People's Democratic Republic of Algeria
Ministry of Higher Education and Scientific Research
University of Oum El Bouaghi

Faculty of Earth Sciences and Architecture

Department of Geography and Urban Planning

2nd Year License of Geography and Regional Planning

Course: WATER AND DEVELOPMENT

Presented by: Dr Roufeida Aibeche

Scheduled course of Study

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Introduction

Water is essential to human life, a source present everywhere and used for economic activities and indispensable to urban life. Its role is also important for flora, fauna and the production of energy and navigation in terms of quantity and quality.

As a result, we can say that water equals life. Unfortunately, water resources are consumed on a daily basis, so our blue planet will soon be thirsty. By 2050, around 9 billion people will need water. In fact, experts predict that all surface water will be consumed by 2100, and that all the water available in the Earth's water cycle will be completely depleted by 2230.

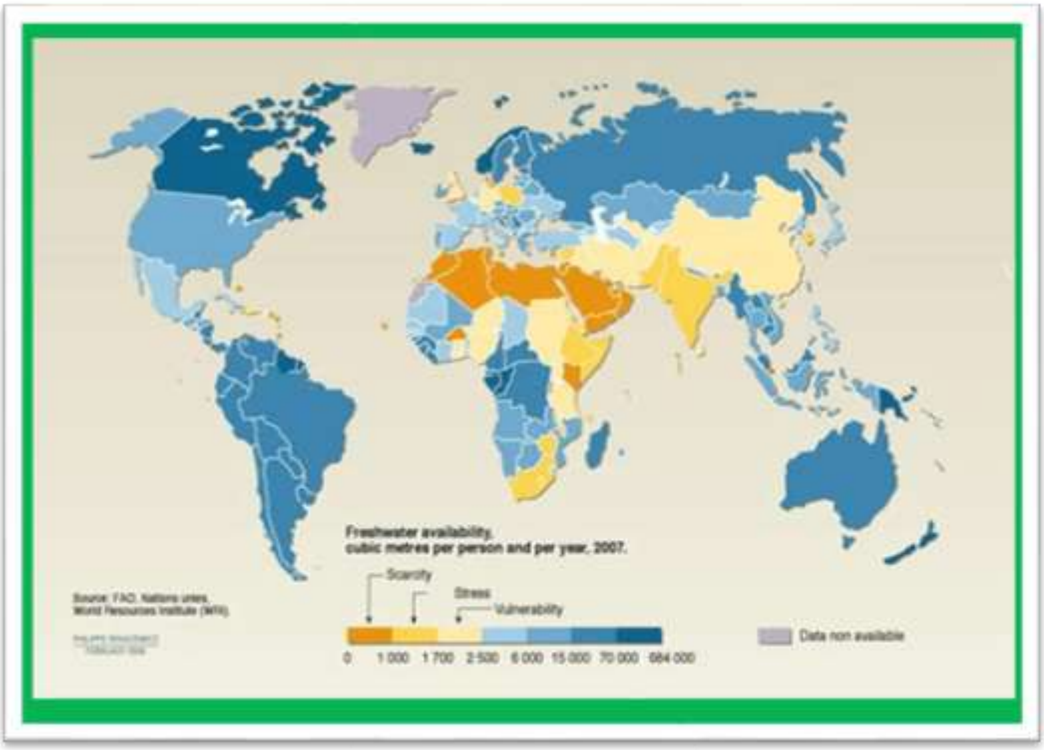

Figure 1: Freshwater availability worldwide with an integrated colored scale
Source: 1

This course aims to explain the importance of water in urban planning and how this sector operates on the national and international levels its role in growth. This course is considered a basic teaching unit for second-year bachelor's students, as it introduces them to one of the most important elements of regional planning which is: water management.

The water cycle:

Water circulates around the Earth in different forms: clouds, rain, rivers and oceans. It flows from the ocean to the atmosphere, from the atmosphere to the Earth, from the Earth to the ocean, and so on, repeating itself ad infinitum. at the same time. In this cycle, all the aquatic environments in the basin (groundwater, lakes, etc.) are interdependent.

Water has been a vital component of Earth's ecosystems, continuously operating in a closed cycle for billions of years. This cycle begins with the sun, the driving force behind the transformation of seawater into vapor. As sunlight warms the vast oceans, water molecules escape into the atmosphere through evaporation. Rising high into the sky, these molecules cool and condense, merging to form clouds that float gracefully across the heavens.

The movement of clouds is governed by the invisible forces of wind and gravity. Winds carry them across continents, while gravity influences their altitude and behavior. Within the clouds, countless tiny droplets of water collide and merge, growing in size and weight. This dynamic process is a constant, delicate balance, influenced by temperature, air pressure, and humidity.

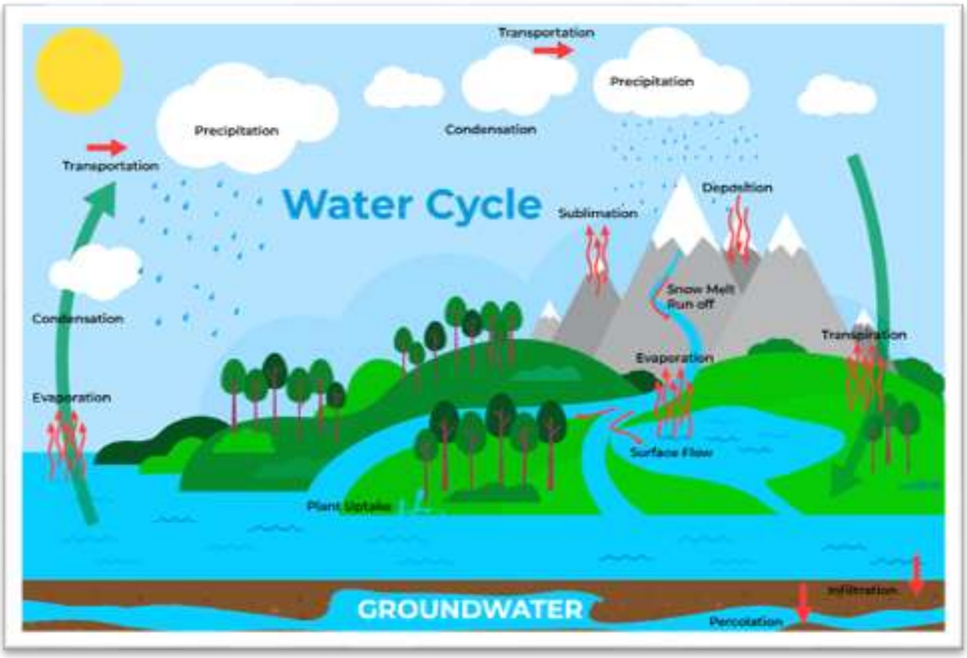

Figure 2: the water cycle. *Source : 2*

When these water droplets become too heavy to remain suspended, they fall to the Earth as precipitation in various forms, such as rain, snow, or hail.

This life-giving water replenishes rivers, lakes, and underground reservoirs, sustaining plants, animals, and human communities. The cycle, seamless and unending, ensures the renewal of Earth's freshwater resources, linking every living being to this ancient and extraordinary process.This rainwater feeds the water table, which in turn feeds the rivers that flow into the sea, and so the water's journey begins again, without end.

The water cycle can be broken down into several stages:

- Evaporation
- Condensation
- Precipitation

Water that can't infiltrate the ground directly runs off the slopes and into lakes and rivers, this water follows their courses to reach the seas and oceans.

