outlet, so the distribution network must be fed by gravity at least.

Piped conduits must be buried (approximately 60 cm) or, at least, protected from the elements for thermal protection (cold - heat), with insulation to prevent freezing and evaporation. In addition, it must be marked with blue polyethylene tape for easy location and identification.

If buried, it will need a bed of sand free of stones or materials (river sand) with sharp edges that could erode the pipeline. It will also be protected on top by a layer of river sand (do not use soil from the excavation) with a minimum thickness of 60 cm (properly compacted) in pedestrian areas, and reinforced concrete slabs in vehicle passages, which, in any case, will be avoided due to the risk of breakage they pose.

3.3 Treatment

The aim of this process is to obtain water with the qualities defined in STANAG 2136, depending on the type of water required in each case, mainly drinking water, emergency water or technical water.

Depending on the quality of the raw water, its treatment will be more or less slow, but in all cases, it will involve the same steps according to the type of water to be produced. Not all treated water needs to be potable; water from firefighting systems may be technical, unfit for consumption, but much quicker to produce and, at the same time, more economical to treat.

The treatment for drinking water will normally be carried out using the water treatment plants provided by the water treatment centre. At present, SETA water purification systems are used.

The basic processes to which raw water can be subjected are as follows:

- Mechanical filter in the suction hopper and another basket filter, prior to the settling tank.
- Addition of flocculant for decantation in lamellar tank.
- Addition of sodium hypochlorite for preliminary disinfection.
- Mechanical flint filter for removing residual solids.
- Carbon filter to improve the organoleptic qualities of the water.
- Addition of anti-scaling agent to improve the performance of reverse osmosis membranes.
- Microfiltration for water refinement.
- Filtered by reverse osmosis for desalination.
- Residual chlorination.
- pH adjustment and remineralisation.
- Passage through an ultraviolet chamber for biological disinfection.

Not all of them are essential; moreover, some can significantly reduce performance, and it may be advisable to remove them if they are not necessary.

STANAG 2136 is the appropriate reference documentation for defining the treatment to be applied.

3.4 Storage

Treated water is stored in tanks that are protected according to the circumstances. These tanks are sized according to daily water requirements and the number of hours of filling, which can be throughout the day or during specific time slots. It is recommended that you create a simple spreadsheet for quick sizing. They are also calculated using the 'camp calculator' developed by the technical office of the Camp Building Battalion (Batallón de Castramentación, BCAS, in Spanish).

The deposits fulfil the following missions:

- Water storage.
- Flow and pressure regulation.
- Maintenance of water quality.
- Maintenance of a minimum emergency level.

The capacity of the tanks must be such that, while guaranteeing supply in the event of a breakdown for a reasonable period, it allows for periodic and frequent water renewal to prevent areas of stagnant water that may encourage the growth of unwanted organisms.

If possible, fire extinguishers shall be located at various points throughout the campsite according to the degree of risk, preferably at intervals of approximately two hundred metres between hydrants, equipped with the corresponding fire pressure units for water projection. The installation of the fire-fighting network shall be carried out separately from the water supply network for human consumption and its tanks shall be independent.

Technical water tanks will also be installed, clearly marked as non-potable, in places where this water is consumed on a large scale, such as vehicle wash facilities in the logistics area.

In the IWM, water tanks may have different functions depending on their location in the system. Some may be dedicated exclusively to drinking water, while others may be used to store rainwater with minimal treatment that classifies it as technical water for use in vehicle cleaning, hosing down and irrigation, and even for firefighting. The premise is not to mix the waters of one with those of another due to their different treatments and uses.

Tanks can be placed above ground, buried or on the surface.

The placement of elevated tanks in military camps depends on the terrain because it is not cost-effective to build a structure to raise them, unless it is infrastructure that was already in place and has been inspected from both a structural and health perspective.

The suitable terrain for gravity-fed water pressure in the distribution network should be between twenty and forty metres above the camp and relatively centralised, which is not very common. On the other hand, it would be a clear target from a security standpoint, which is why its use is not widespread in military camps.

Buried and semi-buried tanks are generally constructed on site, which involves their construction and subsequent abandonment, in addition to the time required for them to become operational. Therefore, the advisability of their use must be assessed. These deposits are also better protected from both external threats and temperature variations.

On the contrary, they are more prone to flooding and, therefore, more susceptible to contamination. In general, they are not widely used in installations that will not be operational for a long period of time.

Flexible surface reservoirs are a quick and effective solution for water storage. Being on the surface, they require a hydropneumatic unit to send the appropriate flow at the correct pressure to the entire distribution network. In areas with high temperatures, they must be installed under light shelters to prevent the proliferation of microorganisms that are harmful to health. These deposits offer the following advantages:

- Wide range of capabilities.
- Quick and easy commissioning at the desired locations.
- Reusable.
- High resistance to temperature variations, between -30 °C and +70 °C.
- Once empty, they can be relocated to a different location if circumstances so require (security, new needs, etc.), which makes the system highly flexible.
- The army and those around us are equipped with them. In our army and those around us.
- Easy acquisition in both National Territory (NT) and AO.

These are, among other reasons, why we recommend using this type of deposit for our camps.

Figure 7. Flexible tank on lorry [online]. Source: Nautic Expo - Depósito de líquidos DYNAMIC Available at: https://www.nauticexpo.es/prod/pronal/product-36084-486339.html [Accessed on: 2026]

There are various models of tanks on the market with different characteristics and capacities.

3.5 Distribution

Drinking water distribution systems must, above all, be rational, economical and efficient; therefore, they must be designed with a view to making the best use of materials so that large consumers such as kitchens and bathrooms are grouped together as much as possible and supplied by meshed networks that guarantee supply in the event of a failure at any point in the network.

Large non-priority consumers, such as laundries and cooperatives, must also be grouped together and connected to the priority network via meshed networks to ensure their supply in the event of a failure. The use of branched networks is also possible. These have the advantage of being more economical, since the diameters of the pipes are smaller the further away they are from the main pipes, but they have the disadvantage that a fault leaves the entire network without supply from the point of the fault, so they are not recommended in principle.

The layout of the networks must be optimised in terms of resources. This is achieved by laying the main pipes in a straight line, i.e. those that supply large consumers and, from there, secondary consumers.

In meshed networks, minimum nominal diameters of 75 to 90 mm are recommended with a recommended calculation speed of 1.4 m/s, so that the permissible speeds are between 0.5 and 1.5 m/s, although it is important that velocities do not exceed 2 m/s, as the pressure loss in the pipe increases dramatically.

The pressure to supply in mWC (metres of water column) must be 5 m above deck, and the standard practice is to use fifteen metres of water column for towns with fewer than one thousand inhabitants and twenty-two metres for towns with between one thousand and six thousand inhabitants. The best option to guarantee this is to have pressure groups at the points of consumption.

The design flow rates must be those of maximum demand, which is equivalent to 2.4 times the average hourly consumption.

For flow rate calculations, the Spanish Technical Building Code (CTE) must be applied, specifically DB HS 4 (CTE Basic Document on Salubrity – Water Supply). This same document describes the construction of the interior supply network, which may be useful if you need to build one, but the most common case is to have the ablution containers already prepared so that a single connection can serve the cold water and Domestic Hot Water (DHW) networks separately with their different pressures.

A simple procedure for calculating flow rates consists of applying simultaneity coefficients as described in the aforementioned document ‘NOP (Spanish Protective Standard) 0301/11 Construction of an advanced combat position (Combat Outpost (COP)/ Forward Operating Base (FOB)/Observation Post [OP])’ from the Notification for the Presentation of Goods (MING) in its Annex G.3. Calculation of the necessary sections.

Having sufficient water does not mean that we should not be careful about how we use it. Despite having sufficient supplies, we should not use more water than is essential, so users must be made aware of the importance of saving water. There are many possible measures, among which the following are noteworthy:

- Fitting of aerators on all taps and flow restrictors on shower heads.

- Distribution of awareness posters in washbasins, taps turned off when not in use, short showers, not using toilets as rubbish bins, etc.
- Rapid repair of leaks by maintenance services.
- Use of separate residual networks to enable rainwater to be used as raw water for purification or as emergency water.
- Raise awareness at ULOG/UABA of the importance of working with industrial washing machines at full load whenever possible.
- Use biodegradable soaps, without phosphates or bleach, to improve the effectiveness of bacterial beds in WWTPs.
- Install grease traps to optimise the efficiency of the WWTP.
- Place hygienic bins in the toilets and have them emptied daily by the cleaning service.
- Avoid or minimise green areas around chapels, cooperatives, etc. If they exist, plant native plants and water them efficiently using technical water.
- Frequently monitor water consumption and keep a record to detect anomalies and correct them as soon as possible. To this end, it is advisable to install water meters on the main supply lines to each building or facility.
- In warm areas, protect nets and tanks from excessive temperatures to prevent evaporation.
- Minimise vehicle washing to what is strictly necessary. Those that are essential for representation and those that are tactical for maintenance. If you have applied a mask and are going to do so again the next day, do not wash it off.

The material used to manufacture the distribution networks will preferably be high-density polyethylene (HDPE) for food use PE100 and supplied from within the country, as will all auxiliary materials, given the proven low quality of these elements in other countries where ET has been deployed. It is advisable to consult the incompatibilities of certain materials with water and of various materials with each other in DB HS 4 of the CTE in section 6.3 in order to manufacture the nets with the appropriate available materials.

Networks must be protected both mechanically and thermally to prevent breakage and freezing. Thermal protection is provided by semi-rigid corrugated shells and tubes that act as insulation, while mechanical protection is provided by beds of fine sand without gravel or sharp-edged elements and a surface layer of the same material at least 10 cm thick. At crossing points with passageways, they shall have the necessary protection to prevent crushing, such as reinforced concrete slabs, metal profiles or the optimal construction solution in each case. The roads should be used in their current layout and a manhole with the corresponding shut-off valves should be installed at each change in straight alignment, duly signposted for the repair of possible faults.

It is also advisable to mark the route on the ground as a precautionary measure to prevent breakages and facilitate repairs.

Distribution networks must be independent according to the following criteria:

- Drinking water networks.
- Technical water networks, including fire-fighting installations.

Both must be clearly separated and marked, specifying whether each tap is drinkable or not. If they coincide at any point along the route, the drinking water network must always be above and the technical network below.

If the two networks described above also coincide with the sewerage network, the latter must be located below both in the order mentioned above.

The calculation of the networks can be done using spreadsheets by the Hardy-Cross method and with the aforementioned *camp calculator*. In MING NOP 0301/2011 'Construction of a COP', Annex 'G' shows the calculation of the distribution networks for a typical COP.

The technical water distribution network will normally be supplied by rainwater collected as described in section 3.1, Collection, and channelled through separate networks from those used for drinking water to underground storage tanks and from there to firefighting tanks, washing facilities, etc. for treatment and storage. Greywater from laundries and kitchens can also be supplied with the appropriate treatment. The calculation of technical water networks is analogous to that of drinking water networks.

Figure 8. Technical water used for firefighting [online]. Source: https://copecdnmed.cope.es/resources/jpg/8/2/1561618197328.jpg [Accessed on: 2026]

4 Wastewater treatment in military camps

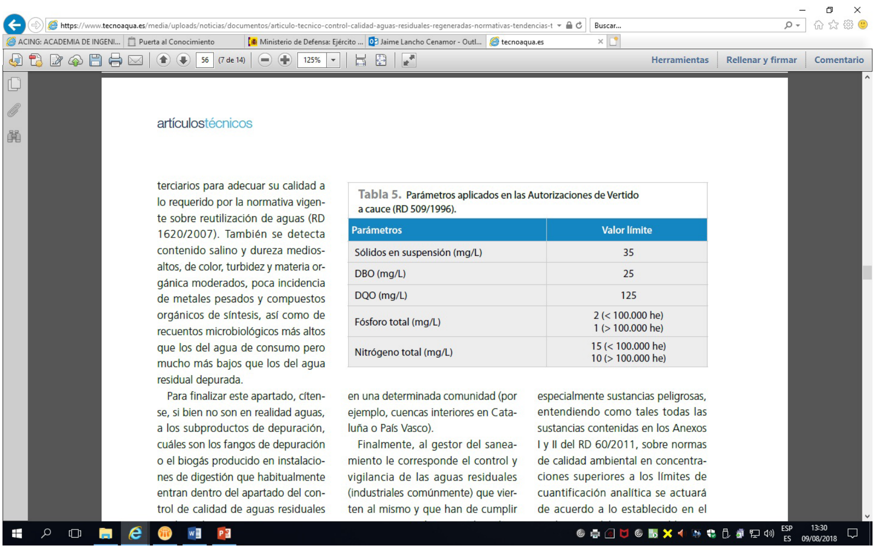
Wastewater is produced by humans and their activities and therefore contains waste. In military camps, this type of water is also produced and is usually classified as:

White water or rainwater, originating from rainfall, which will be utilised for personal benefit.

Greywater from sinks, showers, washing machines, kitchens, etc., which, as it has a separate network from sewage, can be treated and reused as technical water.

Sewage from toilets, which is much more polluted than the previous types, mainly consisting of faecal matter.

Military camps can be likened to small towns in terms of the treatment of this type of water. From this point of view, military camps with fewer than two thousand inhabitants are subject to Article 6 of Royal Legislative Decree 11/1995 on the proper treatment of wastewater and, subsequently, Royal Decree 509/1996, which defines effluent quality in the following table.


artículostécnicos

terciarios para adecuar su calidad a lo requerido por la normativa vigente sobre reutilización de aguas (RD 1620/2007). También se detecta contenido salino y dureza medios-altos, de color, turbidez y materia orgánica moderados, poca incidencia de metales pesados y compuestos orgánicos de síntesis, así como de recuentos microbiológicos más altos que los del agua de consumo pero mucho más bajos que los del agua residual depurada.

Para finalizar este apartado, citense, si bien no son en realidad aguas, a los subproductos de depuración, cuáles son los fangos de depuración o el biogás producido en instalaciones de digestión que habitualmente entran dentro del apartado del control de calidad de aguas residuales

Tabla 5. Parámetros aplicados en las Autorizaciones de Vertido a cauce (RD 509/1996).

Parámetros	Valor límite
Sólidos en suspensión (mg/L)	35
DBO (mg/L)	25
DQO (mg/L)	125
Fósforo total (mg/L)	2 (< 100.000 he) 1 (> 100.000 he)
Nitrógeno total (mg/L)	15 (< 100.000 he) 10 (> 100.000 he)

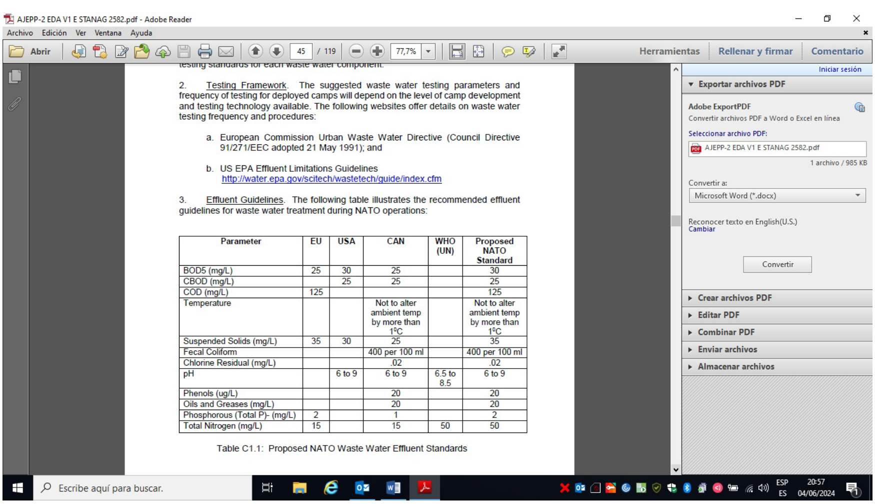
en una determinada comunidad (por ejemplo, cuencas interiores en Cataluña o País Vasco).

Finalmente, al gestor del saneamiento le corresponde el control y vigilancia de las aguas residuales (industriales comúnmente) que vierten al mismo y que han de cumplir

especialmente sustancias peligrosas, entendiendo como tales todas las sustancias contenidas en los Anexos I y II del RD 60/2011, sobre normas de calidad ambiental en concentraciones superiores a los límites de cuantificación analítica se actuará de acuerdo a lo establecido en el

Figure 9. Effluent quality parameters and limits

STANAG 2582 makes the following proposal for effluents:


2. Testing Framework. The suggested waste water testing parameters and frequency of testing for deployed camps will depend on the level of camp development and testing technology available. The following websites offer details on waste water testing frequency and procedures:

a. European Commission Urban Waste Water Directive (Council Directive 91/271/EEC adopted 21 May 1991); and

b. US EPA Effluent Limitations Guidelines http://water.epa.gov/scitech/wastetech/guide/index.cfm

3. Effluent Guidelines. The following table illustrates the recommended effluent guidelines for waste water treatment during NATO operations:

Parameter	EU	USA	CAN	WHO (UN)	Proposed NATO Standard
BOD5 (mg/L)	25	30	25		30
CBOD (mg/L)		25	25		25
COD (mg/L)	125				125
Temperature			Not to alter ambient temp by more than 1ºC		Not to alter ambient temp by more than 1ºC
Suspended Solids (mg/L)	35	30	25		35
Fecal Coliform			400 per 100 ml		400 per 100 ml
Chlorine Residual (mg/L)			.02		.02
pH		6 to 9	6 to 9	6.5 to 8.5	6 to 9
Phenols (ug/L)			20		20
Oils and Greases (mg/L)			20		20
Phosphorous (Total P)- (mg/L)	2		1		2
Total Nitrogen (mg/L)	15		15	50	50

Table C1.1: Proposed NATO Waste Water Effluent Standards

Figure 10. NATO wastewater parameters

The sanitation systems used in military camps, depending on how they group the three types of wastewaters, can be:

- Unitary: in which the three types of water are treated together. This system is, in principle, the least economical, because although less material is used in its construction, it is more expensive to maintain and requires the treatment plant to be oversized to handle more water flow than in separate networks.

– Separator: in this, one network carries sewage and another carries grey and white water. It is more expensive to build, but cheaper to maintain and adjusts the size of the WWTP. Greywater is only combined with white water for treatment and use as technical water.

– Mixed: this is the system most commonly used in military camps. The ablution containers have a single wastewater outlet, which mixes sewage water from the toilets with greywater from the sinks and showers and passes it all into a sewage network.

  On the other hand, rainwater is channelled into another network for use, either as technical water or as raw water to be used in supply after appropriate treatment. Greywater from kitchens, laundry rooms, etc., depending on the situation, can be combined with rainwater for use as technical water or connected to the sewage system.

It is advisable to place a grease trap at the greywater outlet in the kitchen so that this water can be used for technical purposes, thereby facilitating its treatment.

The best option, *a priori*, is to use a mixed system with a single water outlet in the black and greywater ablution containers, with a separate network for this water to the WWTP and another network for rainwater and greywater from the kitchen and laundry for treatment as technical water, taking the precautions mentioned above regarding the separation of networks from the outset, differentiating between the sewage water drainage network (including grease and other contaminants) from those that only carry traces of detergents (personal hygiene).

However, if water scarcity makes it advisable, white water can be used for consumption and greywater from kitchens and laundries can be used for technical water treatment. The rainwater from the first few minutes must be treated as sewage and therefore conveyed to the WWTP. The rest of the rainwater is channelled to the utilisation network, either for purification or for treatment as technical water, depending on the case.

Wastewater should be channelled using the natural slope of the land to feed into the pipes. These can be installed in simple, short, straight sections when connecting ablution containers to septic tanks located a short distance away. in this case, the most basic precaution is to provide an adequate slope towards the tank to facilitate gravity drainage and to respect the outlet diameter of the container, which, in most of the models available to the water treatment centre, is 125 mm. this value can be increased to 200mm with an adapter for ease of supply and a minimum slope of 4 m/km, but in no case can the diameter be reduced as this would cause blockages.

For white and greywater from kitchens and laundry rooms, the layout should take advantage of the natural slope for runoff drainage, as in the case of drainage. The minimum recommended diameter is 200 mm, and the material used should be resistant to erosion, such as polyethylene and PVC. In this case, the relationship between the pipe diameter and the minimum gradient is shown in the following table:

Ø	**200**	**250**	**300**	**400**	**500**	**600**	**700**	**800**	**900**
Minimum gradient m/km	4	2.7	2.2	1.45	1.1	0.8	0.67	0.55	0.5

This ensures that the water velocity remains between the minimum values of 0.5 m/s at average flow and 5 m/s at maximum flow, thereby maintaining the water's carrying capacity and preventing sedimentation in the pipes and possible erosion of the conduits, which could cause premature wear.

The procedure for implementing the restructuring must be established from the outset, as it is needed from the very beginning.

One possibility is as follows:

- Entrance and during the construction of the camp with chemical toilets and a company contracted for their evacuation and maintenance. Drainage of white and greywater outside the campsite area, using the road network or periodic emptying tanks contracted with companies.
- As soon as possible, installation of ablution containers connected to septic tanks that are emptied periodically by contracted companies. Improved drainage of grey and white water.
- Installation of the WWTP and construction of the sewage disposal network. Construction of the rainwater collection network and installation of the appropriate tanks (for raw water intended for purification or technical water treatment).

- Construction of storm water tank. Improvement of the drainage network to the aforementioned reservoir. Construction of a greywater collection network using the existing drainage network. Construction of a greywater treatment plant for use as technical water. Construction of technical water tanks for firefighting purposes initially and, subsequently, for vehicle washing, irrigation and other uses.