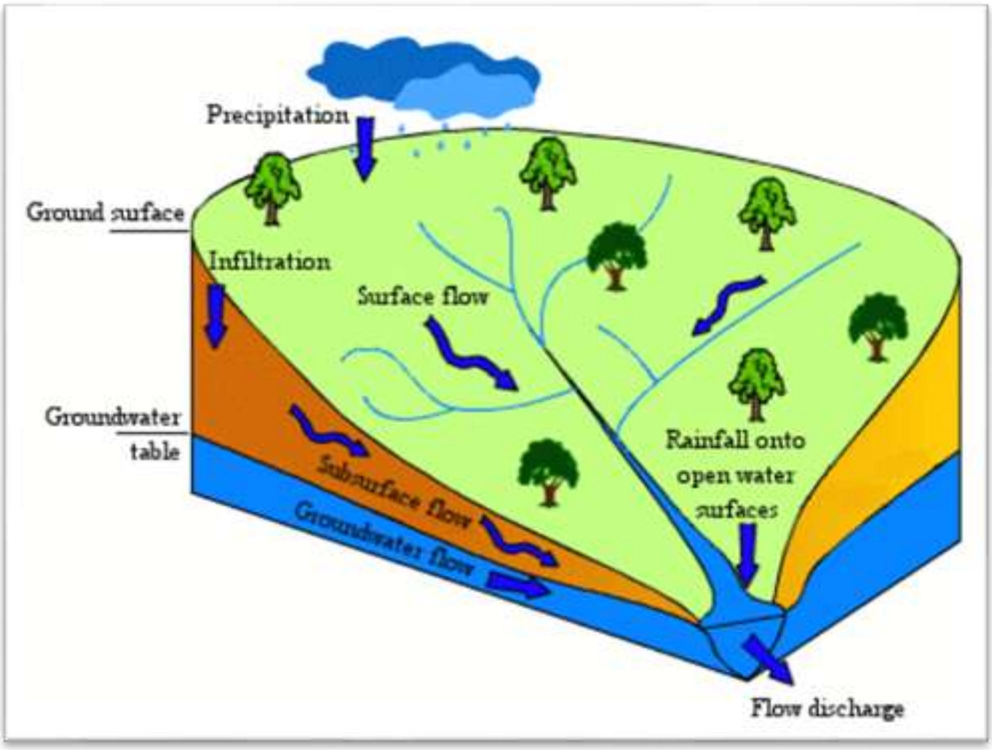

Figure 3: Flow and infiltration diagram. Source: 3

All surface water, including streams, rivers, and lakes, is collectively referred to as drainage water, an essential component of the planet's water cycle. This water moves across the land, carving paths through valleys and landscapes, eventually finding its way to larger bodies such as rivers and lakes. These waterways not only transport water but also carry nutrients, sediments, and organic matter that support diverse ecosystems along their routes. They are dynamic and interconnected, shaping the environment as they flow toward their ultimate destination—seas and oceans.

During its journey, water often lingers in natural reservoirs, such as wetlands, lakes, and underground aquifers, where it may remain for weeks, years, or even centuries. These reservoirs act as temporary storage points, playing a crucial role in regulating water availability, supporting biodiversity, and maintaining the hydrological balance. Eventually, the water continues its cycle, driven by the forces of gravity, heat, and time, flowing once again toward the seas and oceans, where the process begins anew.

The duration water spends within a specific reservoir is known as its residence time, a critical concept in understanding the dynamics of the water cycle. Residence time varies significantly across different reservoirs, reflecting the complexity of Earth's hydrological system. For instance, in the atmosphere, where water exists as vapor and clouds, its residence time is remarkably short—about eight days—comprising just 0.03% of Earth's

Figure 4: the Glaciers. Source : 4

freshwater. Rivers also exhibit brief residence times of only a few days, as their flowing waters are constantly replenished and moved downstream.

In contrast, other reservoirs retain water for much longer periods. Lakes hold water for an average of 17 years and account for 1.47% of Earth's freshwater. Groundwater, hidden beneath the surface, showcases an extraordinary range, with residence times spanning from mere days to several thousand years, contributing to 22.5% of global freshwater. Oceans, while containing a vast volume of water, exhibit residence times of approximately 2,500 years, holding 3% of Earth's freshwater. Glaciers, which dominate the freshwater reserves at 76%, lock water away for thousands of years, acting as frozen archives of Earth's hydrological and climatic history. Together, these varied residence times highlight the dynamic yet interconnected nature of Earth's water systems.

Since the 1992 Rio Conference, l'Académie de l'Eau (Water Academy) has stood at the forefront of addressing the intricate connections between water and various disciplines. This institution, composed of water specialists alongside experts in life sciences, earth sciences, and land-use planning, is dedicated to fostering a deeper understanding of the critical role water plays in shaping our world. Its principal mission is to illuminate the multifaceted relationships between water and other fields, recognizing water as a cornerstone of environmental preservation and a determinant of the quality of life for communities worldwide. (UNESCO official site)

Central to its efforts is the acknowledgment that water is not merely a natural resource but an integral element that intersects with urban development, agriculture, infrastructure, and ecosystem conservation. L'Académie de l'Eau works tirelessly to explore these intersections, emphasizing the need to balance resource management with sustainable development. By fostering interdisciplinary dialogue, it seeks to address the pressing challenges posed by urban expansion, industrialization, and climate change, all of which have profound impacts on water resources and their availability. (UNESCO official site)

Moreover, l'Académie de l'Eau is acutely aware of the constraints that arise from the complex interplay between water and land-use planning. Effective land management requires careful consideration of water availability, quality, and distribution to prevent overexploitation and environmental degradation. By advocating for policies and strategies that integrate water considerations into planning processes, the academy contributes to creating resilient communities and ecosystems. Its work underscores the urgency of aligning development goals with the principles of environmental stewardship to ensure a sustainable future.

1. The state of water resources in Algeria

The impact of water on human health, the environment and the quality of life is very strong because of its presence and interactions in all areas, its cycle brings it into contact with the whole earth (runoff and erosion, infiltration, pollution ...) and gathers it in rivers, aquifers and the sea, so the major interest of man must be to understand the water cycle and learn to consume without endangering the environment.

Conventional water refers to water sourced from traditional and readily accessible origins such as rainwater, river water, and underground aquifers. These sources have sustained human needs for millennia, providing the foundation for drinking water, agriculture, and hygiene. On average, a person requires approximately 3.5 liters of water per day to meet basic hydration needs. However, daily water consumption increases significantly when accounting for essential activities like washing, cleaning, and cooking.

In developing countries, this can amount to 50 liters per person per day, reflecting the minimum requirements for a modest standard of living.

As living standards improve, water consumption tends to rise dramatically due to the adoption of modern conveniences and luxuries. For instance, the use of toilets, washing machines, and the maintenance of private gardens and swimming pools significantly increase household water demand. In industrialized nations like the United States, average water consumption reaches an astounding 450 liters per person per day.

This trend highlights a growing challenge: the more developed and industrialized a society becomes, the greater its water consumption. As traditional water sources become insufficient to meet these escalating demands, the focus has shifted to exploring alternative sources to address the shortfall.

Unconventional water sources have emerged as a crucial solution for addressing water scarcity in the face of rising consumption. These non-traditional sources include saline water, brackish water, and even polluted water that would otherwise be unsuitable for direct use. To make these sources viable, advanced techniques and treatments are employed. Desalination processes remove salt and impurities from seawater, rendering it potable and suitable for various applications. Similarly, water treatment technologies purify polluted or wastewater, making it safe for reuse. These innovations represent a vital step forward in ensuring that growing populations and industrialized nations have sustainable access to water resources while minimizing the strain on conventional supplies.

1.1. Conventional water Algeria, the largest country in Africa and the Mediterranean, covers an area of 2,383,741 km², but 87% of this surface area is represented by the Sahara and the desert, i.e. 2 million km². The climatic zones are highly diversified, and the climate varies from Mediterranean to Saharan, As a result, as shown in the table below, Algeria ranks among the poorest countries in terms of water potential, and is far from the theoretical consumption per capita per year set by the World Bank at 1000 m3.

United states	**1840**	**Morocco**	**387**
Canada	**1623**	**Algeria**	**201**
Spain	**1040**	**Vietnam**	**371**
Italy	**976**	**UK**	**292**
Australia	**839**	**Senegal**	**151**
Japan	**735**	**Cambodia**	**48**
France	**547**	**Tchad**	**26**
Germany	**532**		

Table 1: Water potential in some countries. *Source: 4*

As shown in the previous table Algeria's water potential divided by population is one of the lowest worldwide in comparison to other countries such as Canada or France that already have installed a very efficient water management policies which contains water recycling and preservation of resources.

Algeria's water resources come from surface water and renewable and non-renewable groundwater, but they are not evenly distributed in terms of geography, quantity or type. Climatic data show a steep gradient in precipitation from north to south, and a second, lesser gradient from east to west; Algeria's geography divides the country into clearly differentiated regions in terms of relief, climate, agricultural capacity and aquifer reserves.

The mountain ranges of the Tellian Atlas and the Saharan Atlas, spread out at varying distances from the coast, distinguish the rainy north from the dry south. Between the eastern Tell and the western Tell, rainfall and climate mark a similar difference" (Despois & Raynal, 1975, p87).

These climatic parameters determine the distribution of the Algerian population and urban development. They enable us to distinguish three major regions favorable to urbanization: the coast, the plains and the Tell highlands. In fact, Algeria is divided into four major bioclimatic zones:

- Humid and sub-humid zones

- Semi-arid zones

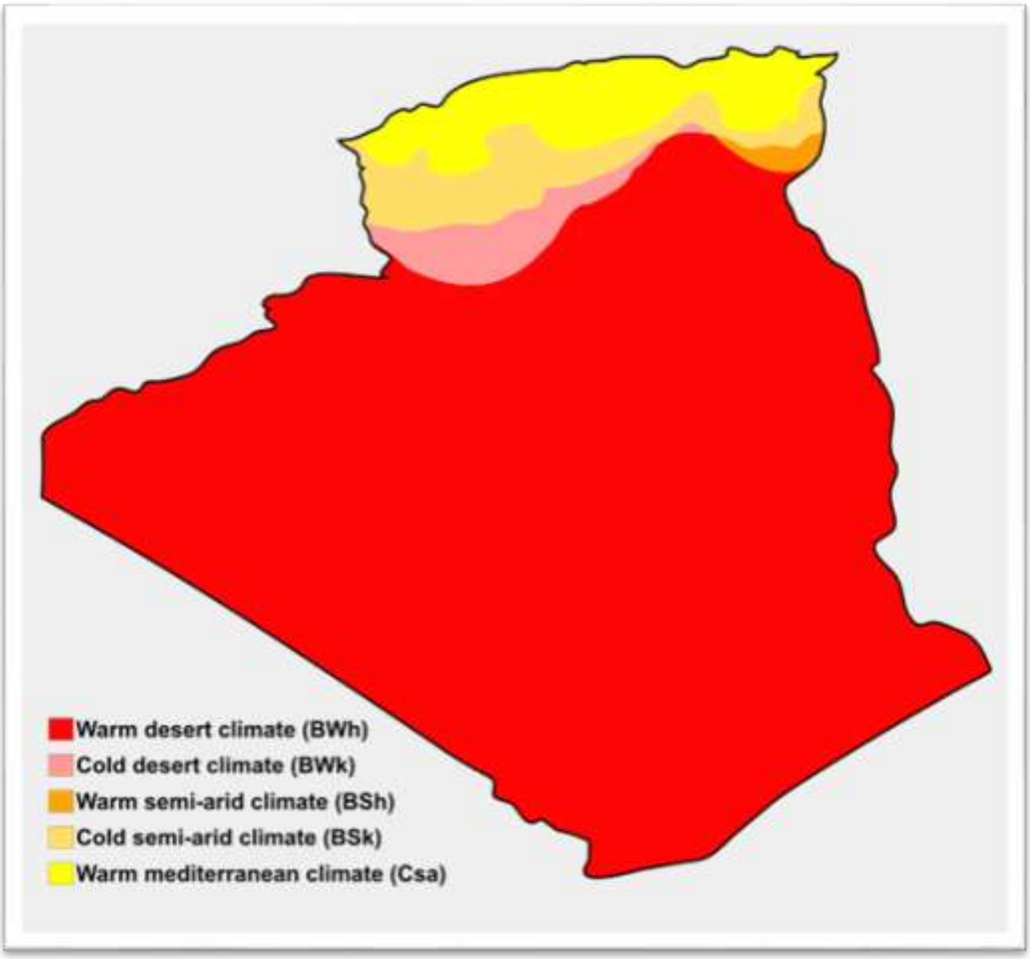

Figure 5: Algeria's climatic regions (Bwh) scale 1/8000 . Source: 5

1.1.1. Pluviometry and Surface Water

In Algeria, rainfall decreases from east to west and from north to south. Eastern Algeria is the wettest region, with an average annual rainfall of 530 mm. The Centre comes second with 480 mm. Finally, the West is drier, with an annual average of 260. Over the country as a whole, average rainfall amounts to 89 mm/year (FAO, 2015), the water that does fall is not captured in its entirety, droughts punctuate the country's history and aridity is a constant threat.

What's important to stress here is that Algeria's climate is characterized by marked aridity and irregular rainfall. According to specialists, by 2025 Algeria will experience a drop in rainfall of between 5% and 13%, and a rise in temperature of between 0, 6 to 1.1°C (Anonymous, 2009). Similarly, in the space of some forty years, between 1962 and 2000, the annual per capita water supply was divided by 3, from 1,500 to 500 m3/capita/year, as shown in the following table:

Year	1960	1990	1995	1998	2000	2020	2030
water supply per m3/inhabitant/year	1500	720	680	630	500	430	/

Table 2: Annual water supply per m3/inhabitant/year in Algeria. *Source:30*

Water resources, threatened by human, industrial and agricultural activities, and by global warming, have become a major issue. However, it has to be admitted that water resources in Algeria are limited, vulnerable and unevenly distributed.

The country's natural water potential is estimated at 18 billion m3/year, broken down as follows: 12.5 billion m3/year in the northern regions, including 10 billion in surface runoff and 2.5 billion in underground resources (renewable). 5.5 billion m3/year in the Saharan regions, including 0.5 billion in surface run-off and 5 billion in underground resources (fossil aquifers). The uneven distribution of rainfall means that surface water is also poorly distributed.

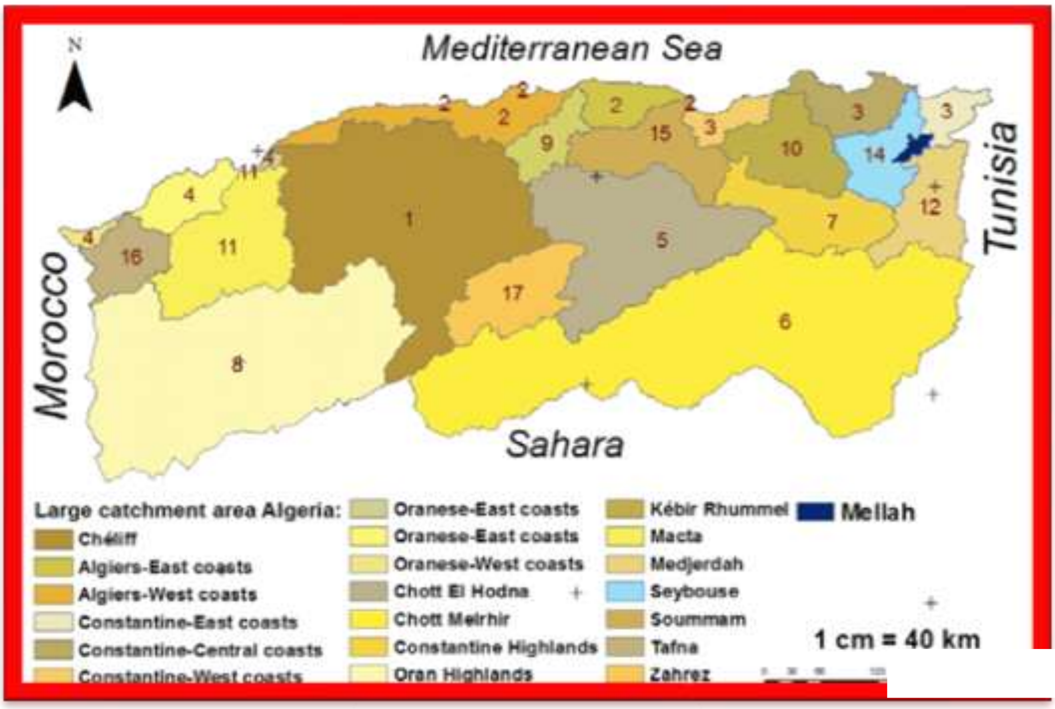

Figure 6: Algerian catchment areas.

Source: 6

Coastal zones are better endowed with water than semi-arid and arid zones, which leads us to say that Algeria, by the force of nature and humankind, is today faced with a problem of availability in sufficient quantity and quality.

In 1996, Algeria undertook a major step in the management and conservation of its water resources by dividing the country into five hydrographic regions. These regions were designed to group together the nation's 17 distinct watersheds, creating a more streamlined framework for water resource planning, allocation, and conservation. This reorganization was an acknowledgment of the diverse hydrological landscapes within Algeria, from arid desert basins in the south to more temperate, river-fed basins in the north. The establishment of these regions aimed to optimize the management of water resources across a country characterized by significant climatic and geographical variations.