Wastewater management must, of course, be progressive and perfectible. To measure wastewater pollution, the population equivalent (PE) unit is used, defined in the regulations as 'biodegradable organic load with a biochemical oxygen demand (BOD_5) of 60 grams of oxygen per day'. For the sizing of the WWTP, reference can be made to a long list of publications, one of which is the *Manual para la implantación de sistemas de depuración en pequeñas poblaciones* (*Manual for the Implementation of Treatment Systems in Small Communities*) CEDEX-CENTA (Spanish National Public Works Research Centre- Experimental Center for New Water Technologies), specifically section 2.11, 'Flows and loads for the design of the wastewater treatment plant'.

The most common wastewater treatment methods in small communities, and therefore applicable to military camps, are:

Pre-treatment, the aim of which is to remove most of the contaminants that, due to their size and nature, should not pass on to other treatment areas, such as coarse and floating aggregates. In our case, fats and cellulose must be removed, as both are highly detrimental to the efficiency of subsequent processes. Grease and hydrocarbon waste must be disposed of as close as possible to kitchens or workshops to prevent emulsification in water.

In turn, it is divided into:

- Roughing, for the removal of small-medium sized particles by intercepting them with grates and sieves.
- Desanding, for the removal of dense materials such as sand with diameters greater than 0.2 mm. This prevents sedimentation in channels, pipes and treatment units, thereby also protecting the pumps from abrasion.
- Degreasing, whose purpose is to remove grease and other matter lighter than water that is floating on the surface. Desanding and degreasing can generally be carried out together using an aerated desander-degreaser with a mobile bridge.

Primary treatments, whose objective is the removal of suspended and floating solids.

The following possibilities exist:

- Septic tanks. They are a simple wastewater treatment system whose main objective is to remove solids from the water. It is used as the sole treatment in camps with fewer than 250 PE or as the primary treatment in camps with up to 1,000 PE.
- Imhoff tank. It is a tank with two distinct areas: an upper sedimentation area where solids settle, and a lower digestion area where the settled solids are stored and digested. They are separated by a structure that prevents gases from passing from the digestion zone to the sedimentation zone. It is used as an alternative to septic tanks with the same limitations regarding the separation of rainwater and greywater.
- Primary decanting. Its objective is to eliminate most of the suspended solids by means of gravity. It involves the construction of the WWTP, which normally entails a financial investment and construction and commissioning times that are only profitable in the case of camps of a certain size, above 500 PE, and with a medium- and long-term forecast of permanence always above two years.

Secondary treatments: the objective is to remove biodegradable organic matter dissolved or in colloidal form and the remaining solids and nutrients. The following options may be used:

- Prolonged aeration. It is a variant of the conventional activated sludge system. It consists of four phases: biological oxidation in the biological reactor, which is suitably aerated and contains a bacterial culture in suspension that degrades organic matter under aerobic conditions; secondary settling, which separates solids from liquids using a settling tank or clarifier, sludge recirculation (culture) to maintain the concentration of microorganisms, and periodic removal of excess sludge for subsequent treatment, which can be dried and stored properly and then transferred to a larger plant contracted for this purpose.
- Bacterial beds. They consist of the traditional variant of biofilm processes. Oxidation is achieved by circulating air and wastewater through a porous medium. The biofilm of microorganisms develops and grows on the surface of the porous filling material, which is usually stone or plastic pieces with a large surface area per unit volume. The wastewater enters

the bacterial bed from above and the air from below, thus producing aerobic digestion so that the sludge and excess water are directed to a secondary decanter-clarifier for separation of sludge and water, part of which is redirected to the bacterial bed.

- Rotary biological contactors. They consist of rotating supports (discs or cylinders) semi-submerged in the wastewater onto which the biofilm adheres. They consist of two phases: the contactor itself and the decanter-clarifier for separating sludge and treated water.

Figure 11. Parts used in bacterial beds [online]. Source: https://th.bing.com/th/id/OIP.mqOQcVtAI2UJJtU2BczGswHaE8?rs=1&pid=ImgDetMain [Accessed on: 2026]

Figure 12. Discs in bacterial bed [online]. Source: https://th.bing.com/th/id/R.55c3fe2266a8fcab38b9534ad9dda10e?rik=fiC9BsLfFk2NfQ&riu=http%3a%2f%2fwww.aguasresiduales.info%2fmedia%2fimages%2fckfinder%2fuserfiles%2fimages%2f1012.JPG&ehk=SLHn0C5XQgHwJRSEdYShXyAHzVZVdrNznvN8bavNUiw%3d&risl=&pid=ImgRaw&r=0 [Accessed on: 2026]

Tertiary treatments produce higher quality effluent in which nutrients and pathogens are removed. This minimises the risks of eutrophication of the receiving waters and contamination by viruses present in the wastewater. Normally, they have an initial phase based on mechanical filters such as sand or diatomaceous earth, followed by other processes such as reverse osmosis filtration and the application of UV light.

These treatments are applied to effluent when the objective is to obtain reclaimed water for subsequent use, i.e., to obtain water that meets quality standards in principle for reuse as technical water, which is not the case in military camps to date. As an additional safety measure, it is advisable to chlorinate the effluent before discharging it into the environment.

Extensive treatments such as lagooning and constructed wetlands are environmentally sustainable, but difficult to implement in current water treatment deployment scenarios, which is why intensive treatments, as described above, are mostly chosen for both secondary and tertiary treatments.

The solid by-products resulting from wastewater treatment at WWTPs (sludge and other debris separated during pre-treatment) must also be disposed of. They are dried out and some are incinerated, others are disposed of in landfills, and the rest can be used as agricultural fertiliser.

Special precautions must be taken about incineration, as the fumes from improper combustion or the wind-blown ashes resulting from it present a high pathogen potential. Incineration must be carried out in a specific furnace at a high temperature to ensure the destruction of pathogenic organisms. In the case of camps, the most practical solution is to hire a local company to remove and subsequently treat this sludge.

For a detailed study of each of these processes and an assessment of their suitability for each specific case based on the advantages and disadvantages of each, we recommend consulting the *Manual para la implantación de sistemas de depuración en pequeñas poblaciones - CEDEX- CENTA* (*Manual for the Implementation of Treatment Systems in Small Communities*).

One solution for treating wastewater in camps is the use of modular, compact, and transportable WWTPs marketed by specialised companies that have the capacity to install them almost anywhere in the world. These WWTPs meet all the requirements for treated wastewater in the NT and, therefore, those of the countries in which the water treatment can be deployed. It is necessary to enter a specialised maintenance contract with the company that installs this type of equipment, in order to ensure that it functions correctly and thus prevent contaminated effluents from being discharged into the country's public waterways.

It is also important to contract with the installation company to supply the chemicals necessary for proper operation, especially if deployed in scenarios where the acquisition of these products may be compromised.

There is the option of installing these compact, transportable treatment plants from different manufacturers for wastewater. Some of them are mounted in standard twenty- and forty-foot shipping containers for ease of transport, and it is also possible to install several in parallel for selective operation depending on the occupancy of the camp.

Figure 13. BRM biological treatment plant with external pressure membranes [online]. Source: https://www.protecmed.com/wp-content/uploads/2017/03/Ejercito-I.jpg [Accessed on: 2026]

These WWTPs must meet a series of requirements in order to be operational and effective in our camps. These characteristics are:

- Be easily transportable with standard container dimensions.
- Modular, so that several modules can work in parallel as required.

- Expandable depending on the increase in camp occupancy.
- Quick installation and commissioning.
- Durable.
- Easy to maintain and operate.
- Reusable.
- Low energy consumption.
- Low maintenance and operating costs.
- Low environmental impact.
- Have comprehensive guarantees and international technical support.
- They must not generate annoying noises.
- They must not produce unpleasant odours.
- High treatment capacity so that effluents comply with current regulations.

There is the possibility of installing large-capacity containerised WWTPs (up to 5,000 PE) that could serve any type of camp that the Spanish army has set up to date.

However, it is important to be aware of the design parameters of these plants, which are often sized for developing countries with much lower water consumption than that produced in military camps, in order to avoid lower-than-desired yields.

The immediate challenges are, on the one hand, to optimise the disposal of waste brine in desalination processes, make better use of rainwater and obtain reclaimed effluent water from WWTPs with parameters that would make it suitable for technical use.

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STANAG 2136. Water Supply on Operations.

STANAG 2582 AJEPP 2 EDA V1 Allied Joint Environmental Protection Publication.

STANAG 2885. Emergency Supply of Water in Operations

Chapter Five

Water and Artificial Intelligence

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Abstract

Owing to the increasing digitalisation of today's world, artificial intelligence has been infiltrating our everyday lives for quite some time. The water sector, despite its general reluctance to change, is also beginning to embrace the new paradigms associated with the application of machine learning techniques. This introductory article aims to give an overview of the future implications that artificial intelligence has or may have in the world of water. It begins with a breakdown of the basic principles of artificial intelligence and machine learning, in order to establish the basis on which to develop the subsequent arguments. The importance of water as a resource and its character as an essential resource for society is then briefly discussed. Emphasis is placed on its cross-cutting nature and its natural tendency to generate complex problems, which, in turn, justifies the potential interest in the use of artificial intelligence techniques. Finally, the text focuses on describing some of the main contributions that artificial intelligence has already made to the world of water resources, the difficulties associated with the paradigm shift

that this entails and the risks associated with the adoption of these new technologies.

Keywords

Machine learning, Artificial intelligence, Algorithms, Machine learning.

Introduction

The term 'artificial intelligence' refers to a set of cross-cutting technologies whose applications have begun to attract widespread public interest over the last decade. Today, there is no universal definition of artificial intelligence, largely because it refers to a field of knowledge experiencing exponential growth and evolving extremely rapidly, but it could be said that it refers to a discipline within computer science that focuses on the automation of complex tasks, such as learning, reasoning or prediction that, traditionally, it was thought only a human intelligence could carry out.

Artificial intelligence algorithms are able to process large data sets, find complex correlations between them and use them to achieve a goal, which may be, for example, the prediction of a certain behaviour. In this sense, there is some debate about whether there is really a difference between artificial intelligence and traditional statistical inference. Without going into details, one could argue that machine learning is nothing more than a logical evolution of statistical inference techniques, derived from technological advances in recent decades. The great contribution of artificial intelligence is the development of algorithms with the ability to learn autonomously from examples, similar to how we humans learn. To better understand what this means, consider, by way of example, what the natural learning process is like: an engineering student starts by memorising a formula, which they then use to solve a series of concrete exercises. During this process, their brain learns to go further, to extrapolate the use of the formula. They understand that the underlying principle allows them to address a myriad of practical issues, not just the theoretical examples they used to learn. Similarly, computer algorithms aim to detect patterns in data sets and then use them for a practical purpose. In fact, this is how algorithms programmed into websites, for example, function, by analysing the history of their users' visits to understand the products of which they may be potential consumers, and, on this basis, they generate personalised advertisements in real time.

Contrary to what many people believe, artificial intelligence is not new. In fact, the term was coined almost seventy years ago, during a conference organised by Dartmouth College in 1956 (Moor, 2006). Similarly, algorithms widely used today, such as decision trees or neural networks, have their roots in the 1950s and 1960s (Rosenblatt, 1958; Belson, 1959; Morgan and Sonquist, 1963), and there are even earlier precedents in academic literature (McCulloch and Pitts, 1943). It can therefore be concluded that artificial intelligence is a discipline with a more than respectable history behind it.

What is new is the democratisation of computing, understood as the availability of computers to the general public, whose processing power is now taken for granted, but which, until a few decades ago, no one could have imagined. Such is the increasing digitisation of our daily activities—and their tracking by third parties—that large databases have emerged that can be exploited by algorithms to improve their predictive abilities. From advertising and marketing to weaponry and defence, via the financial world, there are increasing examples of how the mass adoption of artificial intelligence techniques is having a direct impact on our lives.

The aim of the following pages is to highlight what artificial intelligence can bring to the water sector and to discuss its possible practical implications in the near future. We will start by discussing some basic concepts, such as the notion of machine learning, in order to understand how artificial intelligence algorithms work at a conceptual level. The emphasis will then turn to the cross-cutting nature of water as a resource, whose complexity provides an ideal meeting point with the world of artificial intelligence. It then explains why the use of artificial intelligence represents a major paradigm shift and the difficulties involved in its adoption and gives some examples of real-world applications of artificial intelligence in the water resources sector. Finally, some of the main risks associated with artificial intelligence will be discussed, including its water consumption, its potential vulnerability to malicious threats such as cyber-terrorism, and various ethical issues on which there is still no clear consensus.

1 The basics of artificial intelligence

The advent of artificial intelligence has brought many neologisms into everyday vocabulary. Terminological confusions are frequent and often result from a lax use of terminology by those who use it. Thus, there are many terms relating to the field of artificial intelligence that are commonly heard in the media, and which represent different, but often highly complementary, concepts. Among these, one could include the following words, phrases, and acronyms such as *data science, data mining, generative intelligence, machine learning, AI, ChatGPT, big data, deep fake*, or *deep learning*, many of which have been adopted as loanwords by other languages.

1.1 Machine learning

Perhaps the most relevant concept for the purpose of this article is that of machine learning. Machine learning is the branch of artificial intelligence that aims to programme computers to learn from data sets and, ideally, act accordingly. Machine learning is broadly divided into two categories: supervised and unsupervised machine learning. Both are characterised by the use of mathematical procedures—algorithms—to find complex associations between different types of information contained in a database. The more frequently these associations or correlations are observed, the more reliable they tend to be. For this reason, if only as a matter of probability, it tends to be easier to find reliable correlations when working with larger datasets. Thus, it is not surprising that the world of machine learning is closely related to what has come to be known as *big data*—large and complex data sets that require non-traditional computer software for their correct processing and handling. Similarly, those disciplines in which techniques have reached a greater degree of development and implementation, are precisely those in which the generation of large datasets is inherent.

In the case of supervised learning, the algorithm attempts to predict one variable in the dataset based on the rest, using a set of solved example cases. To contextualise this within the field of water, take the example of a historical record of meteorological variables, such as wind speed and direction, temperature, cloud-coverage, pressure and precipitation. If the variable to be predicted,—or target variable—is rainfall, the algorithm will look for correlations between it and all the other variables—understood as explanatory variables—so that, knowing only the latter, the algorithm will be able to predict how much rain will fall.

Unsupervised learning is characterised by the absence of a target variable. In other words, unsupervised algorithms are not used to predict outcomes, rather they are used to search for patterns in the internal structure of the information within the database on which they are working. Returning to the previous example, the application of an unsupervised algorithm to the dataset would not predict rainfall as a function of the other variables, but would identify, for example, that in that particular dataset, wind direction and wind speed are strongly correlated with each other and with cloud-coverage, but only when the temperature is below a certain threshold, and that there is no significant correlation between any of these variables and instances of extreme precipitation.

At a more advanced level, it may be worth mentioning hybrid systems of machine learning, such as semi-supervised learning, where the value of the target variable is only known as part of the initial data set. Similarly, we have reinforcement learning techniques. This refers to a specific type of training in which algorithms are rewarded or penalised based on their ability to correctly predict an outcome. Ultimately, the performance of such algorithms is assessed according to their ability to maximise the value of a reward function.

Generally speaking, supervised learning algorithms are of more interest to us for this study, so the following text will mainly refer to them. Supervised machine learning algorithms are further divided into two types: classification and regression, depending on the nature of the target variable. Classification algorithms can learn and predict discrete-valued or categorical target variables. For example, they could be used to predict, on the basis of other variables, whether a well bored in a certain location will find groundwater or not. Regression algorithms, however, can learn and predict target variables with continuous values, therefore they could be used to predict the flow rate of a well drilled at a particular location.

1.2 Basic functioning of supervised learning algorithms

Given the introductory nature of this article, as well as the sheer multitude of different algorithms in existence, we will not concern ourselves with detailed explanations of their inner workings. Instead, we will limit ourselves here to providing a generic overview of their application process that can be considered representative of the vast majority of such algorithms. For those interested in further expanding their understanding, it is sufficient to reference some of the best-known algorithms, such as decision trees, random forests, support vector machines or logistic regression, and refer to the specialised literature on the topic (Breiman *et al*., 1984; Breiman, 2001; Pedregosa *et al*., 2011; Géron, 2017).

The application of a supervised algorithm consists of two phases: training, and then, calibration. In the first phase, a part of the available data set is used to train the algorithm, i.e. for the algorithm to establish correlations between the explanatory variables and the target variable. During this process, the algorithm can 'see' the target variable, so it knows the result it should obtain after combining the different explanatory variables. This process also makes it possible to optimise the various mathematical parameters controlling the algorithm. The part of the dataset which was not used during training is then used for the calibration phase, which is when the algorithm's ability to generalise is tested, i.e. whether it is able to predict the target variable when it does not know the outcome beforehand.

The algorithm's ability to predict the target variable can be assessed by different metrics, the simplest being accuracy, which is defined as the hit rate relative to the total number of prediction attempts. In practice, an algorithm unable to find correlations in the training phase will perform poorly during the calibration phase. This is known as underfitting and implies that the mathematical procedures governing the algorithm have difficulty interpreting the input data. The reasons for this can vary greatly. For example, the data set may be too small or lack a structure of interdependence between the different variables. It may also be the case that an algorithm has a very high accuracy in the training phase and a very low accuracy in the calibration phase. This is referred to as overfitting. In this case, one could say that the algorithm resembles a student who learns the exercises by heart and is able to reproduce them in exam conditions as long as they are always the same, but does not understand the underlying principles, therefore will tend to make mistakes when the teacher changes the numbers in the problem.

As mentioned above, each algorithm works differently. Perhaps the simplest example to explain how an algorithm proceeds internally is that of the decision tree. This serves to structure the information contained in a database in order to identify how the combination of the different explanatory variables can predict a given target variable. The name decision tree comes from the fact that information is structured like the branches of a tree: depending on a possible choice, certain possibilities or branches emerge, which in turn branch out into new possibilities. Each branch represents the effect of an explanatory variable, while the value at the end of each branch—the leaves—is the value of the target variable resulting from a given combination of explanatory variables.

To understand this better, think of a database that aims to predict what a person will eat today based on her past history. The available database contains information on what she has eaten each day for the last six months. This information is structured in several columns, which could be, for example, the day of the week, who she ate with, where she ate and, of course, the target variable, i.e. what she ate. A decision tree uses mathematical procedures to find the optimal way to structure this data so that, by knowing what day it is, with whom and where that person is going to eat, it is possible to predict in advance what she will eat today. Let us assume that the tree identifies that the most important variable—the first branching node—is whether the person eats alone or with others. Each of these two options is a branch. The first branch says that, if she eats alone, irrespective of all other variables, the data shows that she will always eat food that she has brought from home, so we would already be able to predict her behaviour. When, on the other hand, she eats with others, the second branch is used. This in turn branches into a new decision node, which corresponds to the second most important variable: the day of the week. The data shows that on Mondays and Wednesdays she eats alone, on Tuesdays she eats with her sister, on Thursdays with a co-worker and on Fridays with her mother. Each of these four alternatives in turn branches into the third most important variable, which is where she eats. Depending on who she has met, she will have a number of favourite places to eat. The location is the final variable: the logic is that each place has a different menu, with a different selection of fixed dishes, and that the person in question always tends to choose her favourites. Once you have a complete tree, if you know that today is Tuesday, that she will eat with her sister and that they will go to a certain Italian restaurant, you will know that there is a high probability that she will eat pasta.

By analogy, it is easy to understand how such a system can help to predict a household's water consumption relative to the explanatory variables such as the number of household members, the time of year and whether the household has a swimming pool.

2 Water: a multi-faceted and cross-cutting resource

Water is a necessary resource for all human beings, whether for hydration and hygiene, good health, food production, economic activity, recreation or environmental conservation. So much so that the level of access to safe drinking water reflects the level of development of any human society and one of the main socio-economic indicators that distinguish developed countries from low and middle-income countries. It is widely known, for example, that there is a high correlation between children's school attendance and the availability of safe drinking water (Ortiz-Correa *et al*., 2016). Water is also a resource of key strategic value, not only because of the fundamental role it plays in the water-energy-food chain, but also because of its involvement, in one way or another, in practically all economic activities. This is why the United Nations defines access to water as a fundamental human right, as well as a prerequisite for guaranteeing many other human rights (UN, 2002; 2010).

Evidently, the relationship between humans and water resources dates back to the dawn of humanity. It is no coincidence that the first four great ancient civilisations,—the Egyptians, settled around the Nile; the Mesopotamians, between the Tigris and Euphrates rivers; the Indus Valley Civilisation, around the Indus; and the Chinese, around the Yellow River—are identified in history books by the shared name of 'hydraulic civilisations'. Even today, rivers form the backbone of all landscapes. One only needs to look at the Nile, along the course of which almost the entire population of Egypt, one of the fifteen most populated countries in the world, resides; or the many rivers in Latin America, including the Amazon, which constitute an important source of transport and communication in the day-to-day lives of the riverside communities.

However, water management remains a major challenge in many parts of the world. The increasing pattern of industrialisation, urbanisation and migration, coupled with a growing global population, has resulted in increasing pressure on water resources. Scarcity, pollution, inefficient usage, spurious interests and conflict arising from competition between users are all capable of jeopardising the security of the supply for humans and for the conservation of ecosystems, representing a persistent concern for individuals, authorities, supply companies, and nature conservation groups, not to mention also for supranational bodies.