The legal foundation for this restructuring was laid out in Executive Decree No. 96-100, which provided a clear definition of a hydrographic basin. According to the decree, a hydrographic basin is "the topographical surface drained by a watercourse and its tributaries in such a way that any flow originating within this surface follows its course to the outlet." This definition underscores the interconnectedness of water systems within a given basin, emphasizing that every drop of water, whether from precipitation o [illegible] t of an integrated system that culminates at a single outlet. This holistic perspective enables better planning for water use, pollution control, and ecosystem protection within each basin.

The decree also established the standard status for public management institutions tasked with overseeing these hydrographic regions. These institutions play a critical role in monitoring water resources, implementing conservation policies, and addressing challenges such as drought, over-extraction, and pollution.

By grounding their work in the concept of hydrographic basins, these organizations can ensure that water management practices are ecologically sustainable and aligned with the needs of both local communities and the environment. This forward-thinking approach has been essential for addressing Algeria's growing water demands while safeguarding its limited and precious water resources.

1.1.2/ Groundwater resources

Renewable groundwater resources in the northern part of the country are estimated at around 1.5 km3/year. These aquifers are fed mainly by rainfall, the distribution of which remains irregular in both time and space. The total volume of groundwater exploited is estimated at

3.2 billion m3/year: 1.8 billion m3/year in the north of the country and 1.4 billion m3/year in the Saharan regions.

The potential in terms of groundwater infrastructure is made up of 23,000 boreholes and 60,000 wells (2012). Groundwater resources make a major contribution to satisfying drinking, agricultural and industrial water needs.

In many urban and rural areas, they represent the only source of water supply, due to the scarcity or non-existence of surface water resources. However, the quality and quantity of this heritage is threatened on a daily basis (many groundwater tables have high levels of salinity, with dissolved salts ranging from 2 to 5 g/l).

The exploitation of water resources in Algeria has become increasingly intense, driven by the ever-growing demands of a rising population and expanding economic activities. As urbanization, industrialization, and agriculture progress, the pressure on these finite resources continues to mount, making sustainable management a critical priority. This challenge is particularly acute in regions where water availability is limited, and effective resource allocation is essential to balance human needs with environmental conservation.

Figure 7: the Northern Sahara aquifer in Algeria, Tunisia and Libya.
Source: 7

As shown in figure 7 where the CT stands for the Complexe Terminal (Terminal Complex) and CI stands for the Continental Intercalaire (Intercalary Continental). These are two major, deep, confined, transboundary aquifer units within the Northwestern Sahara Aquifer System (NWSAS) that are crucial sources of groundwater in Algeria, Tunisia, and Libya. In the southern part of the country, Algeria is home to significant underground water reserves, particularly within the intercalary continental and terminal complex aquifers. These aquifers form part of the vast Septentrional Sahara Aquifer System, a shared resource spanning Algeria, Libya, and Tunisia. This system contains an estimated 40,000 billion cubic meters of water, making it one of the largest freshwater reserves in the world. Covering an expansive area of one million square kilometers, it represents a vital resource for the three nations. Currently, the annual exploitation of this aquifer is estimated at 2.7 billion cubic meters, providing essential support for agriculture, domestic use, and industrial development.

However, the intensive exploitation of the Septentrional Sahara Aquifer System is not without significant risks. Overuse of these resources has led to salinization of the water, which reduces its quality and suitability for consumption and irrigation.

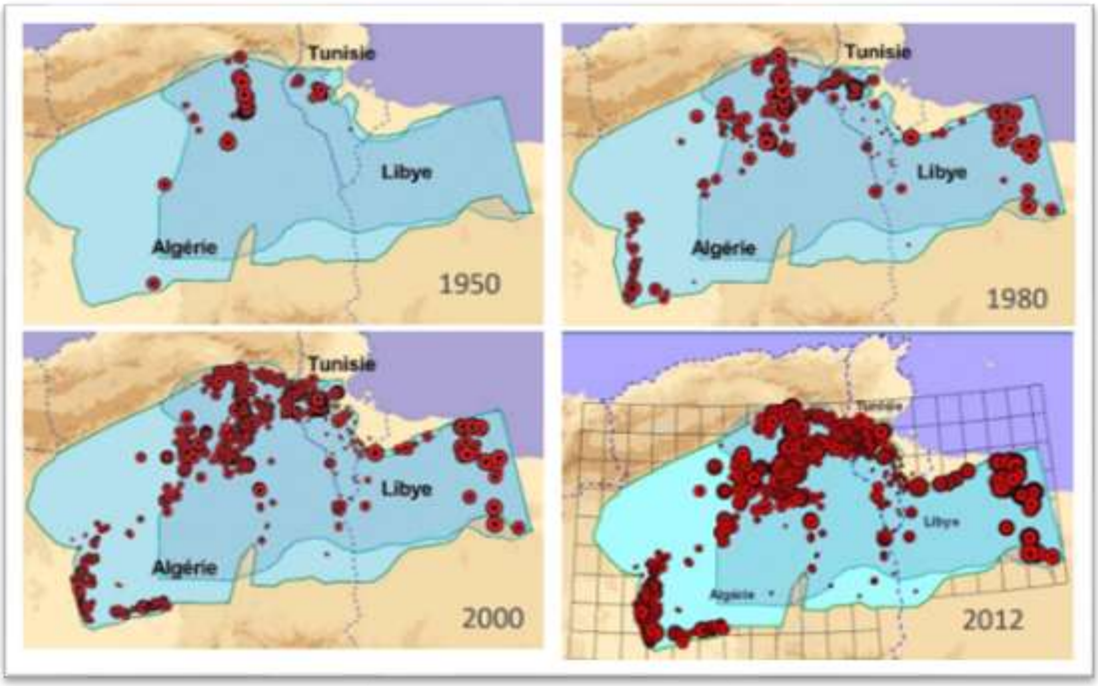

Figure 8: Diagram showing the distribution of water points since 1950 to 2012

Source: 8

The drying up of natural outlets further exacerbates the problem, threatening ecosystems and diminishing water availability for downstream users. Additionally, the shared nature of this resource introduces the potential for interference and conflicts between the three countries that depend on it. Effective transboundary cooperation, sustainable extraction practices, and innovative management solutions are urgently needed to address these challenges and ensure the long-term preservation of this invaluable resource.

The three countries concerned by the future of the system are therefore condemned to work together to find a form of joint management of the Saharan Basin (the following document shows the start of the cooperation agreement before political changes happened in one of the countries) in order to minimize the nuisances associated with these risks.

The studies carried out in this aquifer system have highlighted the most vulnerable zones, but have also identified new abstraction zones, so the necessity for an appropriate decision-making tools and a mechanism for consultation and cooperation is essential.


مرصد الصحراء والساحل
OBSERVATOIRE DU SAHARA ET DU SAHEL
SAHARA AND SAHEL OBSERVATORY

إعلان وزراء الموارد المائية
للبلدان التي تتقاسم منظومة الحوض الجوفي للصحراء الشمالية

Figure 9: the agreement signed between the three countries concerned in 2013. *Source: 9*

1.2 Non-conventional water

The use of non-conventional resources and short water use cycles could limit or reduce pressure on conventional resources, non-conventional resources include water from seawater or brackish water desalination and the reuse of treated wastewater, each has its own advantages and disadvantages in terms of management and use.

With current water treatment and management technologies, it is possible to set up such a cycle where direct withdrawals of conventional resources would represent only 10-20% of the sum of all requirements. However, such cycles are solutions specific to each location and territory studied. This means that, on the scale of a given territory, we need to carry out:

- A precise spatio-temporal inventory of water requirements, in terms of both quality and quantity, in order to classify the different uses,
- A precise spatio-temporal inventory of resources, in terms of quality and quantity, as well as the fragility or robustness of the environment and existing facilities,
- A realistic forecast and projection of the evolution of different needs over time.

The vast quantities of water in the world's seas and oceans can give the impression that this resource is inexhaustible, making it easy to assume that we can rely on desalination to meet our growing water needs. After all, seawater covers approximately 71% of the Earth's surface, and its potential as a water source seems virtually limitless.

However, while desalination technology, particularly reverse osmosis, has advanced significantly in recent years, the process is far from a simple solution to the world's water challenges. The scale of desalination required to meet large-scale water demands is still a daunting task that must be carefully balanced with environmental considerations.

Desalination, despite its technological improvements, comes with significant environmental drawbacks that cannot be ignored. One of the primary concerns is the energy consumption associated with the process, which requires large amounts of electricity to separate salt from seawater.