Regarding the latter, the geostrategic implications of water resources cannot go unmentioned in this overview. Indeed, the general public is generally unaware that access to water lies at the core of long-standing conflicts such as the Israeli Palestinian conflict and was the main cause of a war between Syria and Israel in the 1960s. While the number of recent armed conflicts linked to water is fortunately limited (Wolf, 1998), the fact remains that the conditions of scarcity in many regions of the world has created a breeding ground for future conflict (Makengo *et al*., 2021). This is exemplified via the growing rhetoric of confrontation over shared rivers between countries such as Ethiopia, Sudan, and Egypt, or India and Pakistan, as well as the recurrent problems between China and its neighbouring countries that make up the lower Mekong basin over issues such as the construction of headwater dams, river pollution and overfishing, to mention a few examples.

Many of the major environmental disasters of the last century have left aquatic ecosystems among the most severely affected. The images of the uncontrolled release of radioactive waste from the Fukushima nuclear power plant into the sea in 2011, the slow deterioration of the Aral Sea and the human communities that lived off it throughout the second half of the 20th century, and the oil pollution of the Niger Delta over the last few decades are still fresh in everyone's mind. Spain has experienced similar cases, albeit on a smaller scale, but nevertheless relevant: with regards to the *Prestige* oil spill, the drying up of the wetlands of Tablas de Daimiel National Park, linked to the intensive exploitation of the Estern La Mancha aquifer, and, more recently, the environmental problems concerning the Mar Menor and the wetlands of Doñana.

It follows from the above that, while there is a more or less reliable tradition of water resource management across almost all parts of the world, there is still much room for improvement in many aspects of environmental protection and water management. Therefore, there is no escaping the conclusion that the appropriate use of water resources is a multifaceted challenge, which must always be addressed from a multidisciplinary perspective, considering not only hydrological, but also social, economic, political, environmental, ethical, and cultural factors.

Artificial intelligence is, by its very nature, a technology capable of dealing with complex realities. Perhaps it is this reason that leads some to think of artificial intelligence as a suitable method of reaching the complicated trade-offs that often make water management difficult and tackling the deep-rooted issues that traditional methods have not been able to solve, from a different perspective.

3 Water and artificial Intelligence

3.1 The complex paradigm shift

Compared to sectors such as advertising, insurance or finance, the water industry has a long way to go when it comes to the use of artificial intelligence techniques. This is not at all surprising considering that the water sector is a notably conservative sector, heavily regulated and characterised by significant inertia, as well its slow adoption of new models and technologies. Similarly, the long planning and execution times and high costs of water projects are far from a natural fit with experimental methodologies. The same can be said for the political and public health implications of resource management, and of the strategic and sensitive nature of its usage.

In the field of water, there are a many different applications, models and decision-making structures that are well-established and informed by both practical experience and knowledge of the physical, chemical, geological and biological processes involved in the hydrological cycle. From this perspective, it can be said that artificial intelligence, although it could be an added value, is not perceived as a necessary evolution within the sector. To better understand this assessment, we can start with a conceptual analogy between natural intelligence and artificial intelligence. Perhaps the main difference between the two is the process by which the reasoning that leads to a particular action or response is carried out. Our brain uses millions of neurons to process the information it receives—a stimulus—and compares it with previous experiences to produce a reaction. In the case of artificial intelligence algorithms, the stimulus is a set of data, while the neurons are the mathematical operations for finding correlations between this data which, in turn, allow it to generate a response, equivalent to our reaction. Just as one can only understand the behaviour of the brain in broad terms, one can only understand the complexity with which mathematical operations interact on a given dataset at the level of principles. In other words, most artificial intelligence algorithms work like a black box: we know the input data, and we know that the algorithm is able to give us a correct prediction about it, but, in most cases, we do not know exactly why. This, in a sense, represents a radical departure from the paradigms that have been in place for more than a century. Indeed, as already mentioned, the natural processes that govern the hydrological cycle are well known: despite their complexity, human beings understand the mechanisms that generate precipitation, surface runoff or evapotranspiration, and we are able to predict them to a certain degree of accuracy using numerical models. The fact that artificial intelligence algorithms tend to replace these elementary physical processes with mathematical correlations that are not necessarily obvious detracts from their potential adoption in practice, as it clashes with the mindset of many professionals. From this point of view, the combination of both perspectives is possibly the most promising path for its adoption. In any case, it is to be expected that the latter will be overseen by professionals in the water industry, unlike in other fields, where it is data science professionals who introduce new technologies that, in turn, generate significant turbulence in relation to the activities of long-established professionals. The art and graphic design sector is often mentioned as an example of this.

A major barrier is the absence of a critical mass of trained human agents. Indeed, the bulk of workers in water-related companies and organisations today lack specific understanding of artificial intelligence. While it could be argued that this is not strictly necessary—an Internet user does not necessarily have to have an understanding of programming—it is no less true that a specialised technician who deals with the results of algorithms on a day-to-day basis should have sufficient knowledge of them to know what eventualities could disrupt their performance, in order to prevent and, if necessary, solve them. From this perspective, the paradigm shift would first require a change of mindset among the senior employees of water management companies and organisations, as they should be the first to become aware of the need not only for machine learning-based tools, but also for staff capable of operating them effectively. Both the private sector and academia can play a decisive role in this through specific research and development programmes focused on designing innovative tools to address specific needs. Some examples shall be cited under the heading in the next section.

Another major obstacle to the application of artificial intelligence technologies in the water industry is the frequent absence of large hydrological datasets to work with at local and even regional scales. As a result, it is often difficult to obtain sufficient information for the training of train algorithms, which, in turn, limits the possibilities for developing tools and testing their effectiveness at an industrial level.

Finally, it could be argued that the contributions that artificial intelligence techniques are likely to make in the sector of water management are, generally speaking, less obvious than in other fields. This is not to say, however, that progress to date has been insignificant: it would be fairer to say that academia has led the way, with a mostly exploratory perspective on the potential of artificial intelligence, while industry and public administrations have stood by and waited. It should be stressed, however, that falling behind other areas is not necessarily a disadvantage, but rather quite the opposite, as it allows the opportunity to learn from successes and mistakes.

Still, to reference an encouraging Spanish example, some years ago, Madrid's public water utility, Canal de Isabel II, together with Fundación Canal, carried out detailed research on possible applications of artificial intelligence in the water sector (CYII-FC, 2020). This initiative documents a total of fourty-two specific examples in different European and non-European countries, including, among others, the design of pipeline networks; the prediction of faults in supply systems; the delimitation of algae zones by remote sensing; the development of intelligent irrigation systems; flood and climate prediction; the modelling of extreme weather events or the monitoring of dams with a view to improving their maintenance. Approximately one third of the applications identified were still in the research phase at the time of the report, while another third were in the pilot phase and the remaining proportion in the commercial operating phase. About 60% of experiments were concentrated in Anglo-Saxon countries—the USA, Canada, Australia and the UK—with a further 20% in European countries.

This is not surprising considering that, like most of the major innovation solutions of our time, artificial intelligence tends to find a preferential home in industrialised societies, where the main centres of technological development may be found. However, it is no less true that many direct applications to problems specific to low and middle-income countries have been recorded. In recent years, the authors of this article have had the opportunity to collaborate in an initiative sponsored by the Swiss Cooperation Agency and the government of the Republic of Chad. This initiative, which was successfully completed, involved the development of regional-scale groundwater mapping using machine learning techniques. In this case, the aim was to identify, using mathematical algorithms, pre-existing cartography and satellite images, the main markers for predicting the presence of groundwater in arid areas, in order to improve the water supply of the Abéché region in the east of the country (Gómez-Escalonilla *et al.*, 2022). A UNICEF-sponsored project is currently under way in southern Madagascar. Its main objective is to identify which community wells among those currently supplying rural areas would be suitable for the installation of solar-powered pumps in order to increase their operating speed and improve their energy efficiency (Asplund *et al.*, 2024).

3.2 Real-world applications of artificial intelligence in the field of water resources

As mentioned above, and despite the difficulties, what is certain is that there are now many concrete examples of artificial intelligence applications that have found their way into the world of water resources. This section will be dedicated to citing some of them. Broadly speaking, three levels of application may be distinguished, namely water management at basin level; network management, i.e. the storage, treatment and distribution of the resource, including all aspects of purification and runoff processes; and applications at user level.

Basin-level refers to everything related to improving understanding and management of the hydrological cycle at a regional level, which can often be visualised through the geographical concept of the river basin. In the Spanish context, this occurs at the level of hydrological planning and management, which, above all, is the level at which river basin authorities operate. At this level, the application of artificial intelligence has proven useful as a tool for processing satellite images and assessing changes in the availability of water resources, as well as for assessing the conservation status of ecosystems, both in the short and long term. Similarly, the use of supervised classification algorithms makes it possible to improve estimates of water consumption in the field of agriculture, the primary consumer of the resource worldwide. This, in turn, makes it possible to improve the management of problems related, for example, to the overexploitation of aquifers. In Spain, the use of supervised classification methodologies to identify crops from satellite images and estimate water withdrawals in the Mancha Oriental aquifer can be referenced as an example (Castaño *et al*. 2012).

Applications at the basin scale also include the development of early warning systems for the prevention of water-related risks, such as droughts and floods, as well as the management of water quality in aquatic ecosystems and their pollution problems.

At the network management level, artificial intelligence has been successfully used to optimise the effectiveness of technological infrastructures, both in terms of water treatment and purification (Alam *et al,* 2022; Toryla *et al*, 2023). It has also been used in the collection and interpretation of data, with a view to improving the overall efficiency of the operation of water supply infrastructures, as well as for the management of water losses in the network, the location of faults and points in need of maintenance. There are also examples of artificial intelligence applications for the development of early warning systems for water quality in the network, the pressure optimisation within the network or the application of technologies based on the principle of digital twins.

Finally, at the user level, a number of technologies are already available at the domestic level. This refers to, for example, smart meters, toilets and sprinklers. Some of these technologies are also applicable in the manufacturing sector. Examples include intelligent irrigation advisory systems, which often combine satellite or drone imagery with data on evapotranspiration and soil moisture data to streamline the costs associated with irrigation, and with them, water consumption itself.

In addition to the above examples, there are also applications developed in the field of research. As is the case with many of the exploratory methodologies and tools developed at this level, it is hoped that they will find a place in the production sector insofar as they are capable of responding to real problems and technology transfer mechanisms are adequately designed. These include predicting the evolution of hydraulic potential in groundwater, simulating the behaviour of reservoirs, predicting floods and studying the vulnerability of aquifers to pollution, among many others (Tang *et al*. 2023, Raisa *et al*. 2024, Himanshu *et al*. 2024, Singh *et al*. 2024).

4 Risks associated with artificial intelligence

4.1 Increase in water consumption

It is already clear that artificial intelligence can be used as a tool to improve water resource management in many circumstances. However, the mere fact of using it brings with it a few environmental implications that are becoming increasingly difficult to avoid. Several years ago, it became clear that large data processing centres generate a significant carbon footprint (Dhar, 2020; Henderson *et al*., 2020). More recently, its water footprint has also begun to be discussed (George *et al*., 2023), to the extent that a simple internet search is enough to find references to this issue in mainstream media (Guerrini, 2023) and on portals associated with supranational organisations, such as the OECD (Ren, 2023).

These data centres or servers are physical infrastructures, i.e. they consist of a mass of computer equipment with significant information processing capacity, stored in one or more buildings. Artificial intelligence relies on such supercomputers to store data, train algorithms based on that data, and finally execute them for their intended purpose, all while the system is protected in real time with state-of-the-art computer security measures.

Although there are only a few thousand across the globe, it is estimated that these large data centres already consume around 1% of global electricity and account for roughly the same proportion of the carbon footprint (IEA, 2023). As mentioned above, less has been said about its impact on water resources, but the fact is that a data centre consumes water via multiple channels. The most significant long-term consumption is cooling, as it takes place in real time over the entire lifetime of the infrastructure, which can be estimated in decades. In fact, the combined operation of the computer servers generates enormous amounts of heat, therefore the temperature of the installations needs to be continuously lowered by evaporating large volumes of water. The same can be said for the process of generating the electrical energy that servers need to operate, as power generation in thermal and nuclear power plants is also based on the principle of evaporating water to generate cold.

Cooling is an operational consumption, i.e. it takes place alongside, and is strictly necessary for, the operation of the data centre. There is not much information on the actual water consumption involved, which makes it difficult to compare it to the water footprint of other sectors, but there is some precedent in the literature that suggests that its water consumption is not negligible. Most of them refer to the Silicon Valley region in California, a region known both for its status as a centre for technological innovation and for its recurrent water problems.

For example, it is estimated that the training of a language model, such as the infamous ChatGPT, consumes millions of litres of water for cooling. Similarly, for every ten answers that this algorithm provides to its users, it can consume up to half a litre of water (Ren, 2023). To understand what this means, it is enough to just log on to the application via a web browser and start a casual conversation with the machine. In a way, it may resemble conversations carried out every day over mobile instant messaging applications and can go on for as long as users want. One only has to multiply the number of messages sent in the millions of queries per day and the previously mentioned water consumption to obtain an idea of the water demand involved.

Other operational consumptions include water and sanitation facilities, which are necessary for the day-to-day activities of employees, cleaning, heating and air-conditioning, as well as, where applicable, the watering of landscaped areas. These consumptions are easier to estimate, as they may be considered comparable to those of industrial or service sector buildings of a similar size and with a similar volume of employees.

The other major consumption block is implicit in the physical infrastructure that makes up the data centre itself. It is estimated, for example, that the production of just one of the hundreds of thousands of computer chips that such an installation may contain, requires, on average, around eight thousand litres of water. To this the water footprint of the materials used in the construction process must be added.

Given current trends, artificial intelligence is likely to start taking its own place in water consumption statistics in the near future. This inevitably leads to discussions regarding possible water consumption mitigation strategies. Although this still has a long way to go, several activities can be mentioned, including geographical optimisation, improvements in the water efficiency of systems, a regulative framework, the limitation of fraudulent activities and the implementation of transparency policies (Makridis, 2023).

Geographical optimisation is primarily concerned with implementing servers in humid climates, where water availability does not represent a problem and where hydropower generation is cheap and generally environmentally acceptable. It is also related to the spatial dispersion of installations: while at the regional level this helps to avoid water consumption being concentrated in a single geographical area, in terms of specific infrastructures, greater spatial dispersion facilitates heat dissipation and minimises cooling requirements, albeit at a higher economic cost. This, in turn, is directly related to the implementation of improvements in the water efficiency of data servers, including the development of more environmentally friendly cooling methods and the systematic implementation of energy-efficient chips.

From a regulatory standpoint, it seems appropriate that legislation should provide specific incentives for companies to reduce their water consumption, just as fines or progressive cost increases should be considered for those cases where misuse of the resource may occur. In the same way, the development of labelling strategies can help to stimulate responsible water use by large technology companies, in a similar way to how other industries use environmental seals of approval as a strategy to attract conservation-conscious customers.

Finally, it is worth mentioning that the world of artificial intelligence has some operational advantages. Unlike other fields such as agriculture, where estimating consumption can be problematic, in the case of large technology companies the advantage is that it is perfectly feasible to know the real consumption of the infrastructure, at least when it is connected to municipal water networks.

4.2 Vulnerability to malicious threats

Current legislation defines critical infrastructures as those 'strategic infrastructures whose operation is indispensable and does not allow alternative solutions, so that their disruption or destruction would have a serious impact on essential services' and, in turn, defines essential services as those that are 'necessary for the maintenance of basic social functions, health, security, social and economic well-being of citizens or the effective functioning of State Institutions and Public Administrations' (*BOE*, 2011). The same article of the law defines strategic infrastructures as 'physical and information technology facilities, networks, systems and equipment that support the operation of essential services'. It follows that essential services depend on critical infrastructures, which in turn depend on strategic infrastructures.

Everything that has to do with water treatment and supply is, by definition, an essential service, since, as previously mentioned, water is indispensable for the maintenance of daily activity. Similarly, any infrastructure intended to channel water supply for any use, including its return to the environment, constitutes critical infrastructure. Therefore, the use of artificial intelligence algorithms in the field of water resources would be easily accommodated in the field of strategic infrastructures. Accepting the dependence of water supply systems on artificial intelligence algorithms means accepting that they are, in turn, now subject to the risks to which strategic infrastructures are routinely exposed, including terrorism, organised crime—and also cybercrime—espionage and the effects of natural disasters, among others. Given that some of these threats are as new as the concept of artificial intelligence itself, it is still difficult to establish both the level of vulnerability to which society is exposed by adopting them and the possible consequences that could occur as a result.

Technological innovation brings with it intrinsic risks. Naturally, as new processes and tools are developed, new vulnerabilities also emerge. These are sometimes not easily detected during the development phase and are only exposed when faced with a malicious attack or an exceptional situation. The current paradigm of digitisation, understood as the interconnection of many aspects of daily life through the Internet, is likely to compromise the security of some systems based on the weaknesses of others if firewall mechanisms are not properly implemented. For this reason, processes that are critically dependent on technology may be more vulnerable and less resilient than certain traditional systems. As mentioned above, this is an important challenge to consider in the case of any essential service, including water supply.

An important aspect related to the latter is the anonymity of the network, which tends to mask malicious threats, which in practice can translate into impunity. Indeed, the fact that attacks on a given system can be carried out at anytime from anywhere in the world, combined with the absence of international police and judicial cooperation mechanisms, facilitates cyber-criminal activity and encourages recidivism.

Finally, other threats can be noted including the lack of a culture of privacy and digital security among citizens, as well as many unethical practices carried out by both private and public entities, which share sensitive data and information systematically. All of this is susceptible to vulnerabilities at all scales, and especially at the user level.

The former issue undoubtedly represents a major challenge for the future, whose implications will become ever clearer as digitalisation further influences everyday reality. However, the state of the art, as far as the development of artificial intelligence technologies is concerned, presents additional challenges that are far from being solved. It is true that tried and tested and fully functional applications do exist today, but they tend to address very specific situations and problems. For example, the use of smart meters in supply pipes makes it possible to establish consumption patterns by demographics of a given population. This allows sufficiently accurate prediction of water consumption based on variables such as time of day, time of year, income level and housing type, to name a few, which in turn helps to inform technical decision-making. However, as seen above, water is a fundamentally cross-cutting resource, whose management has not only social and economic, but also environmental, cultural and political implications. From this point of view, a major challenge for the development of useful applications is to provide algorithms that can handle more complex realities adequately. Another example illustrates what this means: with today's technology, it is technically possible to design a pumping system based on artificial intelligence algorithms that can predict the water requirements of an irrigation community in real time, extract water from the aquifer via a well, and automatically distribute it to neighbouring fields for irrigation. However, if the sole purpose of the application is to automate the process of extracting and distributing irrigation water, however successfully this is achieved, there is a risk of creating problems in the surrounding environment, such as the drying up of aquatic ecosystems associated with groundwater or the movement of certain pollutants through the subsoil. In other words, given the cross-cutting nature of the resource, the design and application of artificial intelligence tools in the field of water must always consider the possible direct or indirect consequences on society and ecosystems, in order to incorporate them, as far as possible, into the automated decision-making process and avoid unwanted effects.

As previously mentioned, artificial intelligence still has a long way to go to establish itself definitively in the water sector. From this perspective, it is indeed a novel technology and, as with any novel technology, artificial intelligence is not without its risks. One only has to look at other sectors where artificial intelligence has already achieved a notable level of acceptance to understand this. An example of something that will affect almost everyone is the complexity of the protection of personal data collected by artificial intelligence in an environment as unregulated as the Internet. By their very nature, algorithms require a huge volume of data to establish the correlations that allow them to predict certain variables based on others. This data occasionally comes from individual users, whose privacy may be compromised, sometimes from the data itself and sometimes from the information that can be derived from it, even for malicious purposes. The novelty of the technology prevents it from going beyond a series of generic assessments, however it seems clear that the development of standards for the protection of personal data must be a priority—through anonymisation techniques or otherwise—and for the same reason, artificial intelligence systems must be able to be monitored and, where necessary, audited, so that, where required, appropriate ethical and legal responsibilities can be attributed.

From an ethical point of view, the generalisation of artificial intelligence to water resources raises a number of issues (Doorn, 2021). While it is clear that algorithms can help to find optimal solutions to complex problems, especially when it comes to conflicts between users, it is no less true that the prospects for success will always depend on the analytical formulation of the problems, and ultimately there will always be a higher political decision. There is a duality here that could lead to a less-than-optimal use of technology, even if it provides truly effective solutions. This could, in turn, be detrimental to their adoption.

Finally, it should be borne in mind that the development of new technologies tends to be a source of inequalities, insofar as it is more feasible to have access to this type of applications in industrialised societies and in environments with greater purchasing power than in the context of middle and low-income countries and in disadvantaged social circles.

Conclusions

For some time now, the advent of artificial intelligence has brought about significant changes in everyday life. Some of its practical implications are already evident and are likely to increase in the future. It is to be expected that something similar will occur at the heart of different professional fields, although, as with any paradigm shift, the adoption of artificial intelligence techniques in the production sector will be a gradual process, not without its difficulties, with significant asymmetries from one field to another. While some sectors such as graphic design, banking or marketing have embraced these technologies almost immediately after their conception, the water world has been approaching them at a more cautious pace. This is largely attributed to the critical nature of water as a resource and the pre-existence of well-established management practices and methods rooted in a deep understanding of the chemical, physical, geological and biological processes that govern the hydrological cycle, which means that, without direct opposition, the adoption of these new technologies is not perceived as an urgent necessity.

Even so, there are already many direct applications of artificial intelligence in the field of water resources, both at basin, water supply, treatment and purification level, as well as at the level of the user. In general, these tools address very specific aspects and objectives, such as the optimisation of processes, consumption and costs. In this sense, a significant challenge for the future is the generalisation of its use to more complex problems, which will inform decision-making by giving weight to social, economic, hydrological and environmental variables at the same time.

The adoption of artificial intelligence techniques in the water sector is not without side effects. It is becoming increasingly evident that artificial intelligence has a notable ecological footprint, which translates into significant water consumption at the scale of large data processing centres. The implications of this will need to be addressed on a case-by-case basis, as they are likely to pose management challenges in water-stressed basins. On the other hand, artificial intelligence techniques entail risks related to the growing digitalisation of today's society, i.e. the fragility of its own highly interconnected systems, the problems derived from technological innovation, simultaneously creating new vulnerabilities as new tools are developed, or the absence of a culture of privacy and digital security, both at the level of companies and institutions and of the population as a whole. This represents a potential risk to the public, given the essential nature of water supply and the existence of new threats such as cyber-terrorism. Similarly, artificial intelligence raises important ethical debates in which there is still no clear consensus. For example, there is concern about data protection or social inequalities resulting from a lack of digital skills or access to information technologies.

From this, it may be concluded that the current period of technological flux in industrialised societies represents an excellent breeding ground for innovation, and that it has the potential to contribute to the improvement of water management practices in the future. However, there are inherent risks that will also need to be addressed as and when new challenges arise.

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Chapter Six

Water as a Threat To Security

Alberto Cique Moya

Abstract

Water has been a vital resource for humanity and has played a key role in the history of conflicts. Since the earliest civilisations, human beings have settled near sources of water, which has led to disputes over control of them. Strategists such as Sun Tzu recognised the strategic importance of water, which was used as a weapon through tactics such as poisoning wells or altering river courses. Today, water remains a strategic resource, whose unequal distribution and growing scarcity, combined with the effects of climate change and pollution, are causing tensions at local, national and international levels. The lack of access to drinking water and competition for water resources could intensify if not managed properly.

Continental water, comprising rivers, lakes and aquifers, is crucial for life and economic development. Its scarcity affects millions of people and is essential for agriculture, hydroelectric power generation and its use as a means of communication. Due to its geopolitical and socio-economic importance, water can be a trigger for conflict, especially in areas with ineffective management, leading to problems such as population displacement, food insecurity and environmental degradation. These conflicts can have economic, social and political consequences, impacting areas such as agriculture and political stability, hence their link to the Sustainable Development Goals (SDGs).

To prevent these conflicts, it is crucial to foster international cooperation, shared governance and promote transparency and dialogue between the parties involved. Successful examples of shared management include the Treaty of the River Plate and its Maritime Limits and agreements between Arab countries and Israel. Furthermore, the vulnerability of water infrastructure to sabotage and bioterrorist attacks is a current problem. To protect them, a comprehensive approach to water defence is needed, including physical measures, advanced monitoring and staff training to ensure the security of the water supply and prevent malicious acts.

Keywords

Water wars, Water conflicts, International cooperation, Vulnerability, Water defence.

Introduction

Human beings have always sought to live close to water sources. When they were hunters, they followed the animals they hunted for food, which sought out water to drink. As they became sedentary, they sought out the most fertile land, close to waterways, in order to obtain larger and better harvests. The problem our ancestors faced in accessing these more productive lands was that they were also desired by the different peoples who lived near them, creating ideal conditions for conflict over this vital resource. This has been the most frequent cause of conflict between peoples throughout history (Clark, 1944; Mays *et al.*, 2007; Argudo, 2019).

Aware of this reality, great strategists have always considered water as a means to achieve strategic, operational or tactical advantage. One example, among many others, is Sun Tzu's inclusion of the following thought in chapter XII, 'The Attack by Fire', of his work *The Art of War*: 'Water can be used to divide an enemy army, so that their strength is weakened and yours is strengthened'. This means that the use of water to support an attack signifies 'strength', which constitutes an 'effective weapon' for achieving victory (Tzu, 2015).

Throughout history, water has played a leading role, whether offensively or defensively, so it has always had a 'military aspect', either by allowing borders to be maintained, thanks to river channels, defending fortresses or, as in the case of the siege of *Krissa (Cirra)*, allowing it to be used as a 'vector of transmission' of a toxic substance to subdue a thirsty city (Frischknecht, 2003; Hidalgo, 2019).

The poisoning of wells and, consequently, the military use of water has been a constant throughout history. Thus, in the 6th century BC, the Assyrian armies poisoned their enemies' wells with ergot, an alkaloid of the ergotamine group produced by the fungus *Claviceps purpurea*, which caused the disease known as ergotism among those who consumed it, characterised, among other symptoms, by hallucinations (Vicente and Marquina, 2022).

Also, in the 6th century BC, during the first sacred war between the Delian League and Cirrha, the Greek lawmaker Solon used the stratagem of diverting the course of the Pleistos River, which carried water to the besieged city of Crissa, to prevent water from reaching the city and thus defeat them through thirst. However, this alone was not enough, so he ordered his troops to collect large quantities of the hellebore plant (*Helleborus foetidus*), which contains a series of toxins with cardioactive and spastic effects (hellebrine, ranunculine). When he considered that he had enough and the city was suffering from thirst, he threw the collected plant into the water so that it would mix and dilute in it and then redirected the course of the river towards the city, causing the thirsty besieged to fall ill after consuming the longed-for water, which allowed the defenceless city to be conquered (Mayor, 2009).

It is important to note in relation to this example that two tactics that are detestable under the laws and customs of war are being combined. On the one hand, the implementation of environmental modifications for military purposes, that is, the alteration of the course of the canal that supplied water to the city, and, on the other, the use of practices prohibited in almost all codes of conduct governing our way of life, which is none other than the deliberate contamination of water, and also of food, with toxic substances to infect or poison the living beings that consume them (Cique, 2023).

On the other hand, from a positive perspective, it should be noted that water poisoning is not only used as a military tactic but has also been used throughout history to obtain food resources through the use of toxic plants. Thus, some indigenous tribes 'poison' the water with plant extracts that have a stunning effect on fish or animals (Pitschmann and Hon, 2016).

There are many examples that could be included in this introduction to highlight how water has shaped the fate of armies, but as this is a document from the Spanish Institute for Strategic Studies, it seems appropriate to mention one of the events, albeit surrounded by an aura of legend, that has marked our history.

On 2nd December 1585, members of the *Tercio Viejo de Zamora* were surrounded by the Dutch army, which blocked the waterways in the area occupied by the Spanish and caused a forced flooding of the land. This tactic forced the five thousand Spanish soldiers to take refuge on a small promontory, waiting to be annihilated, as they did not consider surrender an option. Legend has it that on the night of 8 December, a soldier discovered a tablet bearing the image of the Immaculate Conception, ordering a procession to be held with it, which not only boosted the morale of the besieged soldiers but, according to the legend that has come down to us, that night the weather conditions caused the waters to freeze in an astonishing way, thus forging in the collective memory the so-called *Miracle of Empel*.

The freezing of the waters allowed the Spaniards to break out of their confinement and entrusted to the Immaculate Conception, launch a surprise attack on the Dutch and win the battle. This miraculous event led to the tercios dedicating themselves to the protection of the Immaculate Conception, as did her heir, the Spanish Infantry, among other military corps, including the military veterinary corps, as their patron saint (Villatorio, 2016; Latorre, 2023).

The fact that water is a vital strategic resource has made it the cause of the vast majority of conflicts in our history, but also in our present, and surely in our future, due mainly to geopolitical tensions over water use, as well as a consequence of climate change, as can be seen in table 1. Consequently, the international security environment will be further affected, and we will suffer *water wars* (Martín and Justo, 2015; De Stefano, 2019; Detges, Pohl and Schalle, 2017).

Dispute over water in the Nile basin	Dam projects and disputes in the Mekong River basin
Water scarcity and public discontent in Yemen	Water disputes in the Kaveri basin in India
Tensions arising from the use of the Euphrates-Tigris between Turkey, Syria and Iraq	Persistent drought and armed conflict in Somalia increase food insecurity in the country
Cross-border water disputes between Afghanistan and Iran	Local tensions over water privatisation in Cochabamba (Bolivia)

Table 1. Major water conflicts around the world

This introduction would not be complete without mentioning the use of water for criminal or terrorist purposes. In fact, some terrorist groups have recently proposed targeting water infrastructure, although it is important to note that these are less vulnerable than popular literature and or that reported in the media would suggest, not only because, depending on their design, their purification processes inactivate most of the biological agents that could be used. However, the vulnerability of the computer systems of these critical infrastructures cannot be overlooked (La Razón, 2001; Carus, 2001).

1 Water as a strategic resource and threat to security

The 22nd March is the day chosen by the United Nations to celebrate World Water Day. The aim of this day is simply to highlight the importance of conserving and protecting this vital resource for the health of the population and the environment. While this year's theme is 'Glacier Conservation', last year's theme was 'Water for Peace'. Under this slogan, the following three key messages were included (United Nations, 2024b):

- Water can create peace or spark conflict
- Prosperity and peace depend on water
- Water can get us out of a crisis.

These messages are based on the fact that approximately half of the world's population suffers from severe water shortages at least during part of the year (Intergovernmental Panel on Climate Change, 2022), and 2.2 billion people still lack safely managed drinking water (United Nations, 2023a). The geopolitical scenario is complicated because transboundary waters account for 60% of the world's freshwater flows, with 153 countries sharing territories within at least one of the 310 transboundary river and lake basins (United Nations, 2023b). And, from the perspective of this chapter, only twenty-four countries have reported that all their transboundary basins are subject to cooperation agreements (United Nations, 2021), which undoubtedly contributes to conflicts and threats to security.

The following are key aspects that highlight the importance of water as a strategic resource and its relationship to security risks and threats (Food and Agriculture Organisation of the United Nations, 2013; United Nations Security Council, 2016; Milne, 2021; World Bank, 2023):

- Scarcity and availability: the uneven distribution of water across the planet and population growth have made it a scarce resource in different regions of the world. The availability of fresh water per capita is decreasing, leading to tensions and conflicts over access and control.
- Food security: Water is essential for agriculture, and lack of access can threaten food security. Competition between agricultural, industrial and domestic use often leads to tensions and conflicts.

- Conflict and diplomacy: competition for water resources can trigger conflicts between countries or within them. However, it can also foster cooperation and diplomacy to sustainably manage shared resources.
- Impact of climate change: Climate change is affecting water availability and quality, exacerbating shortages in some regions and increasing the frequency and intensity of extreme weather events such as droughts and floods.
- Water pollution and quality: Water pollution from industrial, agricultural, mining and urban activities reduces its availability and quality, threatening human health and ecosystems.
- Inefficient water infrastructure and water management: inadequate water and sanitation infrastructure, poor water resource management, and IT vulnerability in developed countries can have very significant consequences for the population.

Any of these aspects on their own, or in combination with others, highlight the importance of water as a strategic resource in the multipolar world in which we live (Ayala, 2002; Lujan, 2023).

1.1 Water as a source of conflict: past, present and future

Water is an essential resource for life and development, but its sustainable management is crucial to prevent it from becoming a source of conflict and a threat to security in today's world. The importance of this statement relates to the aforementioned slogan 'Water for Peace' from the last World Water Day, which incorporates the following key messages (United Nations, 2024b):

- Water can create peace or spark conflict. When water is scarce or polluted, or when people have difficulty accessing it, tensions can rise. By cooperating on water issues, we can balance everyone's water needs and help stabilise the world.
- Prosperity and peace depend on water. As countries manage climate change, mass migration and political instability, they must place water cooperation at the heart of their plans.
- Water can get us out of a crisis. Harmony between communities and countries can be fostered by uniting around the fair and sustainable use of water, from United Nations agreements and conventions at the international level to actions at the local level.

Water is a vital resource for the survival of humanity and a crucial element for socio-economic development. However, its availability and quality are increasingly under threat due to factors such as climate change, pollution and inadequate management. This makes water a strategic resource of great geopolitical importance, and also a potential threat to security on various scales, from local to global (United Nations Department of Economic and Social Affairs, 2014; Andri, 2023; Hall, 2024).

In fact, water has been and will continue to be a source of conflict, both in the past and in the future, unless effective measures are taken to manage water resources sustainably and promote cooperation among stakeholders at the local, national and international levels in advancing the 2030 Agenda and achieving the Sustainable Development Goals (Spanish Agency for International Development Cooperation, 2022).

As mentioned above, water has historically been a trigger for conflicts and tensions between communities, regions and countries in the past, is so in the present, and will continue to be so in the future due to a combination of environmental, demographic, political and economic factors (Guisández Gómez, 2010; Cerrilo, 2016).

In the past, as mentioned in the introduction, many civilisations have fought wars and battles for control of water sources, rivers and water resources. One need only recall the conflicts in Mesopotamia over control of the Tigris and Euphrates rivers, as well as the water wars between the ancient Greek city-states (Roger-Lacan, 2023).

The shift from a VUCA (volatile, uncertain, complex, and ambiguous) environment to a BANI (brittle, anxious, non-linear, and incomprehensible) environment in the world we live in today has an even greater impact on the generation of water-related conflicts (Cantu, 2023), as access to water and its unequal distribution are frequent causes of conflict at the local level, due to competition for limited water resources that lead to tensions between farmers, urban communities and businesses. At the national and international levels, above all, due to the use and abuse of water from transboundary rivers, or the development of water infrastructure that affects downstream flow and thus alters the geopolitical balance of the area, a situation that is undoubtedly exacerbated by the potential effects of climate change on precipitation patterns and, therefore, on water availability, which will exacerbate regional tensions and existing conflicts.

Perhaps the most paradigmatic example of this is the Grand Ethiopian Renaissance Dam, as the activation of Ethiopia's first hydroelectric turbine marked the beginning of the path to electrical sovereignty, while for Egypt it posed an 'existential risk' in the words of Egyptian President Aldelfatah Al-Sisi, as the diplomatic confrontation between the two countries, joined by Sudan, continues to escalate (Borrel, 2020; Soler, 2002; Erdem, Awad Satti and Abdelrhee, 2021).

The future is no more promising than the present, as water needs continue to grow due to population growth, urbanisation of the natural environment and, without a doubt, the effects of climate change, which will undoubtedly have an impact at the international level due to the consequences at the regional level.

The construction and operation of the Renaissance Dam by Ethiopia, declared a national necessity, has altered the *status quo* of relations with Sudan and Egypt, while ignoring the impact on local populations and their economic environment in order to become an international electricity exporting power in the area. It should not be forgotten that, behind this economic desire to move away from the primary sector in favour of other sectors, there is a significant political component on the part of the Ethiopian People's Revolutionary Democratic Front (Aimé, 2016; Montag, 2021; Romero, 2024).

According to data collected by the Pacific Institute for the period 2020-2023, there were 543 conflicts globally, either because water was used as a weapon or as a cause or target of violence. Graph 1 shows how, since 2000, there has been a significant increase in conflicts worldwide, mainly in Asia and Africa (Pacific Institute, 2023).

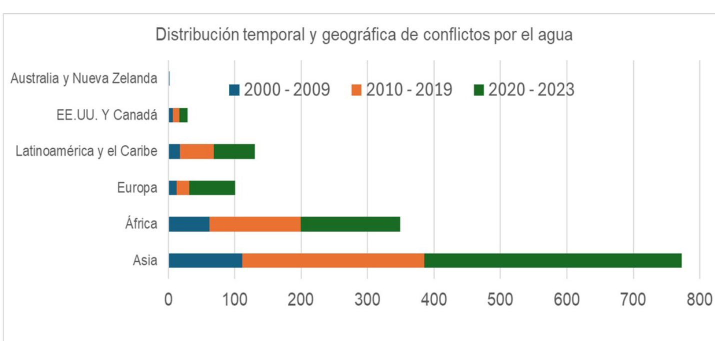

Figure 1. Temporal and geographical distribution of water conflicts (Pacific Institute, 2023)

In this regard, the Pacific Institute establishes three categories to frame water conflicts:

Trigger: water as a trigger or cause of conflict, where there is a dispute over control of water or water systems, or where economic or physical access to water or water scarcity triggers violence.

Weapon: water as a weapon of conflict, where water resources or water systems themselves are used as a tool or weapon in violent conflict.

Casualty: water resources or water systems as victims of conflict, where water resources or water systems are intentional or incidental victims or are targets of violence.

A closer analysis of the data for the period 2020-2024 included in table 2 shows how the number of incidents has increased as a result of Russia's invasion of Ukraine and, to a much lesser extent, Ukraine's invasion of Russia. From attacks on water and sanitation systems to attacks on power stations that leave the population without supply, including the destruction of dams, contamination of drinking water with sewage, or even the disruption of water processing systems at the Zaporizhzhia nuclear power plant (Pacific Institute, 2023).

	Casualty	**Trigger**	**Weapon**
Western Asia	112	46	9
South Asia	12	87	1
Eastern Europe	58	2	10
Sub-Saharan Africa	45	71	3
Latin America and the Caribbean	9	44	1
North Africa	13	12	1
South-East Africa	13	2	
Central Asia		6	
North America	2	9	3
Western Europe	3	5	1
Southern Europe	1	1	

Table 2. Water conflicts during the period 2020-2024 (Pacific Institute, 2023).

This pessimistic scenario will probably become more complicated in the near future, since, if expectations for 2050 are met, water stress, or the relationship between water demand and renewable supply that measures competition for local water resources, will have an impact on the entire world population, which will undoubtedly increase the likelihood of a more insecure world (Kuzma *et al*, 2023).

1.2 Definition of "water wars"

There is no clear definition for the concept of 'water wars', as the definition varies to a greater or lesser extent depending on which factor is emphasised most. As an example, Farley considers that the concept of 'water wars' refers to conflicts over economic exploitation rights to water, whether through support for fishing fleets, the search for underwater resources, or access to fresh water for drinking, industrial and agricultural purposes (Farley, 2021).

The above definition, as can be inferred, does not seem to be the most appropriate for the context of this chapter. Hence a more consensual definition must be considered that encompasses the aspects addressed in this strategy paper, which is none other than: water-related conflicts or 'water wars' refer to political and diplomatic tensions, or violent conflicts that arise between countries, regions or communities due to disputes over access to, control or distribution of surface water resources, such as rivers and lakes, and shared underground aquifers, which may arise due to water scarcity, overexploitation of water resources, pollution, climate change or other factors affecting water availability and quality.

Water conflicts can arise due to factors such as territorial disputes, competition for resources, political difficulties and border demarcation. They can also be triggered by events such as droughts, water stress and water scarcity, which increase competition and pressure on available water resources. The consequences of water conflicts can be significant, leading to environmental degradation, socio-economic consequences and risks to human health and well-being. Understanding the causes and dynamics of water conflicts is crucial for developing strategies to resolve them and ensure sustainable water management (Enayati *et al*, 2021; Angelakis *et al.*, 2021; Gleick and Shimabuku, 2023).

2 Importance of water as a strategic resource

Farley, quoted above, referred to the maritime sphere within a broad concept of 'water wars'. However, for the purposes of this strategy paper, it seems reasonable to limit ourselves to continental water, which includes rivers, lakes and underground aquifers, as set out in the definition above as a strategic resource of vital importance, since it sustains many aspects of human life and terrestrial ecosystems, making it essential to ensure the continued availability of quality water for present and future generations. This is because water affects all aspects of development and is linked to most of the Sustainable Development Goals (SDGs), as well as driving economic development, supporting healthy ecosystems and being essential for life (United Nations, 2022).

The most relevant factors determining the importance of water as a strategic resource are:

- Drinking water supply: inland waters are the main source of drinking water for the human population, as they provide the basic supply for drinking, cooking, and personal hygiene. In this regard, according to World Bank data, nearly 2 billion people worldwide do not have access to safely managed drinking water services, 3.6 billion do not have safe sanitation services, and 2.3 billion lack basic handwashing facilities (World Bank, 2023).
- Agriculture and food security: Continental water is essential for agriculture and livestock farming, as it depends heavily on the availability of irrigation water for growing food, but also for supplying water to animals. Therefore, a sufficient supply of water in terms of both quantity and quality is vital to guarantee food security for populations (The Food and Agriculture Organisation of the United Nations – Earthscan, 2011).
- Electricity generation: hydroelectric power stations use watercourses to generate electricity, thereby contributing to the production of clean, renewable energy. However, this positive aspect becomes a source of tension, as we have seen previously when referring to the Great Renaissance Dam.
- Transport and trade: although this factor is more closely linked to maritime security and its relationship with piracy, we must not forget the role that 'river pirates' play, if we can put it that way, in regional, national and international security, which is fundamentally associated with the development and establishment of mafias (Mustard, 2021). The triple border is a clear example of this, as the border area between Argentina, Brazil and Paraguay is considered one of the most unsafe regions in the world due to the high level of criminal activity, which is

a source of tension between the three countries that share a border, especially when *Hizbullah* is present in the area and is linked to terrorist activity in Latin America (Kheribich, 2024).

– Ecosystems and biodiversity: it is well known that continental aquatic ecosystems are vital for the development and survival of animals and plants. The construction of dams, as discussed above, not only has international consequences, but is also associated with highly controversial environmental consequences (Flores, 2022; Montalvo, 2015).

2.1 Water as a trigger for conflict

Of the 1.386 billion cubic kilometres present on the blue planet, only 93,100 cubic kilometres (less than 1% of the total) are the main source of fresh water (General Secretariat of Education. Department of Education and Employment, 2022). It is therefore not surprising that it is a trigger for conflict due to its great geopolitical and socio-economic importance at a global level.