This energy demand can place a heavy burden on the environment, particularly if the energy is sourced from fossil fuels, further contributing to carbon emissions and climate change. Additionally, the brine waste produced during desalination, which is highly saline, can be harmful when released back into marine ecosystems, potentially disrupting local habitats and marine life. Chemical discharges from the desalination process also pose a risk to water quality and biodiversity.

From a sustainable perspective, desalination should be considered a supplementary, rather than a primary, source of water. Experts agree that desalination can only reliably meet less than 10% of global freshwater requirements, primarily as a back-up resource in areas where other water sources are scarce or polluted. As such, it is essential to prioritize more sustainable water management practices, such as water conservation, wastewater treatment, and improved agricultural irrigation methods, while exploring the potential of desalination as a last-resort solution. In the long term, a balanced, multifaceted approach to water use is necessary to ensure a sustainable future for both human populations and the planet.

2. Mobilizing water resources

The mobilization of water resources can be defined as all the efforts made to collect, manage and use the various water sources available in an efficient, sustainable and equitable way, in order to meet human, industrial, agricultural and environmental needs.

This mobilization includes the collection, storage, treatment and distribution of water, as well as the implementation of policies, practices and technologies aimed at optimizing its use while preserving the quality of water resources and taking into account future needs. In short, water resource mobilization involves maximizing the use of available water resources while guaranteeing their long-term availability and minimizing negative impacts on the environment.

In Algeria, the mobilization of water resources is a crucial issue due to the scarcity of water resources in certain regions of the country and the high demand for water for agriculture, industry and domestic needs.

2.1.1. 2.1 Infrastructures and structures

2.1.2. Development of dams and hill reservoirs

Hill dams are impoundments created by an earthen dam, with capacities ranging from a few tens of thousands to a million cubic meters of water collected in catchment areas varying in size from a few hectares to several tens of square kilometers.

Algeria currently has 75 dams in operation, five (5) of which are due to come on stream shortly, in addition to five (5) other dams under construction. The largest of these is the Beni Haroun dam, a gravity dam located in the far north of the Mila wilaya, with a capacity of 960 million m3.

The actual mobilizable capacity in Algeria is estimated at nearly 5.4 billion m3/year for the country as a whole, while the surface resources mobilized by dams in operation are estimated at 2.2 billion m3/year, out of a storage capacity of around 5 billion m3.

It should be noted that more than two-thirds of the volume of surface water that can be mobilized is located in 4 of the 17 watersheds (Chlef, Algérois, Soummam, Constantinois), which cover a surface area of 75,000 km2, or 3% of the national territory.

2.1.1.1. Site and type selection for dams

The choice of dam site must be based on the following conditions:

- Topographical conditions (watershed boundaries, topography of the river valley, topography of the impoundment site to estimate impoundment volumes according to water levels).

- Geological conditions (stability of supports and foundations, watertightness of the basin, stability of slopes, state of fracturing .....).

- Hydrological conditions (reservoir catchment area, rainfall, river inflows, flooding, solid input, etc.).

Figure 10: Beni Haroun's dam. Source: 10

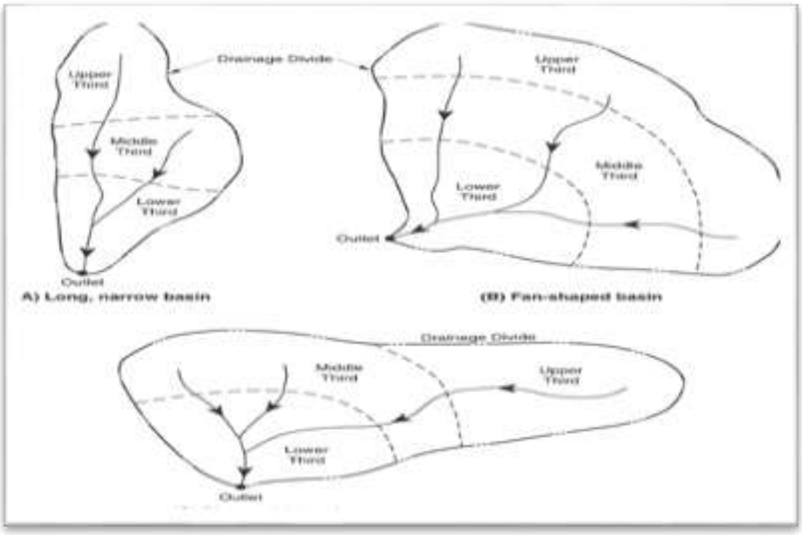

Figure 11: Schematic of typical drainage basin and subdivision shapes. Source: 11

The best location is where the valley narrows, upstream of the narrowing, the valley must be flatter and have a shallower gradient to allow the greatest volume to be stored, the dam is the smallest and therefore the least expensive.

Figure 12 : Some types of rigid dams. Source: 12

A/The type of dam is chosen on the basis of local conditions:

- Geotechnical qualities of the substrate

- Construction material resources (in terms of quality and quantity)

The final decision is made taking into account the expected benefits (energy production, site protection, etc.), costs (acquisition, works, etc.) and environmental impact (natural and human).

B/Classification of dams by type of material and resistance to water pressure:

Dams less than 100 m high are referred to as ordinary dams, while others are referred to as high-rise dams, dams are often classified on the basis of the type of construction materials or the method of resistance to water pressure, the main types of dam are:

❖ Rigid dams (made of assembled materials)

- Weight dams

- Buttress dams

- Arch dams

- Multiple arch dams

❖ Embankment dams (unassembled materials)

- Soil dams

- Rockfill dams

Figure 13: Soil dam. Source: 13

2.1.2. Water Wells and Boreholes

A water well or borehole is a vertical collection structure used to extract water from a water table, contained in the interstices or fissures of a subsoil rock known as an aquifer.

Water can be brought up to ground level either very simply using a container (a bucket, for example) or more easily using a pump, either manual or motorized.

Hand-dug wells are among the oldest sources of water supply. The first wells were very simple holes, unprotected from landslides, which did not stand the test of time and have now disappeared. Much more numerous are the wells dating from the Copper, Bronze and Iron Ages, which can be found everywhere.

Wells and boreholes are very diverse, whether in terms of depth, volume of water, cost or water purity, which may or may not need to be treated before it can be consumed (and which should be checked not only on completion of the work, but on a regular basis).

In fact, there are now three main categories of wells: dug wells, sunk wells and drilled wells, more commonly known as boreholes, an ambiguous term that designates both a structure and a construction technique. The choice of which type of well to use depends essentially on the depth of the water table (for example, it would be very difficult or dangerous for well-diggers to dig a well by hand at a depth of over 30 m), the hydrogeological data available on the site, whether or not speed is required, and the cost of the operation.

A well dug by hand with the participation of the local population is usually much less costly. Finally, the opening of a well dug with a pickaxe is much larger (if only to allow for the descent of the well-diggers) than that of a dark well made by sinking tools into the ground, or of a borehole whose opening is, on the contrary, narrow given the tools used and the great depth to be reached.

A/ Dug wells

Digging in the ground with a shovel and pickaxe is the simplest and oldest technique, and is also the most tiring but least expensive. It requires relatively loose soil and a shallow water table. These wells are often lined with stones to reinforce them and prevent them from collapsing, but it is far preferable to line them (keep them vertical) with concrete rings, often easily made on site with molds.

Alternatively, less rustic mechanical digging techniques can be used to reduce the physical effort required.

The shafts dug are not very deep (usually between 10 and 20 m, exceptionally 30 to 40 m). As they are shallow, they run the risk of being contaminated, and can dry out more easily than other types of well.

Figure 14: Dug well. Source: 14

B/ Driven wells (or wells with filtering points)

Driven wells are a type of water well typically created by driving a small-diameter, pointed-tip perforated tube vertically into the ground. The driving process involves pushing the tube back and forth to penetrate friable soils such as sand or gravel. This technique allows the well to tap into groundwater reserves located beneath the surface, offering a relatively straightforward method for accessing water.