Among the most important factors influencing the outbreak of conflicts are:

1. Scarcity and competition for resources: competition between different actors and economic sectors in a context of progressive water demand leads to conflicts of varying severity depending on the use of an increasingly scarce resource (Frutos *et al*, 2021).
2. Conflict over access to and control of water sources: Nothing has changed in the world in terms of conflicts over access to and control of water sources such as rivers, lakes and groundwater, even at the local and regional level (Maggie *et al.*, 2022).
3. Impact of climate change: global water availability is being affected by climate change. More intense periods of drought followed by flash floods generate tensions among populations in affected areas, as exemplified by 'forced' migrations that contribute to increased conflicts over competition for water resources (Koubi, 2019).
4. Water pollution and degradation: the contamination of water resources by industrial, agricultural and urban waste contributes to the degradation of water quality in many parts of the world, mainly as a result of armed conflicts, which

undoubtedly contributes to perpetuating these conflicts over time (Mukete *et al.*, 2016).

Perhaps mining activity is an example of how geostrategic interests clash or relate to the economic interests of companies, as they cause severe environmental damage through the intensive use of natural resources such as water and affect communities settled in those territories subject to intensive environmental mining exploitation, which can lead to social conflicts (Azamar *et al*, 2018).

5. Population displacement: Water scarcity and related conflicts can lead to the displacement of populations, both within countries and across borders. This displacement may increase social and political tensions, as well as conflicts between ethnic groups and communities (Fatli, 2018).

2.2 Water as a military tool or weapon of conflict

As we have seen throughout this chapter, controlling access to water has been one of the most commonly used tactics in wars, but also one of the most reviled throughout history and today, with the same purpose, i.e. to regulate the flow of water in order to attack the interests of the opponent. An example of this is the control of river basins, as well as military attacks or sabotage of water infrastructure such as dams, canals, pumping stations or distribution networks, among other infrastructure, with the aim of interrupting or affecting the supply of water for human consumption, agriculture and other uses, which undoubtedly exacerbates the humanitarian crisis and food insecurity, not to mention the fact that it also affects the control of electricity production.

Strategic control of water proves crucial in the Arab Israeli conflict. Thus, Israel's control of the Golan Heights gives it a strategic advantage over Syria and Jordan due to its control of the Jordan River and its tributaries (Inbar, 2019).

The destruction of the Nova Kakhovka Dam in the Kherson region led to the evacuation of entire towns due to the resulting flooding, as well as a subsequent drought, and a battle over the narrative in order to accuse the opponent of causing the environmental disaster (Euronews, 2023; Gettleman, 2023). Furthermore, in early 2022, Russian troops cut off the water supply to the city of Mykolaiv for twenty-four days, and when it was restored, the water was undrinkable due to the accumulation of salt and toxic chemicals (Dolgin, 2023). In fact, in the first three months following the invasion of Ukraine, sixty-four impacts on Ukrainian water and hydraulic resources have been identified (fifteen of them potential), ranging from the destruction of dams to attacks on water infrastructure, including threats to the Zaporizhzhia nuclear power plant and the flooding of mines. In addition to serious environmental consequences, these attacks have resulted in the cessation of water supply or treatment for some sixteen million Ukrainians (Shumilova *et al.*, 2023).

On another note, during the Yemeni civil war, attacks have been carried out on water infrastructure, including pumping stations and water treatment plants. These attacks have disrupted the water supply to the population. This, combined with pollution from industrial waste and chemicals, further complicates the situation and exacerbates the humanitarian crisis caused by the war (Strategy, Defence and Foreign Affairs, 2021).

On the other hand, this section must also mention accidental or intentional contamination of water sources as a result of military activities or accidental spills from water supplies. With regard to deliberate acts, throughout ancient and recent history, they have proven to be one of the most effective tactics for achieving strategic, operational and tactical objectives in order to weaken the opponent and cause harm to the civilian population, not to mention their use for terrorist purposes to generate fear in society through contamination with chemical and biological agents and radioactive substances. Whatever the source, it is important to note that water pollution can have devastating effects on the health of aquatic ecosystems and biodiversity, as well as on the human health of communities that depend on these sources for their basic needs.

During the Syrian war, there have been repeated deliberate attacks on civilian water supply infrastructure, most often by Russian or Syrian government forces, but also by rebel forces. Furthermore, reiterating what was stated at the beginning of this section, Syrians have repeatedly been denied access to water as a means of pressure or collective punishment by Bashar al-Assad's regime. Associated with this, the deterioration of public health systems, including water purification systems, appears to be behind the cholera outbreak currently affecting the country (Lund, 2023).

3 Consequences of water conflicts

Political tensions or open conflicts associated with water resource management and access have consequences in all areas, from the economic to the environmental, including social and political aspects at the local, regional, national, and even international levels. These consequences are often interlinked, further complicating the resolution of water conflicts.

- Economic consequences: accidental or intentional damage to water infrastructure can cause significant economic losses in sectors such as agriculture, industry and tourism, depending on the extent of the damage caused. Added to this are the costs associated with rebuilding damaged infrastructure and the associated loss of productivity, not to mention the fact that the economic instability resulting from conflicts can affect foreign investment and hinder long-term economic development (Schillinger *et al*, 2020).
- Social consequences: it is safe to say that one of the main consequences of water conflicts is that they can cause mass population displacement, increase food insecurity and exacerbate poverty. This undoubtedly contributes to creating a climate of insecurity at all levels, but especially among different ethnic groups or sectors of society, and exacerbates people's vulnerability, exposing them to precarious living conditions, violence and exploitation (Iosue and Sonawane, 2023). On another note, water scarcity and inadequate sanitation can increase the risk of waterborne diseases such as diarrhoea, cholera and vector-borne diseases.
- Environmental consequences: these are caused by the pollution of water resources, their overexploitation and ineffective management. The contamination of water resources and the degradation of aquatic ecosystems have direct and indirect consequences in the short, medium and long term on biodiversity and the health of ecosystems, and can contribute to desertification, soil salinisation and the loss of natural habitats.

  The aforementioned example of the destruction of the Nova Kakhovka dam has had devastating consequences for the environment and biodiversity of the affected regions, which undoubtedly affects the stability of ecosystems, reduces their resilience to environmental changes, and threatens food security and the well-being of human populations.

Desertification associated with climate change will contribute even more to meteorological changes in larger areas and further exacerbate the rainfall deficit, thereby increasing the likelihood of conflicts over the issues discussed in this chapter (Campillo, 2018).

In relation to environmental consequences, mention must be made of the loss of cultural heritage associated with the construction of dams which, although they may have beneficial effects for the population, agriculture and livestock farming, cannot rule out the harmful effects associated with the flooding of land affected by the construction of a reservoir. An example of this is the controversial construction of the Ilisu dam in Turkey, which would affect the natural environment and archaeological sites in the city of Hasankeyf, as well as causing the forced displacement of some eighty thousand people. These events sparked strong international social mobilisation due to Turkey's failure to comply with international regulations on dam construction (Leverink, 2015).

– Political consequences: it is important to note that ineffective water resource management and lack of cooperation can undermine political stability and governance in affected areas. In this regard, conflicts over water can increase tensions between neighbouring countries and trigger geopolitical disputes at regional and international level, not to mention that in national conflicts, such as internal conflicts or civil wars, water becomes a weapon of war.

  During the Somali civil war, water infrastructure was a central component of the conflict, as control of wells was key during the war, further exacerbating the humanitarian crisis in the region thanks to the terrorist actions of the Islamist group Al Shabaab in its attack on the Somali government. by cutting off water sources, attacking tanker trucks, or flooding wells that supplied towns as government troops liberated cities, thereby undermining political power through so-called 'water terrorism' (America Abroad, 2014; Insecurity Insight, 2023).

  During the conflict in South Sudan, shortages of drinking water and disruption to water supply systems have exacerbated food insecurity in the region. The lack of access to water for irrigation has reduced agricultural production and left many communities dependent on humanitarian aid to meet their basic food and water needs (Kemisa, 2023).

4 Approaches to resolution and cooperation

Conflicts and tensions related to control of and access to water resources are one of the greatest challenges to peace and stability at the global level, a situation that is exacerbated in Southeast Asia, the Middle East and East Africa. However, we must be aware that we have different approaches available to resolve these conflicts in a sustainable and peaceful manner, primarily by promoting cooperative resource management, multilateral diplomacy and the promotion of peace.

- With regard to cooperative water resource management, efforts must be made at the international level to reach agreements and establish cooperation mechanisms at the regional, national or international level for sharing transboundary resources (Taher Kahi *et al*, 2016).
- Multilateral diplomacy involves the participation of multiple actors, both state and non-state, to achieve peaceful solutions in this type of conflict and build trust between the parties (Molna *et al*, 2017).
- Promoting peace and dialogue between the parties is vital to reaching lasting agreements that reduce the risk of conflict, and the participation of community leaders is essential to creating an environment of trust (Keskinen *et al*, 2021).

There are two paradigmatic examples of the importance of the three factors described above: the Mekong River agreement and the resolution of the Darfur conflict thanks to cooperative water resource management, including the construction of wells and canals, water flow regulation, environmental impact mitigation, and sustainable development in the region (Mohamed, 2023; Kittikhoun and Staubli, 2016).

4.1 Strategies for preventing water conflicts

Preventing conflicts over water, which can escalate into water wars, is crucial to promote peace, stability and cooperation in regions where water resources are disputed. To achieve this objective, it is necessary to implement effective strategies that address the underlying causes of conflicts and promote sustainable and equitable water resource management. These strategies may include measures for cooperation, shared governance, and peaceful dispute resolution (Zareie *et al*, 2021):

– Promoting cooperation and dialogue between communities and countries that share water resources is a priority in order to reduce the risk of conflict. By establishing platforms for dialogue and cooperation mechanisms to promote mutual trust and develop joint solutions for water resource management.
– Implement shared governance systems that involve stakeholders in decision-making for proper resource management. In this regard, it is important to note that governance and resource management are the determining factors in conflicts, rather than the lack of water.
– Promoting transparency and access to information relating to water resources will help prevent conflicts by reducing mistrust among the actors involved.

The promotion of international cooperation and dialogue led to the signing of the the Treaty of the River Plate and its Maritime Limits in 1973 between Argentina and Uruguay, which established joint management of shared water resources in the River Plate basin and its maritime front, including the regulation of navigation, environmental protection and the promotion of sustainable economic development in the region.

Previously, mention was made of the Arab-Israeli conflict over the management of the Jordan River basin, a situation that was attempted to be resolved through the peace and friendship treaty between Egypt and Israel, signed in 1979, which included provisions on cooperation in the use of the water resources of the Jordan River and other shared watercourses, enabling the signing of a peace agreement that remains in force today (Palominio, 2019).

5 Vulnerability of water infrastructure

Since ancient times, humans have been aware of the dangers of consuming contaminated water. For centuries, they have used the "scorched earth" tactic to achieve tactical and operational objectives by contaminating drinking water, throwing animal or human corpses into wells, lagoons or rivers to make them unfit for consumption (Pérez Vilatela, 1989; Smart, 1997; Ostfield, 2004). To corroborate this assertion, one need only recall the manual written Aeneas the Tacticion, in which he advised military leaders to "make the water undrinkable" from which the enemy drew their supplies in order to achieve their objectives, while, on the other hand, he warned of the danger of contaminating their own water supplies during sieges (Dembek, 2008; Fleming, 2005).

In this regard, codes of conduct such as the Laws of Manu written in the 3rd century BC exhorted against using this medium to achieve military objectives with the following admonition: 'Let him not throw urine or faeces into the water, nor saliva, nor (clothes) defiled by impure substances, nor any other (impurity), nor blood, nor poisonous things' (Bühler, 1886). Hence the need to adopt measures to prevent and control drinking water from intentional contamination with 'those microorganisms, toxins or, more generally, substances of biological origin capable of causing disease in humans, animals or plants or, more rarely, damaging material', which is how biological agents are known from the point of view of biological defence (Spanish Army Training and Doctrine Command, 2007).

The deliberate contamination of water in a biological warfare context is defined as a specialised type of warfare that uses biological agents to achieve strategic, tactical or operational objectives in order to destroy the enemy by causing the maximum number of casualties. In contrast, bioterrorism is based on the use or threat of use of biological agents by individuals or groups with political, religious, ideological, or ecological motivations. The aim of bioterrorism, unlike biological warfare, is to destroy the spirit of society by instilling fear and uncertainty. Consequently, the actual epidemiological impact could be reduced, but the degree of general disruption caused by the mere idea that such a thing is feasible is enormous. In addition to the above, a biocrime would be any criminal (murder, extortion, revenge, etc.) or psychopathological act involving the use of biological or chemical agents, or radioactive substances (Clifford and Fauci, 2005).

This potential illicit use, regardless of the objective and intent, has been a constant concern throughout history, but for the purposes of establishing a frame of reference, it seems reasonable to recall the article published in 1941 by FBI Director J. Edgar Hoover in the *Journal of the American Water Works Association* entitled 'Water Supply Facilities and National Defense', in which he expressed his concern about the vulnerability of water supply and distribution systems (Hoover, 1941):

> '[...] Among public utilities, water supply facilities offer a particularly vulnerable point of attack to the foreign agent, due to the strategic position they occupy in keeping the wheels of industry turning and in preserving the health and morale

> of the American populace. Obviously, it is essential that our water supplies be afforded the utmost protection […]'.

Without attempting to be exhaustive, so far this century there have been numerous episodes of sabotage or attempted sabotage of water supply systems, mostly involving chemical substances, but also biological agents, demonstrating the vulnerability of the water system (table 3) (Purver, 1997; Carus, 2001; Gleick, 2006; Martín Martínez, 2016; Newsweek Staff, 2001).

2002	Rome (Italy)	Four men from the Salafist Group for Preaching and Combat (GSPC) were arrested in possession of chemicals, false documents, and detailed maps of the water supply network in the area of the US Embassy.
	Denver (USA)	Two Al Qaeda operatives were arrested with plans to poison the water supply.
2004	USA	The FBI and the Department of Homeland Security issue a bulletin warning that terrorists were attempting to recruit workers at water plants as part of a plan to poison the drinking water.
2006	Tring (England)	A water tank was deliberately contaminated with herbicide.
	Denmark	Strychnine (a pesticide) was deliberately dumped into a Danish marsh.
2007	China	Two hundred and one people died when water deliberately contaminated with fluoroacetamide (a pesticide) was used to make porridge.
2008	Varney Virginia USA	A man was arrested with two bottles of cyanide to poison the water supply.
	Thailand	The water supply of a Burmese refugee camp (with a population of thirty thousand people) was intentionally poisoned with herbicide.
2009	The Philippines	The Moro Islamic Liberation Front (MILF) poisoned water sources that were being used by government soldiers and the population.
2010	Kashmir (India)	Maoist rebels poisoned a pond used as a source of drinking water by the Central Reserve Police Force, a paramilitary group.
	England	A pair of neo-Nazis, father and son, were found guilty of several terrorism charges, including manufacturing ricin and conspiring with Serbian Nazis to poison water supplies used by Muslims.

2011	Pakistan	Materials seized during the raid that killed Osama Bin Laden revealed plans to poison water supplies.
	Cádiz (Spain)	A plot to poison the water supply was uncovered in response to the death of Osama Bin Laden.
2012	Australia	Two five-thousand-litre tanks of drinking water were deliberately poisoned with Diuron (a herbicide).
	Afghanistan	Hundreds of girls at a school fell ill when the water supply was deliberately poisoned.

Table 3. Incidents of deliberate water contamination in the period 2000-2012

Spain, despite the differences with other countries, is no stranger to incidents related to sabotage activities in supply systems, usually through the manipulation of electrical systems and water tank pumps (Trespaderne, 2018; Bermejo, 2018). However, after 9/11, the authorities increased security controls at these types of facilities to prevent possible terrorist attacks. With this in mind, but with the overall objective of protecting the population from consuming contaminated water, the National Drinking Water Information System, or SINAC (its acronym in Spanish), was established, taking as its water quality or criteria the provisions of Royal Decree 140/2003, which establishes the health criteria for the quality of water for human consumption (Subdirectorate General for Environmental Health and Occupational Health, 2015).

5.1 Vulnerability of water supply systems to deliberate water contamination

The security of drinking water supplies is a fundamental pillar of public health and the well-being of communities around the world. However, water infrastructure is exposed to a variety of threats, including the possibility of deliberate water contamination. This malicious act can have devastating consequences and jeopardises public health, economic stability and national security. Understanding the factors that determine the vulnerability of water infrastructure to intentional water contamination is essential for developing effective risk reduction strategies and protecting the security of water supply.

Water supply systems are vulnerable, to a greater or lesser extent, to radiological, chemical and biological contamination resulting from the multiple stages that water goes through, depending on the installation that connects the supply sources to domestic connections, whether these are collection facilities, treatment facilities or supply and distribution networks. It should be noted that, with regard to collection, the risk increases at the end points, being greater in raw water pipes, while the most vulnerable points, depending on the contaminant in question, are those within the secondary networks at the end points of distribution (figure 1).

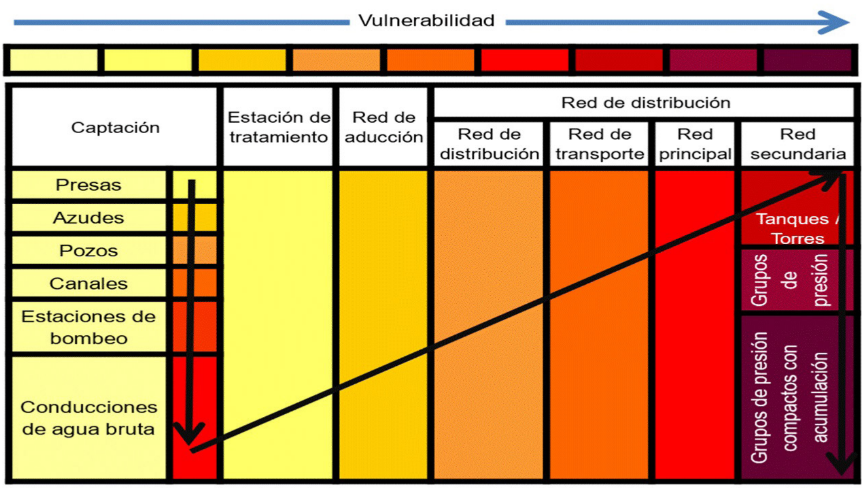

Figure 1. Vulnerability of water supply systems

The factors determining the vulnerability of water supply systems (Pérez García *et al.* 2011; Maiolo and Pantusa, 2018; National Research Council, 2007; Baecher, 2006):

1. Unauthorised access to facilities: the vulnerability of water infrastructure to deliberate contamination can be exacerbated by a lack of security around water supply facilities and systems. Unauthorised access to water treatment plants, pumping stations and other critical infrastructure increases the risk of deliberate tampering and contamination of the water supply.

2. Interconnection of supply systems: this can facilitate the rapid spread of contaminants in the event of a deliberate attack. Contamination of a water source can affect multiple communities and regions, underscoring the importance of implementing robust safety measures throughout the supply network.

3. IT vulnerability: with the increase in digitalisation and automation in water infrastructure, there is a growing risk of cyber-attacks targeting control and monitoring systems. Remote manipulation of these systems may enable perpetrators to disrupt the water supply or deliberately contaminate the water without being easily detected.
4. Responsiveness and early detection: Rapid response and early detection of deliberate contamination are essential to minimise the impact on public health and the environment. Implementing advanced monitoring systems, safety protocols, and emergency plans can help to quickly identify the presence of contaminants and take appropriate measures to mitigate the associated risks.

To reduce the vulnerability of water infrastructure to intentional water contamination, a holistic approach is needed that addresses both the physical and cyber aspects of security. This includes improving the physical security of facilities, strengthening cybersecurity capabilities, promoting staff awareness and training, and implementing rapid detection and response measures. Only through an integrated and proactive approach can we effectively protect the security of the water supply and mitigate the risks associated with intentional water contamination (America's Cyber Defence Agency, 2024; News Analysis, 2020).

The safety of drinking water supplies is a fundamental concern for public health and the well-being of communities around the world. However, water infrastructure is exposed to various risks, including the possibility of deliberate contamination of drinking water. This malicious act could have serious consequences for the health of the population and the stability of society in general. It is therefore crucial to implement effective measures to reduce the vulnerability of water supply systems to deliberate water contamination and to ensure the security of supply.

5.2 Water defence: a tool against the threat

Just as

> "Water security is a term that refers to a society's ability to have sufficient water in terms of both quantity and quality for its own survival and for carrying out various productive activities. In this way, a society with water security is in a position to reduce poverty and raise living standards (Iberdrola, 2024).

Water defence is emerging as a crucial strategic response to protect drinking water sources from threats such as deliberate contamination. In a world where the security of drinking water supplies is essential, water protection stands as a comprehensive concept that seeks to safeguard the quality and safety of the water that reaches our homes. This approach addresses not only the physical protection of water infrastructure, but also the implementation of preventive and rapid response measures to counteract possible malicious acts that could compromise public health and social stability (Beltrán, 2024; North Atlantic Treaty Organisation, 2019).

Water defence refers to a set of measures and strategies designed to protect drinking water sources from threats such as deliberate contamination. These measures may include the physical protection of water infrastructure, the implementation of advanced monitoring and detection systems, staff training, and public awareness campaigns on the importance of drinking water supply security. The main objective of water defence is to guarantee the quality and safety of drinking water and mitigate the risks associated with possible malicious acts that could compromise the health and well-being of the population (ALMA Water Solutions, 2024).

Water defence refers to a set of measures and strategies designed to protect water sources, water infrastructure and drinking water supplies from a variety of threats and risks, including pollution, scarcity, natural disasters and malicious acts (American Society of Civil Engineers, 2011; Water Hub, 2024).

- Physical protection of water infrastructure: water defence involves implementing measures to strengthen the physical security of water treatment and distribution facilities. This includes the installation of surveillance systems, access controls, perimeter fences, and other physical barriers to prevent intrusions and acts of sabotage that could contaminate drinking water.
- Advanced monitoring and detection: water protection relies on the implementation of advanced monitoring and detection systems to quickly identify the presence of contaminants in drinking water. This involves the use of technologies such as real-time sensors, automated water analysis, and early warning systems to detect potential threats and take immediate preventive action.

- Staff training and awareness: it is crucial that staff who operate and maintain water infrastructure are properly trained and aware of the importance of water defence. This involves providing training in security, emergency response procedures and safety protocols to ensure an effective response in the event of deliberate contamination incidents.

Conclusions

- Water wars have significant economic, social, environmental and political consequences that can prolong and exacerbate conflicts, as well as hinder sustainable development and peace in the affected regions. It is imperative to address these challenges in a comprehensive manner and promote cooperation and diplomacy in order to manage water resources equitably and sustainably.
- Water wars have a devastating impact on human well-being and food security, exacerbating the vulnerability of affected populations and increasing dependence on humanitarian aid. It is essential to address these challenges by promoting peace, cooperation in water resource management, and strengthening the resilience of local communities.
- Water wars have profound long-term political, social and economic ramifications, affecting the stability, welfare and development of the regions and countries concerned. Addressing these challenges requires a comprehensive approach that promotes cooperation in water resource management, peaceful conflict resolution, and sustainable development at the local, national, and regional levels.
- There are approaches to resolution and cooperation in water wars that can help mitigate conflicts and promote peace and stability in affected regions. These approaches focus on cooperative water resource management, multilateral diplomacy, and the promotion of dialogue and peace among the parties involved.
- Preventing water conflicts that could lead to 'water wars' requires the implementation of strategies that promote cooperation, shared governance, and transparency in water resource management. These measures can help promote peace, stability and sustainable development in the affected regions.

– It is necessary to make an effort to prepare for reducing the vulnerability of water infrastructure, demonstrating that water defence is key to reducing the threats to which it is subjected.

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Zareie, S.; Bozorg-Haddad, O. y Loáic, H. A. (2021). A state-of-the-art review of water diplomacy [online]. *Environ Dev Sustain*. 23, pp. 2337-2357. [Accessed: 2026]. DOI: https://doi.org/10.1007/s10668-020-00677-2

Chapter Seven

Hydrographic Projects as a Geopolitical Tool

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Abstract

From a geopolitical point of view, the construction of dams, both for hydroelectric power and water management projects, raises concerns, as the emergence of disputes over the management of shared basins can heighten insecurity and, at worst, lead to armed conflict.

Each basin has different dynamics owing to the geopolitical interests of its member countries, which may or may not lead to a higher risk of conflict. This chapter details some of the water resources projects that are causing geopolitical tensions between the riparian countries concerned.

Keywords

Hydrographic projects, Shared basin, Hydro-hegemony, Water conflict.

Introduction

Although the capacity of hydroelectric power is expected to be overtaken by wind and solar from 2030 onwards, it will continue to play a key role in decarbonising the electric power system and improving system flexibility (IEA, 2024). If the world is to fully decarbonise and meet the climate targets established in the Paris Agreement, installed hydroelectric power capacity, including pumped storage hydropower (PSH), would need to be doubled by 2050 (IRENA, 2023). In other words, the capacity of installed hydroelectric power should reach approximately 3,000 GW, including 420 GW of PSH. Most of this additional potential lies in Asia, South America and Africa (IRENA, 2023).

Currently, hydroelectric power accounts for around 16% of global energy generation (UN WATER, 2024). Today, it is one of the most cost-effective means of generating electricity and is often the preferred method when available. For example, in Norway 99% of the country's electricity is generated by hydropower (IRENA, 2023).

Although still capital-intensive, hydropower is one of the cheapest sources of electricity. China continues to be a leader in the industry, in terms of increasing its capacity, having added 24 GW by 2022, equivalent to three quarters of all global growth. China is home to the world's largest hydropower plant: the 22.5 GW Three Gorges Dam, which produces between 80 and 100 terawatt-hours per year, enough to power seventy to eighty million homes (IRENA, 2023).

Hydroelectric power remains an important part of China's 14th Five-Year Plan for Renewable Energy, published in 2022[1], but any further additions to capacity are expected to slow over the coming years due to a decreasing number of suitable sites and environmental constraints.

India is also continuing to develop several large hydroelectric power projects, with significant capacity expected to be ready in the next few years. Hydroelectric power is one of the crucial technologies if it expects to honour its commitment to reach 500 GW of clean electricity by 2030[2].

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[1] The original Chinese version is available at: https://www.ndrc.gov.cn/xxgk/zcfb/ghwb/202206/P020220602315308557623.pdf

[2] See: https://powermin.gov.in/en/content/500gw-nonfossil-fuel-target

This boom in the development of hydropower projects worldwide can have negative societal and environmental impacts if they are poorly planned and managed. Such undesirable effects include forced population resettlement, altered discharge regimes, fragmentation of ecosystems and habitat change.

From a geopolitical point of view, the construction of dams, whether that be for hydroelectric power or water management projects, raises concerns that the emergence of disputes in the management of shared basins could aggravate insecurity and, in the worst case, generate conflict.

While water has been seen as a cause for cooperation, it is possible that, as demand for water increases, countries will exercise their hydro-hegemony more belligerently for fear of losing their sovereignty and control over shared water. In such cases, neighbouring basin countries may retaliate, which could lead to some highly complex geopolitical dynamics.

It is also worth noting that while there have been no inter-state wars over water, there have been instances of intra-state conflict and violence over water, particularly in regions facing severe water scarcity. These conflicts often occur at the local level, between different user groups, communities or regions within a country. Issues regarding water often represent one of many factors contributing to wider political, territorial or ethnic disputes (Matthews, 2023).

Each basin has different dynamics owing to the geopolitical interests of its member countries, which may or may not lead to a higher risk of conflict. The lack of cooperation frameworks between countries with shared basins, geopolitical interests unrelated to water management itself, and the involvement of foreign powers acting as mediators are factors that influence the emergence or aggravation of conflicts when dams are built, especially hydroelectric mega-projects.

Under customary international law based on the 1968 Helsinki Rules and the UN Convention on the Law of the Non-Navigational Uses of International Watercourses, a downstream riparian state cannot prevent interventions in a river by the upstream riparian state. However, a downstream riparian state may request that they receive prior notice of its intention to intervene and the complete and detailed technical information, that the upstream riparian state pays due consideration to the concerns of the downstream riparian state, that they are consulted in advance and that the upstream riparian state accepts the principle of avoiding 'substantial' or 'significant' damage to the downstream riparian state. Sometimes, however, these conditions are not met and complex geopolitical disputes follow.

The following includes examples of basins in which the construction of water resources projects is causing tensions that are at risk of escalating.

1 The Asia-Pacific and water crises

The Asia-Pacific region is home to areas with some of the highest levels of water stress in the world (FAO and AWP, 2023). Population growth and high consumption patterns, pollution and mismanagement all exasperate this water crisis.

The construction of dams to solve water resources problems, derived from inefficient and unsustainable water use and the effects of climate change, are giving rise to situations of diplomatic confrontation which, although they have not yet evolved into armed conflicts, are having repercussions on the stability of the region. The economic-political nature of their construction can be a very useful tool for exerting pressure on the regional balance of power.

1.1 Kunal River (Afghanistan and Pakistan)

The 480-kilometre-long Kunar River rises in the Hindu Kush mountains of Afghanistan and plays a crucial role in the region's water supply. Following its course southwards, the river eventually converges with the Kabul River in Afghanistan's Nangarhar province, which in turn joins the Indus River.

Plummeting groundwater levels in several provinces of Afghanistan have resulted in a lack of safe drinking water. With more than two-thirds of Afghans are affected by drought and currently only producing around 600 megawatts (MW) of electricity, with a potential to produce more than 23,000 MW of hydroelectricity, the expansion of hydroelectric power plants is crucial for Afghanistan[3].

[3] See: https://www.eurasiantimes.com/afghanistan-unleashes-hydro-power-on-pakistan-dam/

Figure 1. Location of the Kunar River

Afghanistan, under Taliban rule, intends to build a hydroelectric dam on the Kunar River with the capacity to generate 45 megawatts of electricity and to irrigate 34,000 hectares of agricultural land[4]. This decision has significantly increased tensions with Pakistan, a neighbouring country that relies heavily on water from rivers originating in Afghanistan. If the Afghan Taliban go ahead with this dam without involving Pakistan, tensions may arise that could lead to a potential conflict between the two countries. There is no water treaty between Pakistan and Afghanistan, and current water use is governed only by customary practices[5].

According to experts, the extremist group lacks the expertise and funding to carry out the project as dam construction requires technical specialised technical knowledge and a solid supply chain[6].

Plans to build the Kunar dam are already affecting the fluctuating political and security relations between Afghanistan and

4 See: https://amu.tv/76296/

5 See: https://tribune.com.pk/story/2452399/the-kunar-river-rift

6 See: https://www.rferl.org/a/azadi-pakistan-taliban-hydroelectric-dam-afghanistan-siddique-briefing/32743288.html

Pakistan. Kabul's decision to remedy the water shortage has been a cause for alarm for Pakistan, which considers the Islamic Emirate's unilateral decision to build a dam on the Kunar River to be tantamount to a hostile act[7]. However, Afghan authorities have accused Pakistan of exaggerating the dam's impact, given that it will not be large, it will store little water, and its intended use is for the generation of electricity[8]. For Pakistan, the reduction of the Kunar River's water flow could have far-reaching consequences for its agricultural sector, potentially affecting food security and economic stability. From Afghanistan's perspective, the dam is seen as a crucial step towards self-sufficiency, particularly in terms of controlling and utilising its water resources for domestic needs[9].

On the other hand, the investment of a Chinese company in the Kunar hydroelectric power projects represents a significant step towards improving Afghanistan's energy infrastructure. These dams are expected to bolster the region's power supply, which could allow Afghanistan to export electricity to neighbouring countries in the future[10].

However, if Afghanistan insists on absolute sovereignty over the Kunar River, it could pose threats to the region. Pakistan, located upstream at Chitral, could divert water into the Swat River in response. The best solution would be for both countries to avoid using this issue for political leverage and instead adopt a mutually beneficial solution that serves both sides[11].

1.2 Helmand River (Iran and Afghanistan)

The Helmand River issue highlights the challenges of sharing scarce water resources between Afghanistan and Iran, exacerbated by water scarcity, socio-economic instability and climate change. It is the longest river in Afghanistan and flows into Lake Hamun on the border between the two countries.

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[7] See: https://www.eurasiantimes.com/afghanistan-unleashes-hydro-power-on-pakistan-dam/

[8] Ibid.

[9] See: https://daryo.uz/en/2024/01/14/tensions-rise-as-afghanistan-plans-hydroelectric-dam-on-kunar-river-in-pakistan

[10] See: https://www.khaama.com/chinese-firm-to-construct-three-hydroelectric-dams-in-kunar-afghanistan/

[11] See: https://tribune.com.pk/story/2452399/the-kunar-river-rift

The Helmand River dispute remains a source of tension, as the management of upstream waters in Afghanistan significantly affects Iran's water security. Iran has accused Afghanistan of withholding water from the Helmand River for years, in violation of a 1973 treaty that allocated 820 million cubic metres annually to Iran[12]. The Afghans deny this, arguing that the reason for the river carrying less water is the lack of rainfall. However, Afghanistan built, just before the border, the Kamal Khan dam, which was inaugurated in 2021. Tehran maintains that this explains why the volume of water agreed in the treaty is not flowing to Iran. (Kocatepe, 2024).

Figure 2. Helmand River Basin. Source: Kmusser CC BY-SA 3.0 [online]. Available at: https://commons.wikimedia.org/w/index.php?curid=10323588 [Accessed: 2026]

1.3 The Indus Basin (Pakistan and India)

To understand the hydro-strategic rivalry between India and Pakistan, one has to go back decades, specifically, to the forma-

[12] See: https://www.specialeurasia.com/2025/01/30/helmand-river-iran-afghanistan/#:~:text=The%20Helmand%20River%20dispute%20remains,sustainable%20solutions%20with%20Afghanistan%27s%20cooperation

tion of the two states after colonial independence. The border lines between India and Pakistan were drawn along the so-called 'Indus Basin'. The placement of these lines benefited India for the management of dams regulating water-flow to Pakistan, as evidenced by India's 1948 water blockade and Pakistan's complaint to the United Nations in 1951. Unlike India, Pakistan depends almost exclusively on the Indus, and the southern regions downstream are particularly vulnerable to those stresses on the basin's water supply. This makes Pakistan one of the most water-stressed countries in the world[13].

In 1960, India and Pakistan signed the Indus Waters Treaty (IWT) with the World Bank as a signatory to the agreement. The agreement came after nine years of negotiations and divided control of six rivers between the two countries. Pursuant to the treaty, India gained control of the Beas, Ravi and Sutlej rivers, while Pakistan gained control of the Indus, Chenab and Jhelum.

In the Indus Basin, tensions between India and Pakistan are demonstrating a growing trend. For years, the two countries have disagreed over India's two planned hydroelectric power plants in Jammu and Kashmir: Kishanganga with 330 megawatts and Ratle with 850 megawatts[14].

Pakistan considers the construction of the dam on the Kishanganga River—a tributary of the Jhelum and located in Indian-controlled Kashmir—to be a violation of the 1960 Indus Water Treaty, as it will not only alter the course of the river, but also deplete the water level of rivers flowing into Pakistan.

In accordance with the treaty, India has the right to generate hydroelectricity through projects on western rivers which, subject to specific design and operational criteria, is not restricted.

Pakistan opposes the Kishanganga dam project because it would reduce the flow of the Jhelum River. In 2017, the World Bank said India is permitted to build hydroelectric power facilities on the tributaries of the Jhelum and Chenab rivers with certain restrictions under the 1960 treaty.

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[13] See: https://climate-diplomacy.org/case-studies/water-conflict-and-cooperation-between-india-and-pakistan

[14] See: https://www.indianewsnetwork.com/es/20250121/upholds-and-vindicates-our-stand-india-welcomes-neutral-expert-s-stand-on-indus-water-treaty-with-pakistan

Figure 3. Indus Basin. Source: Kmhkmh, CC BY 3.0 [online]. Available at: https://commons.wikimedia.org/w/index.php?curid=51835800 [Accessed: 2026]

The two countries disagree on whether the technical design features of these two hydroelectric power plants contravene the treaty. Pakistan requested the World Bank to facilitate the establishment of an arbitration tribunal to examine its concerns about the designs of the two hydroelectric power projects, while India requested the appointment of a neutral expert to examine similar concerns about the two projects.

In May 2018, Prime Minister Narendra Modi inaugurated the Kishanganga project despite Pakistan's objections. Experts are cautious and warn that these projects along India's upper reaches would give India the power to store enough water to control or limit water supply to Pakistan during a crucial period of agricultural production[15].

Although no major conflict had arisen between the two nations over the sixty years of the Indus Treaty, these ongoing projects could become a source of unmanageable water-related conflict, especially in the wake of India's withdrawal from the Indus Water Treaty in retaliation against Pakistan following the 22 April 2025 terrorist attack on the Baisaran grasslands of Pahalgam in which twenty-six people, mostly tourists, were killed[16].

The IWT was considered one of the most successful water-sharing agreements, as it was able to overcome geopolitical tensions between India and Pakistan. However, the suspension of the agreement signals a hardening of India's stance on cross-border terrorism and a possible military escalation between the two countries that is of particular concern, given both have nuclear weapons.

1.4 Central Asia (Kyrgyzstan, Tajikistan, Kazakhstan, Uzbekistan, Turkmenistan)

Water scarcity in Central Asia has become an acute and irreversible problem and will only worsen in the future[17].

Water management in Central Asia has been a bone of contention between these five neighbouring countries, often resulting in a tense political climate in the region. The Central Asian Republics (CARs) consist of the 'energy-poor but water-rich' upstream states (Kyrgyzstan and Tajikistan) and the 'energy-rich but water-poor' downstream states (Kazakhstan, Uzbekistan and Turkmenistan). The upstream states use the water resources within their borders to generate huge amounts of energy through hydropower. At the same time, water-intensive crops such as wheat and cotton contribute significantly to the GDP of downstream countries. This situation has been heightened by droughts due to climate change, costing Central Asia more than 5% of its regional GDP[18].

15 See: https://www.dawn.com/news/1320850

16 See: https://newsable.asianetnews.com/india/pahalgam-terror-attack-names-of-all-26-victims-released-check-full-list-here-snt/articleshow-pce1exr

17 See: https://eurasianet.org/unexplained-spill-fuels-concern-about-afghan-canal-project

18 See: https://climateadaptationplatform.com/central-asias-response-to-water-scarcity-and-climate-change/

The main sources of water in Central Asia are the two rivers, Amu Darya and Syr Darya, which closely connect the riparian states. The five countries in the region collectively consume almost 127 billion m^3 of water every year, of which agriculture accounts for more than 80%[19].

Figure 4. Amu Darya and Syr Darya basins. Source: Theglobalobservatory.org

Since gaining independence in 1991, the sharing of water has become one of the most sensitive issues in the region. Problems related to the use and management of water took on an interstate dimension as the newly independent nations saw the fragmentation of the unified water management system in Central Asia.

Under the 1992 agreement, the Interstate Commission for Water Cooperation of Central Asia (ICWC) was established to address issues relating to the regulation, responsible use and protection of water resources from interstate sources. In addition, the five republics signed an agreement in 1993 on joint activities to solve the Aral Sea problem with the aim of promoting environmental rehabilitation and ensuring the socio-economic development of the region[20].

[19] See: https://www.idsa.in/publisher/issuebrief/the-future-of-water-management-in-central-asia

[20] See: https://www.mfa.gov.tm/en/articles/56?breadcrumbs=no&title=aral

However, these agreements were undermined given the countries' failure to balance regional cooperation regarding water resources with the needs of the energy sector. This alienated upstream countries whose interests are focused on the generation of hydroelectric power.

In 1998, the Central Asian Republics, with the exception of Turkmenistan, signed an agreement on the 'Use of Water and Energy Resources of the Naryn Syr Darya Cascade Reservoirs'. The agreement concerned the sustainable use of energy and water resources in the Syr Darya River basin, with the aim of resolving disputes over water and energy (OECD, 2021).

In 2009, the Central Asia Water and Energy Programme (CAWEP) was launched by the World Bank, in partnership with the European Union, Switzerland and the United Kingdom. Its objective was to strengthen the enabling environment to promote energy and water security at a regional level and in the beneficiary countries.

A 2017 report by the Swiss Agency for Development and Cooperation affirms that their intense competition for water resources and use for irrigation and the generation of hydroelectric power is mainly due to uncoordinated national strategies. The report estimated that the cost of inaction to improve water management in Central Asia is up to USD 4.5 billion annually. A combination of low water efficiency, negative externalities caused by unilateral actions and competing national priorities have caused disagreements and contributed to political and diplomatic disputes between Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan despite a general commitment to cooperation[21].

In the Amu Darya river basin in Central Asia, the proposed Rogun dam along the Vakhsh river in southern Tajikistan has become a source of tension between Uzbekistan and Tajikistan causing concern about escalation towards wider regional destabilisation and even inter-state violence.

The Vakhsh River provides approximately 25% of the water to the Amu Darya and Uzbekistan is concerned about the loss of water downstream due to the Rogun dam upstream. Although this dam is located within Tajikistan and far from international borders, the diversion of water from the basin could negatively affect Uzbekistan's cotton industry.

[21] See: https://www.eda.admin.ch/countries/uzbekistan/en/home/international-cooperation/strategy-uzbekistan/looking-back.html

The construction of the Rogun hydroelectric power plant began in 1976, when Tajikistan was part of the USSR[22]. The project was relaunched in 2006. If completed, at 335 metres high and with thirteen cubic kilometres of storage, Rogun will become the largest structure of its kind in the world[23]. Decades in the making, the hydroelectric power plant near the town of Rogun will have its third and last generator in operation by the end of 2025.

The Rogun hydroelectric power project not only promises to significantly improve the energy capacity of Tajikistan—a country where more than 90% of its electricity comes from hydropower sources—but also plays a crucial role in regional energy cooperation and security[24]. The dam not only leads Tajikistan towards energy independence but also provides a bargaining tool for energy trade policies with neighbouring Uzbekistan and Kazakhstan, which are willing to exchange gas for electricity. It is estimated that approximately 70% of the electricity generated by the Rogun hydropower plant will be exported to Central Asian countries once the plant reaches full capacity[25].