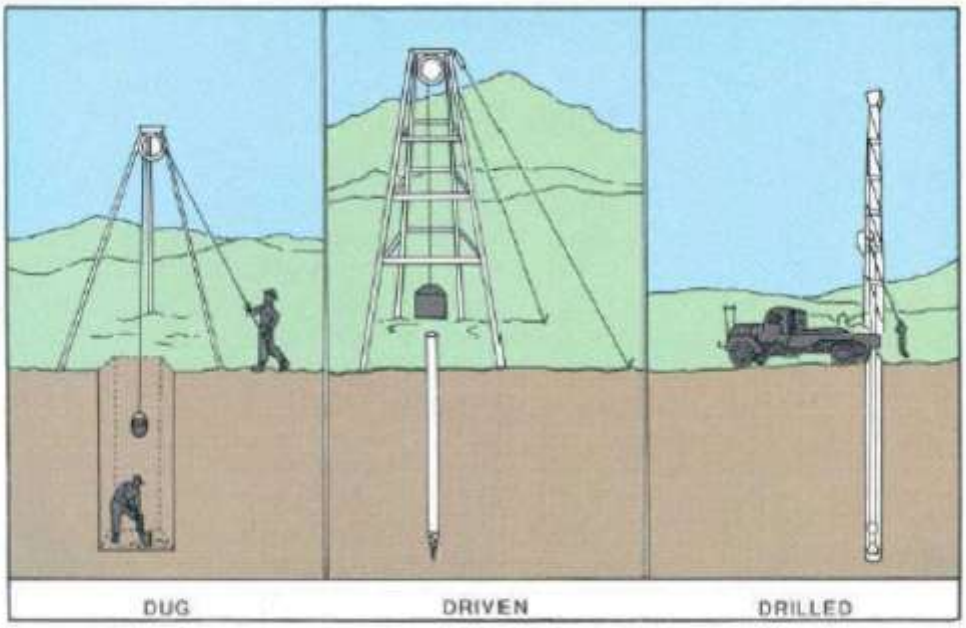

Figure 15: different types of wells. Source: 15

The tube is usually fitted with a filter or strainer at the bottom to prevent sand, silt, and other particles from entering the well, ensuring that the water remains clean and free of debris. In some cases, a special technique known as "havage" is used, where the tube is installed differently, but the general principle of water extraction remains the same.

Driven wells are typically used for extracting groundwater from moderate depths, usually ranging from 15 to 100 meters, depending on the specific technique and soil conditions. They are ideal for areas where the water table is not too deep and where other methods,

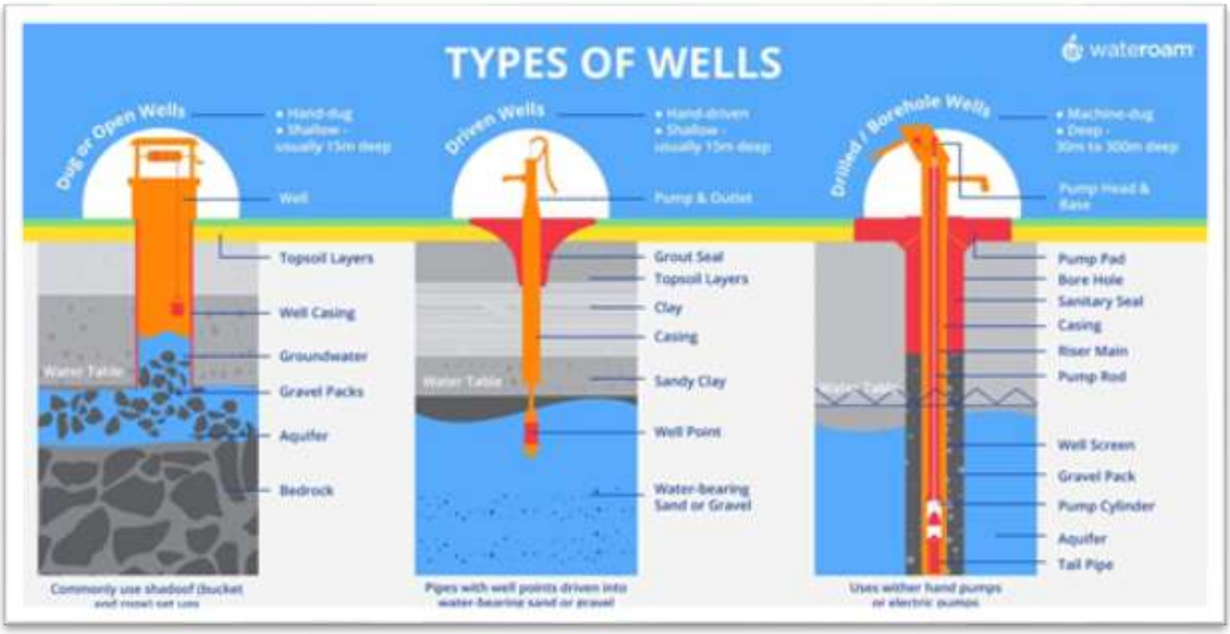

Figure 16: types of wells explained. *Source: 16*

such as drilling, may be cost-prohibitive. The well construction itself is relatively simple and can often be completed quickly compared to other types of wells, such as drilled or bored wells. However, the depth limitations of driven wells make them less effective in regions with deeper groundwater tables, restricting their use to areas where shallow groundwater is abundant and accessible.

Despite their advantages, driven wells, like dug wells, are still vulnerable to contamination and other risks. The shallow nature of these wells makes them more susceptible to pollutants from surface runoff, septic systems, or nearby industrial activities. Additionally, driven wells are at risk of drying out, especially in times of drought or when groundwater levels fluctuate. While they offer a practical solution in many scenarios, their limitations in depth and vulnerability to environmental factors mean that they are less reliable over the long term compared to more advanced groundwater extraction methods. Ensuring their maintenance and protection from contamination is crucial for preserving their functionality.

C/ Drilled wells or boreholes

A large number of modern wells are drilled using advanced techniques that allow access to groundwater sources located deep beneath the Earth's surface. These wells are typically created using two methods: percussion drilling, which involves a tool being repeatedly struck against the ground, and rotary drilling, where a cutting tool such as an auger, drill, or drill bit rotates around a vertical axis to break apart rock formations.

This rotary action allows for more efficient penetration of hard layers of earth, and the broken rock residues are often brought to the surface as sludge, where they can be removed and disposed of. These wells can reach impressive depths of up to 300 meters, providing access to groundwater reserves that may otherwise be unreachable through traditional methods.

In addition to modern wells, Algeria's water management system relies heavily on a variety of hydraulic infrastructures, such as dams and boreholes, to harness and distribute conventional water resources. Dams are particularly important in the northern regions, where they store water from seasonal rainfall and help regulate water flow for agricultural, industrial, and domestic use. Boreholes, on the other hand, are often drilled in areas where groundwater is the primary water source, particularly in arid and semi-arid regions like the Saharan zone. These infrastructures are essential in ensuring that water is available throughout the year, despite the country's erratic rainfall patterns.

Another key component of the hydraulic system is the network of canals, which serve to channel water from one location to another, providing a reliable means of irrigation and transportation. Canals are often constructed to compensate for the lack of natural rivers or to replace those that are difficult to navigate due to seasonal changes, sedimentation, or erosion. These man-made waterways ensure that water can be transported efficiently over long distances, facilitating the irrigation of farmlands, the supply of water to urban areas, and the support of local economies. The use of canals plays a critical role in managing Algeria's water resources, especially in regions where natural watercourses are scarce or unreliable.

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2.2. Channeling and treatment

2.2.1. Components of a water supply system AEP

A/ Backflow or pumping stations

Is the part between the pump and the reservoir, the pump in the borehole pumps the water back to the reservoir or water tower through the discharge pipe.

B/ Storage

Serves two purposes:

- To build up a reserve of water, available even when the pump is stopped
- To separate pumping from distribution, otherwise you would have to pump every time someone wanted water, and stop as soon as all the taps were turned off.

From the reservoir, the water flows through the pipes under its own weight, so the higher the reservoir, the further and faster the water can go, that is why some reservoirs are on the ground (cheaper), but others have to be raised - water towers - so that the water has sufficient pressure to supply the whole village.