At present, the dam presents several problems. The first is that costs are soaring to a level that makes it difficult to see where the government will find the necessary funds to finish the job[26]. According to World Bank data, Tajikistan is spending 80% of the state budget's infrastructure investment on completing the Rogun dam to the detriment of education and health projects. The impoverished population has even been forced to buy bonds in the Rogun project. Meanwhile, they suffer continuous blackouts, as 95% of the country's energy is generated by hydroelectric power plants, and in winter a natural reduction in glacier run-off results in a shortage of water for hydroelectric generation. There is nothing left in the coffers to invest in diversification

[22] See: https://uwecworkgroup.info/%D0%B0-la-guerre-comme-a-la-guerre-military-geopolitics-see-return-of-controversial-megaprojects/

[23] It will be equipped with six 600 megawatt turbines, equivalent to a total installed capacity of 3,600 megawatts, the equivalent of three nuclear power plants. See: https://www.webuildvalue.com/en/stories-behind-projects/dam-tajikistan-green-future.html

[24] See: https://www.isdb.org/news/isdb-and-tajikistan-consolidate-cooperation-in-hydropower-sector-with-us150-million-financing-agreement

[25] See: https://daryo.uz/en/2024/06/21/tajikistan-to-export-70-of-rogun-hpp-electricity-to-central-asia

[26] See: https://eurasianet.org/tajikistan-roghun-dam-budget-spiral-to-make-authorities-sweat

of energy sources: instead, all money is spent on Rogun, which has become something of a national fetish[27].

With its hydroelectric power potential, Tajikistan could soon become a major energy producer, enabling it to increase its status in regional geopolitics. The benefits in this area outweigh the exorbitant costs of the Rogun dam project[28]. Tajikistan has already spent USD 3.3 billion on it but is at least USD 6.1 billion short of completing the dam. Over the last decade, the projected costs of completing the Rogun dam have increased by 15% per year[29].

On the other hand, environmental assessment is scarce and the potential transboundary economic and social impacts of the hydropower plant are very high. The Rogun dam is expected to displace at least forty-thousand people. Moreover, there is a risk that valuable ecosystems such as the Tugay forests of Tigrovaya Balka—a UNESCO World Heritage site—could be seriously affected. And since the river's flow to the Aral Sea will be drastically reduced, there will also be repercussions for neighbouring countries downstream: Afghanistan, Turkmenistan and Uzbekistan[30].

Despite concerns about the project and the rising costs, Rogun continues to attract investment from around the world (including Europe, China and Iran), as Tajikistan is at the crossroads of important geopolitical interests—it borders Afghanistan and China and in recent decades has been mainly under the Russian sphere of interest. Recently, however, Europe has also been trying to expand its influence in this region, to reduce Central Asian countries' dependence on Russia and to counterbalance China's Belt and Road Initiative[31].

[27] See: https://uwecworkgroup.info/%D0%B0-la-guerre-comme-a-la-guerre-military-geopolitics-see-return-of-cont

[28] See: https://www.geopoliticalmonitor.com/rogun-hydropower-plant-nears-completion-in-tajikistan/

[29] See: https://www.internationalrivers.org/news/civil-society-organizations-urge-international-banks-and-funds-to-rethink-the-approach-to-the-rogun-hydropower-dam-in-tajikistan/

[30] See: https://www.internationalrivers.org/news/civil-society-organizations-urge-international-banks-and-funds-to-rethink-the-approach-to-the-rogun-hydropower-dam-in-tajikistan/

[31] See: https://www.internationalrivers.org/news/civil-society-organizations-urge-international-banks-and-funds-to-rethink-the-approach-to-the-rogun-hydropower-dam-in-tajikistan/

The scale of the Rogun project is impressive, but its strategic importance for this area of extreme poverty and high political sensitivity is of global significance. Tajikistan shares a 1,300 km (830 miles) border with Afghanistan. A secure supply of electricity sourced from Tajikistan could transform the economies of these regions and provide new jobs and opportunities for their impoverished and war-weary citizens. The commissioning of the Rogun dam could therefore contribute to the long-term stability of Tajikistan and Central Asia[32].

1.5 Yarlong Tsangbo-Brahmaputra Basin (China and India)

China is a global hydroelectric power powerhouse, with more large dams in service than any other country. Hydroelectricity is China's second largest energy source after coal and accounts for almost one-fifth of all energy production in the country[33].

China has plans to build around one hundred dams to generate hydroelectric power from the main rivers that rise in Tibet, potentially the largest water grab in history[34].

This rapid construction of dams in China, including at least eight new ones on the Brahmaputra River in Tibet, has raised concerns about Chinese attempts to control India's water supply. The proposed dams on the Yarlung Tsangbo River in Tibet are close to the Indian border in Arunachal Pradesh. In this region, the Chinese have managed to build three dams over a distance of 24 km on the Brahmaputra River over a period of ten years. This dam construction is taking place at an unprecedented pace and scale[35].

The Tibetan Plateau is the largest source of freshwater in the Indo-Pacific region, home to 1.35 billion people: one fifth of the world's population. China has control of the six major river systems draining East and South Asia. It controls the entire stretch of the Huanghe (Yellow River) and the Yangtze, as well as the upper reaches of the other four great rivers: the Lancang (Mekong), the

[32] See: https://thinkscotland.org/2024/05/building-rogun-harnessing-the-waters-of-tajikistan/
[33] See: https://www.abc.net.au/news/2021-05-25/chinas-plan-to-build-mega-dam-on-yarlung-tsangpo-brahmaputra/100146344
[34] See: https://www.eurasiantimes.com/new-boiling-lac-chinas-constructing-of-worlds-largest-dam/
[35] See: https://arunachalobserver.org/2024/07/01/beware-of-chinas-dam-binge-chinas-dams-in-tibet-may-pose-threat-to-water-supply-of-india/

Figure 5. Yarlong Tsangbo-Brahmaputra Basin [online]. Source: https://www.drishtiias.com/daily-news-analysis/india-china-on-brahmaputra [Accessed: 2026]

Salween, the Yarlong Tsangbo (Brahmaputra) and the Indus, all four of which have their sources on the Tibetan plateau. Three of them cross gorges up to two thousand metres deep. These rivers descend from an altitude of more than five thousand metres to less than two thousand metres in Chinese territory. As they cascade down from their Tibetan heights, they have long been almost inaccessible.

Of the five major rivers flowing from the plateau, China has established a system of hydroelectric dams on the largest two: the Mekong River, flowing through South-East Asia, and the Brahmaputra River, flowing through India and on into Bangladesh where it is named after the Jamuna; its largest source of freshwater[36]. So far, the three riparian countries concerned have not signed any agreement governing the management of the Brahmaputra basin, raising concerns about China's dam-building activities[37].

This lack of a Brahmaputra basin management agreement has been compensated by the signing of a series of Memoranda of

36 See: https://ipdefenseforum.com/2024/03/prc-weaponizes-water/

37 See: https://media.defense.gov/2024/Mar/11/2003410996/-1/-1/1/VIEW%20-%20MANHAS%20&%20LAD.PDF

Understanding (MoU) that are regularly updated. In 2002, a MoU was signed on the provision of hydrological information about the Brahmaputra River during the flood season, which was renewed in 2008, 2013 and 2018. Similarly, in 2004, a MoU was signed on the Sutlej River, which was renewed in 2010 and 2015. Under these MoUs, China has an obligation to provide India with real-time data on water levels, discharge and rainfall from the hydrological stations of the two rivers during the flood season (June-October). This data is used by India to help manage its water resources and mitigate the risk of flooding that often occurs when rivers overflow as a result of heavy rainfall.

However, following the Doklam Standoff on the India-China border in 2017, the latter party stopped publishing hydrological data on the Brahmaputra, citing damage to data collection sites[38]. However, as diplomatic relations improved in 2018, data sharing between the two countries resumed, demonstrating that when relations are positive, both sides are more likely to work on water issues.

Both MoUs expired in 2023, however the two countries are currently in the process of renewal. For the time being, China has continued to provide data on the Sutlej River.

The main problem of cooperation is that these MoUs are not legally binding and there is no process for resolving disagreements between the parties. Therefore, India and China also have an Expert Level Mechanism (ELM) to discuss transboundary water issues. The ELM has met regularly since 2006 but has not been able to resolve any of the major disputes between the two countries[39].

Most of the hydroelectric power projects along the Brahmaputra basin proposed by India and China are in the border area of the Tibet Autonomous Region and Arunachal Pradesh, an area that is already volatile due to ongoing disputes over territorial claims by the two nations. Without a mutually agreed official border between the two countries, both assert competing claims to this territory. These claims are related to the management of water resources by both countries.

[38] See: https://www.ndtv.com/india-news/china-upgradaing-data-collection-station-wont-share-info-on-brahmaputra-1749268

[39] See: https://www.natstrat.org/articledetail/publications/india-china-cooperation-in-water-resources-expert-level-mechanism-188.html

If China abandons its claim to the state of South Tibet/Arunachal Pradesh, its claim to sovereignty over Tibet—the source of Asia's major rivers—would be weakened. Meanwhile, India is unwilling to cede the land to its rival, as the territory is the site of China's victory against India during the Sino-Indian War in 1962. Bangladesh, for its part, being the most downstream country in the Brahmaputra basin, fears that any unilateral water development upstream, whether that be in China or India, would reduce the water flow within Bangladesh and severely damage its overall development, specifically in the agricultural sector.

Of all the water projects China is undertaking on the Brahmaputra, including the diversion of water to the arid areas of northern China, the ambitious project to build a super-dam on the Great Bend stands out. This area features one of the largest untapped hydroelectric resources on the planet[40], as the water makes a sharp turn and drops three thousand metres through a gorge before flowing across the border into Arunachal Pradesh in India[41].

This project is part of the 14th Five-Year Plan and was already approved by the National People's Congress in March 2021. However, little is known about the current status of the project except that sufficient infrastructure has been built to begin transporting heavy equipment, materials and workers through the world's deepest canyon. Beijing has a history of keeping work on large dam projects on international rivers secret until the activity can no longer be hidden in commercially available satellite imagery.

This mega-project, with a planned capacity of sixty gigawatts, would generate three times more electricity than the Three Gorges dam, currently the world's largest hydroelectric power plant. The project will play an important role in realising China's goal of achieving peak carbon emissions by 2030 and carbon neutrality by 2060[42].

However, while some promote the super-dam as an excellent clean energy solution, others express concern about the environmental and social costs surrounding the project. The Three

[40] See: https://www.abc.net.au/news/2021-05-25/chinas-plan-to-build-mega-dam-on-yarlung-tsangpo-brahmaputra/100146344

[41] See: https://www.aspistrategist.org.au/how-the-brahmaputra-river-could-shape-india-china-security-competition/

[42] See: https://www.tbsnews.net/environment/china-dam-brahmaputra-wont-be-harmless-if-water-not-diverted-165307

Gorges dam itself displaced nearly 1.5 million riverbank residents and created significant regional ecological disruption[43]. Another important factor is that the mega-dam is being built in Medog (formerly Pemako), considered the holiest place in Tibet[44].

But what is most concerning for riparian states is the high seismic risk in the area where the dam is planned to be built, as the south-eastern part of the Tibetan Plateau lies on the geological fault line where the Indian and Eurasian plates collide. An earthquake could cause the dam to collapse, turning it into a water bomb endangering the communities downstream in India and Bangladesh[45].

From a geopolitical point of view, China's intention to build the mega-dam remains a cause of concern for India. The storage could lead to a weakening of the river flow in the winter water season India could facing a water shortage. Conversely, if China were to release any excess water from the structure during monsoons, India and Bangladesh would then face flood risks[46].

From this perspective, the mega-dam will give China leverage over India and is even suspected of weaponising transboundary waters to possibly 'choke the Indian economy'[47]. It would not be the first time that India has accused China of using water coercively and even of using water as 'water bombs'[48].

In response to the construction of the dam, India has announced plans to build its own dam at Yingkiong in Arunachal Pradesh to offset the adverse impact of the Chinese dam, control flooding and generate 10 GW[49]. This proposal increases tensions and generates a scenario of 'water wars' over shared resources between the nations involved[50].

43 See: https://weather.com/en-IN/india/news/news/2024-03-08-could-china-brahmaputra-super-dam-create-indian-water-disaster

44 See: https://ipdefenseforum.com/2024/03/prc-weaponizes-water/

45 See: https://internationalaffairsreview.com/2024/02/19/chinas-new-dam-on-the-brahmaputra-a-threat-to-bangladesh-india/

46 See: https://www.indiatodayne.in/opinion/story/opinion-china-plans-mega-dam-at-yarlung-tsangpo-canyon-pose-threat-to-other-countries-1047023-2024-07-11

47 See: https://ipdefenseforum.com/2024/03/prc-weaponizes-water/

48 See: https://www.thehindu.com/sci-tech/energy-and-environment/chinas-mega-dam-will-be-water-bomb-arunachal-mp/article69426788.ece

49 See: https://timesofindia.indiatimes.com/india/explainer-how-india-plans-to-counter-chinas-mega-dam-in-tibet/articleshow/103450052.cms

50 See: https://weather.com/en-IN/india/news/news/2024-03-08-could-china-brahmaputra-super-dam-create-indian-water-disaster

India's plans for its own hydroelectric power projects near the border with China underline the strategic importance of these construction projects. Both nations use water infrastructure to assert territorial claims and influence regional geopolitics.

On the other hand, China is taking advantage of India's perceived intransigence on water issues with its neighbours to build stronger ties with countries such as Bangladesh and Nepal[51]. For example, China has offered to fund water projects in Bangladesh and routinely provides water data to Bangladesh at no cost, unlike its approach with India[52].

The proposed super-dam on Great Bend of the Brahmaputra River therefore symbolises more than just a hydroelectric power project, rather it represents a strategic tool in the complex geopolitical landscape of South Asia. While the risk of direct conflict over water may be low, the construction of the dam and its implications for water management and regional power dynamics highlight the intricate interplay between infrastructure development and international relations[53]. Amid an increasingly complex and fractured geopolitical environment, enduring Sino-Indian tensions over river governance could become a key driving force behind wider tensions in the region.

1.6 Mekong Basin (China, Myanmar, Laos, Cambodia, Vietnam and Thailand)

The Mekong River, with a length of 4,350 km, rises in the Tibetan plateau and flows through China to Myanmar, Laos, Cambodia, Vietnam and Thailand. The river sustains approximately sixty million people living in its lower basin, which is also a very fertile area for rice cultivation. The Mekong Delta produces around 50% of Vietnam's rice and accounts for 31.3% of the country's GDP[54]. This basin faces two major challenges to its water

[51] See: https://nepaleconomicforum.org/unlocking-the-geopolitics-of-hydropower-in-nepal/
[52] See: https://www.thinkchina.sg/politics/can-bangladesh-secure-its-water-future-china-and-india
[53] See: https://connectingnations.com/2024/08/brahmaputra-dam-dispute-escalates-water-war-between-india-and-china/
[54] See: https://es.vietnamplus.vn/desarrollan-economia-circular-en-delta-del-mekong-de-vietnam-post200097.vnp#:~:text=El%20Delta%20del%20Mekong%20es,del%20sector%20agr%C3%ADcola%20de%20Vietnam

resources in the 21st century: the effects of climate change and dam constructions.

Some countries upstream of the river have built several dams to generate energy. These hydroelectric power facilities on the Mekong River may cause a decrease in river and sediment flow reaching downstream areas, which would affect rice cultivation, the main food source for tens of millions of people in the region. This decrease in water quantity could contribute to salt intrusion and erosion in the Mekong Delta. The change in the Mekong's water flow would also increase riverbank erosion[55].

Figure 6. Mekong Basin. Source: Shannon. CC BY-SA 4.0

55 See: https://www.mekongeye.com/2024/06/03/dams-truly-green/

Dams can also prevent fish migration and alter river flows. The Mekong River Commission has said that the fisheries sector in the Mekong River may suffer losses of USD 23 billion by 2030, and the impacts of deforestation may result in an additional loss of USD 145 billion[56].

In terms of the energy business, the Mekong River has become an opportunity for investors to build hydroelectric power dams to sell power to governments that are trying to reduce emissions. For example, the Thais have invested in major dams that sell electricity. One example is the Pak Beng dam in Bokeo province, which is the fourth largest dam the Lao government has planned for the Mekong River. The 912-megawatt, USD 1.88 billion dam is a joint investment between Datang Overseas Investment of China and Gulf Energy Development of Thailand. 95% of the electricity generated will be sold to Thailand, while the rest will go to Laos[57]. This dam is an integral part of Laos' goal to become the 'battery of South-East Asia'[58]by using the Mekong to generate electricity and sell it to neighbouring countries. However, the dam is posing some problems for Laos. On the one hand, Chinese financing has

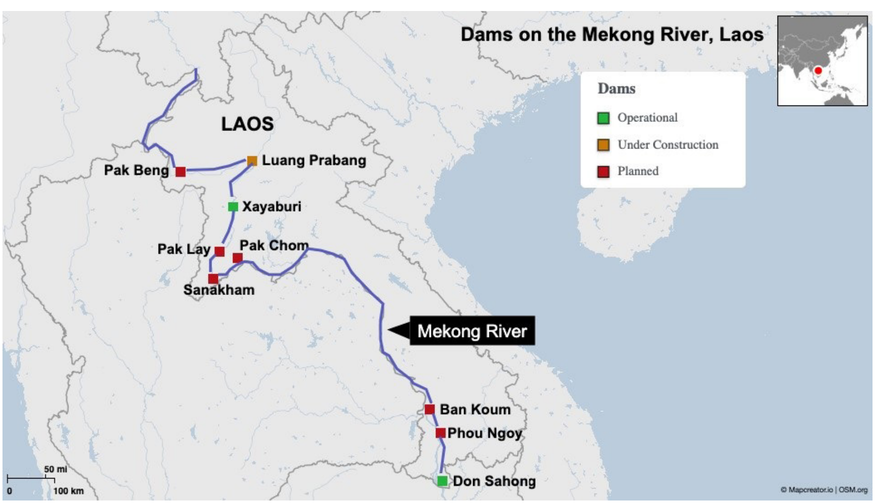

Figure 7. Construction of dams in Laos [online]. Source: https://chinaglobalsouth.com/analysis/china-thailand-flock-to-laos-rivers-for-electricity/ [Accessed: 2026]

56 See: https://e.vnexpress.net/news/news/environment/vietnam-cares-about-impacts-of-mekong-river-dams-4749868.html

57 See: https://www.benarnews.org/english/news/thai/laos-dam-mekong-thai-power-deal-09212023151235.html

58 See: https://apnews.com/article/luang-prabang-laos-unesco-world-heritage-9370038fe4d133f2388ce3cd92efb9af#

meant that it has a significant debt that it is struggling to pay off[59] and, on the other, due to the speed with which dam projects are approved, they are often accepted without thorough consideration of their impact.

Another project of concern is the Luang Prabang dam, one of nine[60] that Laos plans to build on the Mekong. The Luang Prabang dam—eighty metres high and 275 metres wide—is expected to be completed by 2030 and expected to generate 1,460 megawatts of power, most of which will be exported to Thailand and Vietnam[61].

The local population has expressed their disagreement, as they believe that the dam will not generate much power for Laos, but will supply new shopping centres in Bangkok, and therefore there is an imbalance between those are negatively affected and those who benefit[62]. In fact, the Xayaburi dam downstream of Luang Prabang, which became operational in 2019, has already affected this city by transforming the Mekong River into a lake due a reduced flow[63]. In addition, the dam is to be built close to an active fault line and an earthquake would have catastrophic consequences for the city of Luang Prabang and the surrounding area[64].

UNESCO has also expressed its concerns that the construction of the dam risks losing Luang Prabang's World Heritage status[65].

This boom in dam construction on the Mekong in Laos is not without its critics. A study on hydroelectric power potential and existing cross-border energy trade between Laos, Cambodia and Thailand shows that, over the period 2016 to 2037, regional elec-

[59] See: https://asia.nikkei.com/Spotlight/Coronavirus/Laos-debt-woes-worsen-as-bills-for-China-funded-dams-loom

[60] The 728-megawatt Phou Ngoy dam, with an expected completion date of 2029, would join the operational Xayaburi and Don Sahong dams, as well as the Pak Beng, Pak Lay, Luang Prabang and Sanakham dams, in various stages of planning. This dam will be followed by two others, Pak Chom and Ban Koum.

[61] See: https://www.france24.com/en/live-news/20240221-you-can-t-imagine-the-damage-dam-threatens-historic-laos-town

[62] See: https://ny1.com/nyc/all-boroughs/ap-top-news/2024/02/01/fears-grow-that-dam-across-mekong-river-in-laos-could-harm-world-heritage-site-of-luang-prabang

[63] See: https://apnews.com/article/luang-prabang-laos-unesco-world-heritage-9370038fe4d133f2388ce3cd92efb9af

[64] See: https://news.mongabay.com/2021/12/in-laos-a-very-dangerous-dam-threatens-an-ancient-world-heritage-site/

[65] See: https://ny1.com/nyc/all-boroughs/ap-top-news/2024/02/01/fears-grow-that-dam-across-mekong-river-in-laos-could-harm-world-heritage-site-of-luang-prabang

tricity demand and CO_2 emission reductions can be met by the construction of only 82% of the planned dams[66]. There is even a proposal to introduce a moratorium on dam construction in Laos[67] as Cambodia has already done[68].

The countries surrounding the Mekong Basin recognise the indispensable role of hydroelectric power for meeting energy demand and for driving economic growth but are also aware of the potential transboundary impacts of hydroelectric power development[69].

The Mekong River Commission (MRC[70]) attempts to resolve disputes over the simultaneous use of the Mekong, but excludes some parties, mainly China. The MRC has few ways to prevent private infrastructure companies from building dams. A country that objects can be overruled if a majority of the commission sees value in a dam that is clearly within a nation's jurisdiction, even if the dam affects downstream neighbours. However, despite this possibility, dialogue and the search for understanding are often the guide followed by the countries belonging to the commission. For example, the 14th Regional Forum presented design changes for the Pak Beng, Pak Lai and Don Sahong hydroelectric power projects. These changes are aimed at improving sediment management, transport and fish migration[71], which are of central importance given the Mekong's position as the world's largest inland fishery[72].