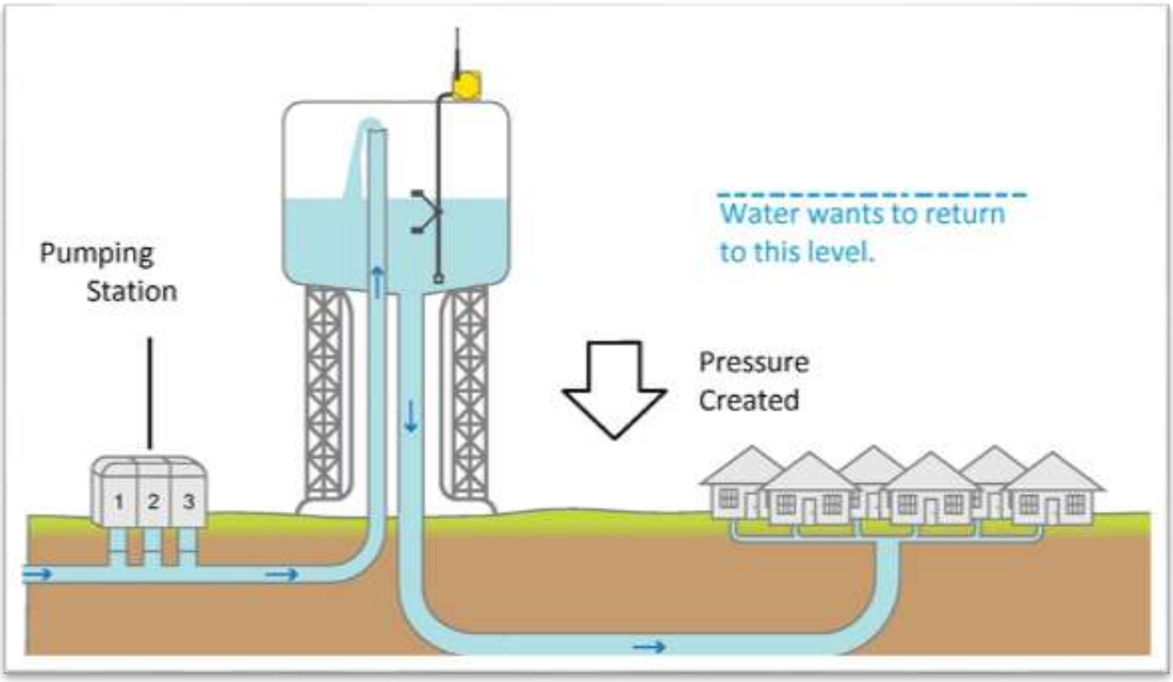


Figure 17 : Diagram of water mobilization. Source : 17

Figure 18 : metal water tower. *Source :* 18

Water towers are either made of metal (when a small capacity is required) or reinforced concrete (for larger capacities, but more expensive).

C/ Distribution

Refers to the part after the reservoir: *The network*

The distribution network is used to distribute water to distribution points (standpipes, drinking troughs, truck-filling jibs, individual connections). It consists of a set of pipes (in PVC, polyethylene or galvanized steel), buried in the ground, with special components to facilitate maintenance (fittings, valves, suction pads, manholes).

A network can be either arborescent, i.e. made up of branches that separate to go to water points (more economical), or meshed, i.e. its branches can join together to form loops (meshes), which ensures better pressure balance (but complicates leak repair).

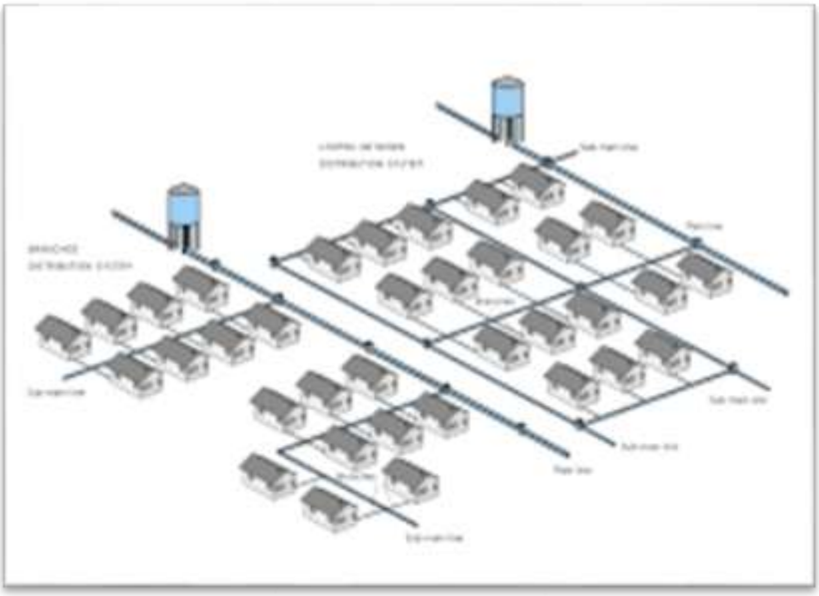


Figure 19 : The two Different types of water distribution network. Source : 19

D/ Water points

- Standpipes (or BF): These are public water points, serving non-subscribing residents. They therefore have a high flow rate, and often several taps.

- Private connections (or BP): These are water points inside concessions; the household with this water point is a subscriber to the water service.

- Watering troughs: These are watering points for livestock, designed to facilitate the watering of different types of animal. Here, the water is particularly dirty.

Figure 20 : a drinking trough. Source: 20

2.2.2. The different drinking water treatment processes

Water treatment is a critical process that ensures the safety and quality of water before it is supplied to the population. There are two primary levels of treatment, each corresponding to the quality of the water source being used. The first level applies to water resources of poor quality, such as surface water from rivers or lakes, which are often contaminated with organic matter, pathogens, and pollutants. For such sources, treatment is absolutely essential from the very beginning, typically at the catchment stage, before the water can be made safe for public consumption. The water must undergo a thorough cleaning process, often involving filtration, to remove these impurities and ensure it meets safety standards for drinking.

In contrast, the second level of treatment applies to resources considered to be of relatively good quality, such as water drawn from boreholes or wells. Although these sources may not be immediately contaminated, there is still a risk of pollution due to factors like aging infrastructure, poor hygiene practices at water collection points, or leaks in the distribution network that allow soil or bacteria to enter the water. In these cases, treatment is still necessary to prevent contamination and ensure the water remains safe for use. One common method for treating such water is chlorination, which helps kill any potential pathogens, making the water less vulnerable to further contamination.

Rapid filtration is a specialized method of water treatment used primarily in drinking water systems. This technique involves forcing water through various layers of filters to remove impurities, including suspended solids, bacteria, and other contaminants. The process is effective in producing clean, potable water but comes with significant challenges. First, it requires expensive equipment, including pumps and advanced filtration materials, which need regular maintenance to ensure optimal performance. Additionally, specialized technicians are required to monitor and maintain the system on a daily basis, adding to the operational costs.

Due to these high costs and the need for specialized personnel, rapid filtration is typically only used in large-scale pumping stations where there is sufficient infrastructure and resources to support such an intensive treatment process. For smaller municipalities or rural areas, the high financial burden often makes it an impractical option. Instead, alternative, more cost-effective treatment methods may be employed for smaller-scale water projects. Rapid filtration is, therefore, reserved for larger urban centers or industrial applications where the volume of water being processed justifies the investment in advanced filtration technology.

The extensive investment required for rapid filtration means it is rarely seen in municipal drinking water projects, particularly in regions where budgets for water treatment are constrained. For many smaller communities, the focus may be on simpler, less expensive methods of treatment, such as chlorination or basic filtration systems, which can still effectively treat water for everyday use. These methods, while not as comprehensive as rapid filtration, help mitigate the risks of waterborne diseases and improve overall public health.

However, even in large cities where rapid filtration might be feasible, challenges remain. Aging infrastructure, increased water demand, and climate change-related issues, such as reduced water quality in source bodies, make maintaining effective treatment systems a constant challenge. As such, water utilities must remain vigilant, ensuring that their systems are regularly updated and maintained to prevent contamination and ensure a continuous supply of clean water to the population.

Ultimately, the choice of water treatment method depends on a variety of factors, including the quality of the water source, the scale of the treatment facility, and available resources. Regardless of the method used, the goal remains the same: to ensure that the water supplied to communities is safe, clean, and free from harmful contaminants. As water scarcity and pollution continue to threaten global water supplies, investing in effective treatment systems will be essential for safeguarding public health and ensuring access to safe drinking water for all.

2.2.3. Water resource mobilization in Algeria

In its activity report for the first half of 2021, the Ministry of Water Resources of Algeria painted a picture of both challenges and progress concerning the country's water resources. The eastern regions of Algeria were noted to be in a "fairly comfortable" situation, with dams operating at a relatively healthy filling rate of 70%.

This positive outlook in the east contrasts with the more critical situation in the west and central regions, particularly in Greater Algiers, where a "significant shortage" of surface water resources continues to affect water availability. This discrepancy highlights the regional imbalances in water distribution, underscoring the need for targeted solutions to address water scarcity in the more affected areas.