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66 See: https://scholarship.claremont.edu/cgi/viewcontent.cgi?article=4777&context=cmc_theses

67 See: https://bkktribune.com/the-last-days-of-beautiful-luang-prabang/

68 See: https://www.internationalrivers.org/news/sites-of-struggle-sacrifice-mapping-destructive-dam-projects-along-the-mekong-river/

69 See: https://www.mrcmekong.org/media-releases/building-transparency-and-trust-mrcs-14th-regional-stakeholder-forum-set-course-for-sustainable-mekong-development/2024/

70 The MRC is an intergovernmental organization established in 1995 to promote regional dialogue and cooperation in the Lower Mekong River Basin. Based on the Mekong Agreement between Cambodia, Lao People's Democratic Republic, Thailand and Vietnam, the MRC serves as both a regional platform for water diplomacy and a knowledge hub for managing water resources and supporting sustainable development in the region.

71 See: https://www.mrcmekong.org/media-releases/building-transparency-and-trust-mrcs-14th-regional-stakeholder-forum-set-course-for-sustainable-mekong-development/2024/

72 See: https://apnews.com/article/science-thailand-southeast-asia-united-states-cb2d4c4b1420b91db3d9ed3ca700d787

2 Africa

To encourage sustainable development and economic growth through a transition to clean energy, the African continent aims to urgently accelerate the development of renewable energy. Currently, wind energy contributes 0.01% to the subcontinent's energy sources, solar energy provides 2%, geothermal energy accounts for 4-5%, hydroelectric power contributes 17%, while fossil fuels dominate the energy landscape with a substantial 77%[73].

In 2023, 2 GW of hydroelectric power was installed across the continent. The major contributors to this development were Nigeria (740 MW), Uganda (408.2 MW), Democratic Republic of Congo (381.7 MW) and Tanzania (261.7 MW)[74].

2.1 The Nile Basin (Egypt, Ethiopia and Sudan)

Of all the hydroelectric projects in development on the African continent, the Grand Ethiopian Renaissance Dam (GERD) stands out for its magnitude. The negotiations involving Ethiopia, Sudan and Egypt on this Ethiopian project exemplify the difficulties associated with effective management of shared water resources.

The Grand Ethiopian Renaissance Dam is located on the tributary of the Blue Nile in the northern highlands of Ethiopia, from where 85% of the Nile's water flows. It is located thirty kilometres south of the Sudanese border and is the largest hydroelectric dam project in Africa. It has a width of around 1,780 m and a height of 145 m[75].

With this project, Ethiopia will be able double electricity production to supply the 60% of the population currently without electricity and also provide businesses with a steady supply of electricity to drive development. In addition, it could also provide electricity to neighbouring countries such as Sudan, South Sudan, Kenya, Djibouti and Eritrea[76].

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[73] See: https://www.nepad.org/blog/empowering-africa-enhancing-access-electricity-through-renewable-energy

[74] See: https://elperiodicodelaenergia.com/africa-anade-2-gw-capacidad-hidroelectrica-2023-aprovecha-10-potencial-continente/

[75] See: https://www.webuildgroup.com/en/projects/dams-hydroelectric-plants/grand-ethiopian-renaissance-dam-project/

[76] See: https://climate-diplomacy.org/magazine/conflict/politics-grand-ethiopian-renaissance-dam

Figure 8. Nile Basin. Source: CC BY-SA 4.0

Despite being downstream, Egypt has been the hydro-hegemonic power of the Nile. Virtually all of Egypt's freshwater consumption depends on the Nile, both for human consumption and agricultural production. In addition, the water of the Nile is also used for electricity production thanks to the development of hydroelectric projects including the Aswan High Dam.

The dam has been a source of contention between Egypt, Sudan and Ethiopia since construction began in 2011. The 1929 and 1959 treaties gave Egypt and Sudan Nile water rights with the possibility of vetoing projects from upstream countries—such as Ethiopia—if it was felt that such projects would deprive them of their share of water.

Before construction of the dam began, Ethiopia expressed its disagreement with the existing signed treaties, considering them old and unfair, especially when they prevented economic development and access to electricity for a large part of its population[77].

Egypt, Sudan and Ethiopia signed a new treaty in 2015. However, talks on how Ethiopia should use Nile water to fill the dam have broken down on multiple occasions. Since then, the risk of armed conflict arising from disagreements over the operation of the dam has remained moderate.

Construction of the dam began in 2017, just as the Arab Spring and the ensuing political instability in Egypt were taking place. The US intervened in 2019, to try to reach an agreement between Egypt and Ethiopia, but with little success.

Not only can the parties not agree on an outcome, but they cannot even agree on the method of mediation. Egypt prefers to internationalise the issue, while Ethiopia prefers African Union mediation. Egypt and Sudan want a legally binding agreement that will have an impact on how Ethiopia fills the dam in times of drought. Ethiopia considers this proposal unacceptable.

Egypt is also concerned that, in periods of drought, Ethiopia may fill the reservoir with water to increase its power generation capacity, rather than letting it flow downstream. Without an agreement, Ethiopia could adopt an approach that maximises electricity generation after droughts by first recovering storage, which would be unfavourable. As for Sudan, although it is also a

[77] See: https://www.dw.com/en/how-could-ethiopias-dam-dispute-escalate/a-66798628

country affected by Nile water levels like Egypt, its response to the dam has been limited by the conflict within the country.

For Ethiopia, GERD is much more than a hydroelectric power project: it represents the attainment of greater regional prominence and geopolitical weight in the region. GERD has cost USD 4.7 billion, representing around 7% of their country (Matthews, 2023). To finance the construction of the dam, the government has resorted to crowdfunding to sell bonds, refusing financial assistance from Cairo to guarantee 100% ownership, but accepting funds from China to cover investment in associated power generation equipment[78]. Construction of the Renaissance Dam is likely to be completed in September 2025[79].

Ethiopia's unilateral action to continue the dam's operation has led to increased regional tension and further internalisation of the conflict.

Firstly, the rivalry between Egypt and Ethiopia has become evident through the ongoing conflict in Sudan. In the ongoing Sudanese civil war, Egypt, Eritrea, South Sudan and Somalia support General Al Burhan, while Ethiopia and the United Arab Emirates back his rival Hemedti.

Secondly, while Egypt seeks the support of Arab League countries, considering that the water security of Egypt and Sudan is an integral part of Arab national security (Matthews and Vivoda, 2023). Ethiopia, on the other hand, prefers disputes to be conducted within the African Union. The call for African Union mediation was supported by China, which had consistently refused to take sides and sought a delicate balancing act to protect its substantial investments in both Egypt and Ethiopia. However, even the African Union, with the support of China, has not been able to bring the two sides to an agreement. Although direct tripartite negotiations have stalled, the UN Security Council continues to encourage the three states to resolve the dispute.

Thirdly, the dispute over GERD is set against a backdrop of broader geopolitical interests, particularly those of China and the United States, but also those of Russia.

78 See: https://www.disruptionbanking.com/2023/09/04/why-is-china-financing-the-grand-ethiopian-renaissance-dam-gerd

79 See: https://www.egypttoday.com/Article/1/139164/Ethiopian-controversial-dam-to-be-inaugurated-by-September-2025-Abiy

While avenues for cooperation and engagement still exist, the possibility of military confrontation remains. Egypt is a major military power in the Middle East, with a strength far superior to that of Ethiopia. Their water scarcity means that any reduction in their access to the waters of the Nile could be considered an existential threat, which would justify an escalation of the war (Matthews and Vivoda, 2023).

One possibility considered since the construction of the dam began was its destruction—an idea supported by Trump himself[80]. However, this possibility seems unlikely given the level of the reservoir. Any damage to the dam would have catastrophic consequences, especially for Sudan.

The risk of some kind of military intervention cannot be entirely ruled out. Egypt could consider conducting a combined armed attack from both the air and the ground alongside its Sudanese allies. In fact, the two countries have been collaborating to strengthen each other's military capabilities. In November 2020 and April 2021, they conducted joint air exercises called the Nile Eagles, followed in May 2021 by joint ground and air military exercises called Homat Al-Nile[81]. However, the outbreak of internal conflict in Sudan in the spring of 2023 may have diverted attention and resources away from resolving the problem within its borders, to the detriment of its involvement in the conflict over the Renaissance Dam.

Currently, there is no clear end in sight, nor even a clear path towards a resolution. In the coming years, as the GERD becomes fully operational and the waters of the Nile become more susceptible to climate change, the dispute could become even more significant between Egypt, Sudan, and Ethiopia, and for the region as a whole[82].

Given the risk of armed conflict, there are initiatives that aim to promote the sustainable and shared use of water and energy from the GERD. On the one hand, Ethiopia could, in addition to satisfying its domestic market, expand its electricity exports in the region and become the 'renewable energy battery of East

80 See: https://www.france24.com/en/live-news/20201023-trump-suggests-egypt-may-blow-up-ethiopia-dam

81 See: https://www.egypttoday.com/Article/1/100383/Egyptian-Sudanese-air-forces-hold-joint-exercises-dubbed-Nile-Eagles

82 See: https://climate-diplomacy.org/magazine/conflict/politics-grand-ethiopian-renaissance-dam

Africa' (Matthews, 2023). In terms of water management, Egypt could benefit from the GERD, as instead of storing water in the Aswan High Dam, it could be stored upstream in the Ethiopian highlands, where evaporation is less intense, potentially saving four million cubic metres of water per year[83]. To this end, Egypt and Ethiopia should sign a legally binding agreement on the operation of the GERD that guarantees the continuous flow of water to downstream states[84].

Another option proposed is the reduction of the capacity of the reservoir to ensure that both Sudan and Egypt will have sufficient water. The difference can be offset by promoting other renewable energy projects, such as solar or wind power, which also have significant potential for expansion in Ethiopia, and even Egypt would be willing to offer its support[85].

Proposals for managing the Nile basin and the GERD to avoid conflict are varied and are being studied from the perspective of the interdependencies between rivers and energy systems. This approach can help decision-makers find practical, multi-sector solutions for sharing benefits (Etichia, 2024).

3 The Middle East

The Middle East is one of the most water-scarce regions in the world, with an annual average of five hundred and fifty cubic metres of water resources per capita. This is half the threshold of one thousand cubic metres per capita for water scarcity according to the UN Water Stress Index[86].

Although fossil fuels have shaped geopolitical relations in the region, water has also been a natural resource that has influenced the development of conflicts in the area and is expected to play an even greater role due to the water stress expected in the region.

83 See: https://natoassociation.ca/the-ethiopian-dam-and-its-impact-on-egypt-and-sudan/

84 See: https://www.newarab.com/analysis/could-nile-dam-dispute-between-egypt-and-ethiopia-escalate

85 See: https://www.dailynewsegypt.com/2023/07/26/renewable-energy-could-offer-a-win-win-solution-for-gerd-crisis/

86 See: https://iraq.un.org/en/229713-finding-institutional-solutions-water-scarcity-mena

3.1 Tigris and Euphrates (Türkiye, Syria, Iraq)

The Euphrates River rises in Türkiye and its waters flow through parts of Türkiye, Syria and Iraq. The Tigris basin, the second largest river in Western Asia after the Euphrates, is shared by four countries: Iraq, Iran, Syria, and Türkiye. Both basins face common problems, such as dam construction, the climate crisis and poor water management, as farmers continue to use ancestral irrigation techniques that flood their fields[87].

Figure 9. Tigris and Euphrates river basins. Source: CC BY-SA 3.0

The Tigris and Euphrates River system is home to the largest wetland ecosystem in the Middle East[88]. Both rivers are central to the region’s economy and stability. Both rivers rise in Türkiye, and their basins have been characterised by inadequate management, a lack of cooperation, and unilateral irrigation decisions that have often led to a zero-sum game with neighbouring countries in the basin[89].

87 See: https://www.spiegel.de/international/world/the-garden-of-eden-dries-up-iraqi-marshlands-under-threat-a-ccedbf40-a2cd-4ffd-9384-161e66494b59

88 See: https://reliefweb.int/report/iraq/forgotten-people-marsh-arabs-iraq

89 See: https://arabcenterdc.org/resource/water-politics-in-the-tigris-euphrates-basin/

Although cooperation efforts were renewed in the 2000s, no formal agreement has yet been reached on the management of the basin's waters[90]. Neither Türkiye nor Iran has signed the 1997 United Nations Convention on the Law of the Non-navigational Uses of International Watercourses, and therefore they are not bound by international law in relation to the management of transboundary basins[91].

During the final decade of the 20th century, the Turkish government built multiple dams on the Tigris and Euphrates rivers as part of the South-Eastern Anatolia Project (GAP), which is considered one of Türkiye's economic development projects. Although the aim of this project was to increase agricultural land and provide hydroelectric power[92], its implementation has caused rivalries and influenced the development of conflicts in the region, particularly in Syria and Iraq.

The flow of the Euphrates towards Syria depends on the water released from the Atatürk Dam. According to the 1987 agreement signed between Türkiye, Syria, and Iraq under the auspices of the United Nations, Syria's share of the Euphrates River should be 500 m^3/s. However, for around two years, Türkiye has been withholding the agreed-upon amount of water[93].

On the Tigris River, the Ilisu Dam has also reduced Iraq's water supply by 34%[94], and sandstorms have even occurred in Iraq due to water shortages[95]. Construction of this dam began in 2006 as part of the South-Eastern Anatolia Project, and its design was surrounded by controversy, as it would cause the 12,000-year-old city of Hasankeyf to be completely submerged, causing population displacement and significant cultural loss[96].

The Ilisu dam was inaugurated in 2021, and with it, the Turkish government aims to supply 4% of the country's electricity[97] in

90 See: https://climate-diplomacy.org/case-studies/turkey-syria-and-iraq-conflict-over-euphrates-tigris

91 See: https://shafaq.com/en/Report/Water-War-looms-in-the-Middle-East-horizon

92 See: https://www.researchgate.net/figure/The-dams-in-the-Euphrates-River-DSI-2015_fig2_303745464

93 See: https://npasyria.com/en/105448/

94 See: https://es.euronews.com/2021/11/07/erdogan-inaugura-la-central-hidroelectrica-de-ilisu-la-megapresa-del-rio-tigris-en-turquia

95 See: https://arvak.am/en/turkey-iraq-will-the-water-conflict-be-over/

96 See: https://e360.yale.edu/features/turkeys-dam-building-spree-continues-at-steep-ecological-cost

97 See: https://es.euronews.com/2021/11/07/erdogan-inaugura-la-central-hidroelectrica-de-ilisu-la-megapresa-del-rio-tigris-en-turquia

a bid to promote low-carbon energy[98]. However, in 2022, there was a 60% decrease in the flow of the Euphrates and Tigris rivers compared to 2021, leading Iraq to threaten to end economic relations and trade with Türkiye[99].

According to a study conducted by the United Nations Environment Programme (UNEP), water availability in Iraq will decrease by around 20% by 2050, threatening the long-term stability of the agricultural and industrial sectors[100]. Iraq's water reserves are currently at their lowest level in eighty years following a dry rainy season[101].

Therefore, proper water management is key to preventing an escalation of instability in the region. There is growing awareness that collaboration is necessary given the extreme water stress experienced by nations such as Türkiye, Syria, and Iraq. After years of confrontation over water resources, there is now a greater chance that disputes over the Tigris and Euphrates rivers will be resolved. In April 2024, during Erdoğan's visit to Iraq, the Framework Agreement between the Government of the Republic of Iraq and the Republic of Türkiye on Cooperation in the Field of Water was signed[102]. This agreement does not concern Türkiye's management of water resources, but rather joint investments aimed at utilising water resources within Iraq's borders and improving existing infrastructure, as well as establishing water treatment plants to use water efficiently and treat wastewater for irrigation[103].

These recent diplomatic contacts indicate a willingness to reach practical agreements, emphasising the advantages for both sides, such as water distribution plans and infrastructure cooperation initiatives. Iraq has taken the lead in its mediation efforts, signalling a move towards cooperation and perhaps setting a standard for future water management in the area. If this collaborative attitude persists, it could open the door to more efficient and

98 See: https://e360.yale.edu/features/turkeys-dam-building-spree-continues-at-steep-ecological-cost

99 See: https://hawarnews.com/es/167821764022862

100 See: https://unsdg.un.org/latest/stories/call-action-building-sustainable-efficient-and-climate-resilient-agrifood-system

101 See: https://thepeninsulaqatar.com/article/25/05/2025/iraqs-water-reserves-lowest-in-80-years-official

102 See: https://www.rudaw.net/english/middleeast/iraq/220420244

103 See: https://anlatilaninotesi.com.tr/20240425/turkiye-irak-arasinda-su-sorunu-nasil-cozulecek-1083148983.html

sustainable water governance, mitigating the adverse effects of water scarcity in the Middle East[104].

3.2 Tributaries of the Tigris and the Shatt-al-Arab River (Iran and Iraq)

Iran and Iraq frequently disagree over water-related issues. As a result of Iran's actions, the flow rates of the Sirwan and Little Zab, both tributaries of the Tigris River, have decreased significantly[105]. This decline has accelerated the process of land and environmental degradation, particularly in the marshlands[106]. For example, the Kolsa dam in the Iranian region of Sardasht has caused an 80% drop in water levels in the Little Zab[107].

The history of water shared between Iraq and Iran differs from the situation with Türkiye. The two countries signed an agreement in 1975 to share water jointly, known as the Algiers Agreement, on the shared border of the Shatt al-Arab River. However, after war broke out between the two countries, former Iraqi President Saddam Hussein withdrew from the agreement in 1980, deeming the waters of Shatt al-Arab to be belonging entirely to Iraq. This justification is what Iran uses today to avoid adhering to the allocation of Iraq's water quotas. Although the amount of water Iran provides to Iraq is much less than that provided by Türkiye, the crisis with Iran is more complex[108].

The Shatt al-Arab is formed by the confluence of the Tigris and Euphrates rivers in the city of al-Qurnah, in the province of Basra. Approximately two hundred kilometres long, the river flows into the Persian Gulf at Al-Fāw, the southernmost point of Iraq. The river is an important economic artery for Iraq, as it serves as a navigation channel for ships heading to the ports of Basra via the Persian Gulf[109]. Furthermore, given the arid climate in this part of the Middle East, the river water is crucial for agriculture.

[104] See: https://trendsresearch.org/insight/hydropolitics-and-water-disputes-in-the-mena-region/

[105] See: https://www.dw.com/en/dam-building-projects-could-fuel-water-stress-in-middle-east/a-55169989

[106] See: https://1001iraqithoughts.com/2024/03/08/water-stress-threatens-national-security-in-iraq/

[107] See: https://www.mei.edu/publications/water-scarcity-could-lead-next-major-conflict-between-iran-and-iraq

[108] See: https://shafaq.com/en/Report/Water-War-looms-in-the-Middle-East-horizon

[109] See: https://savethetigris.org/will-iraq-lose-its-benefits-from-shatt-al-arab-river-to-iran/

Figure 10. Location of the Shatt al-Arab River. Source: Author's own elaboration

Over the years, Iran has dammed the Karun River, a tributary of the Shatt al-Arab River in southern Iraq, as well as rivers flowing into the Kurdistan region. These dams exacerbate Iraq's water scarcity problems and add to the other challenges facing the country in terms of water security, such as those also caused by dam construction in Türkiye, low rainfall levels due to climate change, poor water management and pollution[110].

With Türkiye and Iran controlling most of the region's water resources, the Federal Government of Iraq and the Kurdistan Regional Government (KRG) have minimal options for improving access to water at the national level. These authorities have devel-

110 See: https://www.rudaw.net/english/middleeast/iraq/290420242

oped different strategies to address the growing water shortage. However, these are complicated by poor water infrastructure and unsustainable irrigation systems[111]. To address these challenges, external actors, particularly China, are playing an increasingly important role in the future of Iraqi water security[112]. For Iraq, water is a geopolitical tool used by both Iran and Türkiye, and it considers dam projects to be essentially political projects[113].

Conclusions

Countries are increasingly responding to challenges related to water, food and energy security by constructing dams and reservoirs and diverting water from one area to another. The planning, development, and management of dams in transboundary basins must be governed effectively and cooperatively to ensure that negative environmental and socio-economic impacts are limited and that any potential conflicts are mitigated.

Despite growing tensions between states, armed conflicts over transboundary freshwater have been relatively limited to date. However, growing water needs and declining supplies, climate change, and shifts in environmental and development priorities are straining transboundary hydroelectric relations. When water belongs to an international river system, these measures can lead to interstate riparian conflict.

While concerns about water scarcity can lead to interstate conflicts, they can also play an important role in building cooperation.

The need to reach viable agreements to avoid a major conflict over water must be recognised. Throughout the world, the only way to combat growing friction is to create and respect binding and mutually acceptable frameworks with all neighbours, whether bilaterally or multilaterally, respecting international law. However, in the absence of such agreements, countries could use their energy resources as a bargaining chip to establish a symbiosis of interests that would reduce the tension of water conflicts.

In any case, negotiation is the only viable way to prevent further escalation and ensure regional stability in shared international basins.

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111 See: https://www.kurdishpeace.org/policy/dams-are-not-the-solution-to-water-scarcity-in-iraqi-kurdistan/

112 See: https://www.thinkchina.sg/economy/can-china-save-iraq-its-water-crisis

113 See: https://shafaq.com/en/Report/Water-War-looms-in-the-Middle-East-horizon

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