The report also emphasized the vital role of surface water in the country's water supply, with 60% of these resources being directed toward meeting the population's drinking water needs. By the end of May 2021, the 80 dams in operation had accumulated reserves totaling 3.38 billion cubic meters (m3), a substantial volume considering the country's water demands. However, this amount still represents only a portion of the total potential, as these dams have a combined installed capacity of 7.7 billion m3. The difference between available and total capacity serves as a reminder of the need for continued investment in water storage and management infrastructure to optimize the use of these resources, particularly during times of drought or irregular rainfall.

In addition to surface water, Algeria also relies heavily on its groundwater resources to supplement its water supply. The report revealed that there are 26,152 operational boreholes across the country, which together produce 951 million cubic meters of water annually. Groundwater remains an essential source of water, particularly in regions with limited access to surface water, such as the arid southern areas. However, the continued extraction of groundwater, without sufficient replenishment, raises concerns about long-term sustainability, prompting calls for more efficient water use and stricter regulation of groundwater resources to prevent depletion and environmental degradation.

To further bolster water availability, Algeria has also turned to non-conventional water resources, including seawater desalination and brackish water demineralization. During the first half of 2021, the Ministry highlighted the operation of ten major seawater desalination plants and 26 brackish water demineralization plants, both of which play a critical role in supplementing the national water supply. These plants produce desalinated water at an average rate of 1.6 million cubic meters per day (m3/d), while brackish water demineralization plants add an additional 112,475 m3/d. These non-traditional sources of water have become increasingly important in light of the growing pressure on conventional water supplies, particularly in coastal regions and areas where freshwater resources are limited.

These investments in desalination and demineralization are vital for ensuring the continued availability of drinking water for Algeria's population. As of 2021, the total volume of water mobilized from both conventional and non-conventional sources is enough to supply the drinking water needs of around 43.9 million people. The total daily water demand across the country is approximately 6.6 million cubic meters, with each person requiring an average of 150 liters per day. This figure highlights the immense challenge of meeting the growing water needs of a rapidly expanding population while also accounting for the demands of agriculture and industry.

Despite these efforts, the report also signals the importance of balancing water demand with sustainable management practices to ensure long-term water security. With surface water resources under increasing pressure and groundwater being tapped at unsustainable rates, Algeria faces a delicate balancing act between ensuring sufficient supply and safeguarding its water resources for future generations. The reliance on non-conventional water sources, such as desalination, plays an essential role in diversifying the country's water supply and mitigating the risks associated with over-reliance on conventional sources.

Ultimately, the activity report underscores the need for continued investment in water infrastructure, technology, and management strategies to meet the country's water demands while ensuring the sustainability of its water resources. As climate change and population growth add further strain to water supplies, Algeria's future water security will depend on innovative solutions, efficient water use, and a robust strategy for managing both conventional and non-conventional water resources to meet the needs of its people and its economy.

2.3. Major water transfers

Water transfers represent the transport of a volume of water from one geographical location to another, often from a place of abstraction to a place of distribution and use. These structures comprise a means of transport (pipe or canal), a means of propulsion (gravity or pumping) and any intermediate water intake, storage and/or regulation/security structures.

The major transfers in Algeria are:

- Arzew-Oran "MAO" and EL Harrache-Douéra
- Beni Harroun transfer with the passage of water from the ain kercha pumping station to the koudiet M'daouar dam (W.Oum EL Bouaghi_Batna), and the Oued -djer diversion: this will transfer 25hm(cube)/year over a 3km tunnel to the Bouroumi dam, currently in operation for the irrigation of 24,000ha.

- Other transfers include the Taghrist dam (W. Khenchela ,kef Eddir W. de Tipassa),Taht and its transfer(W .Mascara), Beni Slimane (W .Médéa),Ouledjet mellegue (W. Tébessa)
- Oued Athmania _Ain Kercha(W.Batna_khenchela),d'Ain Kercha vers barrage Ouurkis (W. Oum EL Bouaghi)
- transfer from Boussiaba dam to Haroun dam(W .Mila) ,
- transfer from Ighil emda to M ahouane (W. Sétif)transfer from Tabellout to Draa Diss (W. Sétif) drinking water supply from Oued Athmania dam to chelghoum EL Alaid , Tadjenant and Constantine.
- Transfer from Mostaganem to Arzew and Oran
- South/North transfer
- In Salah /Tamanrasset transfer

2.4. <u>Traditional means of mobilization</u>

Traditional means of water mobilization refer to methods and techniques that have long been used to access and use water, often before the advent of modern technologies.

These means have been developed over the centuries by different civilizations to meet water needs for agriculture, human consumption and livestock breeding....
Two examples are given below:

- **<u>Qanat:</u>** is a hydraulic structure designed to capture groundwater and convey it to the outside world, it consists of a series of vertical wells connected to a slightly sloping drainage gallery, which carries the water to cisterns or an insurgence.

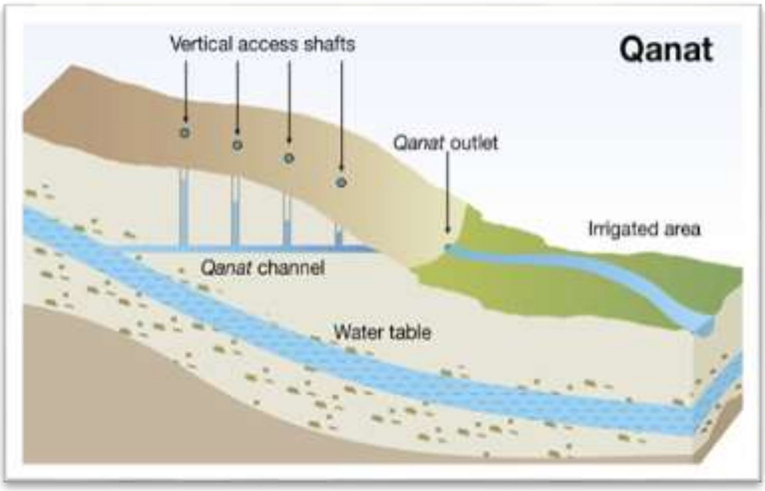


Figure 21 : qanat.   Source: 21

- **The noria**: "A hydraulic machine used for irrigation, consisting of an endless chain wrapped around a drum and to which is attached a series of containers that draw water from a well or stream and pour it, at the top, into a reservoir" (Green,Journal,1933, p.140).

Figure 22: Noria. Source: 22

3. Human consumption

In the field of water use and consumption, it is essential to differentiate between several key terms and concepts that help clarify the dynamics of water allocation and usage. These terms include need, demand, abstraction, and consumption, each representing a distinct aspect of how water is utilized. Understanding the distinctions between these concepts is crucial for effective water management, especially in regions experiencing water stress.

These terms provide a foundation for evaluating both the quantity and quality of water available for various uses, as well as for assessing the environmental and social impacts of water consumption.

One important concept is "withdrawal," which refers to the quantity of water taken from the natural environment for use in various activities, whether for domestic, agricultural, or industrial purposes. After withdrawal, the water is often returned to the environment, typically after some form of treatment or use.

This distinguishes it from "consumption," which involves the portion of water that is used and not returned to nature. In consumption, the water is either absorbed into products or evaporates, making it unavailable for reuse in its original form. Understanding the volume of withdrawal and consumption is essential for tracking water usage and managing supply systems effectively, especially in water-scarce regions.

"Water demand" is another critical concept, defined as the amount of water a user requires to maximize their utility or health, assuming no physical or economic constraints. Water demand can be influenced by a range of factors, including population growth, economic development, and technological advances.

By estimating water demand, planners and policymakers can predict the quantities of water required for various sectors and determine the risk of water scarcity in a given region. This estimation allows for better planning and management of water resources, helping to gauge water stress and inform decisions related to water conservation, infrastructure development, and policy implementation.

Water demand has four main sources:

- Agriculture
- Energy production (hydroelectricity)
- Industrial production
- Domestic consumption (urban water cycle)

3.1. Agricultural use

Agriculture is one of the economic sectors that uses the most raw water. This sector alone consumes around 70% to 80% of the world's freshwater resources. In Algeria, agriculture has long been a priority in the use of water resources, and is the largest water-consuming sector in all regions of the world except Europe and North America.

Irrigation has played a considerable role in increasing food production in recent decades, but its total contribution remains lower than that of rain-fed agriculture. A small irrigated area can replace and produce as much as a larger, low-yield rain-fed area, but the productivity of irrigated land is three times higher than that of cultivated, non-irrigated land.

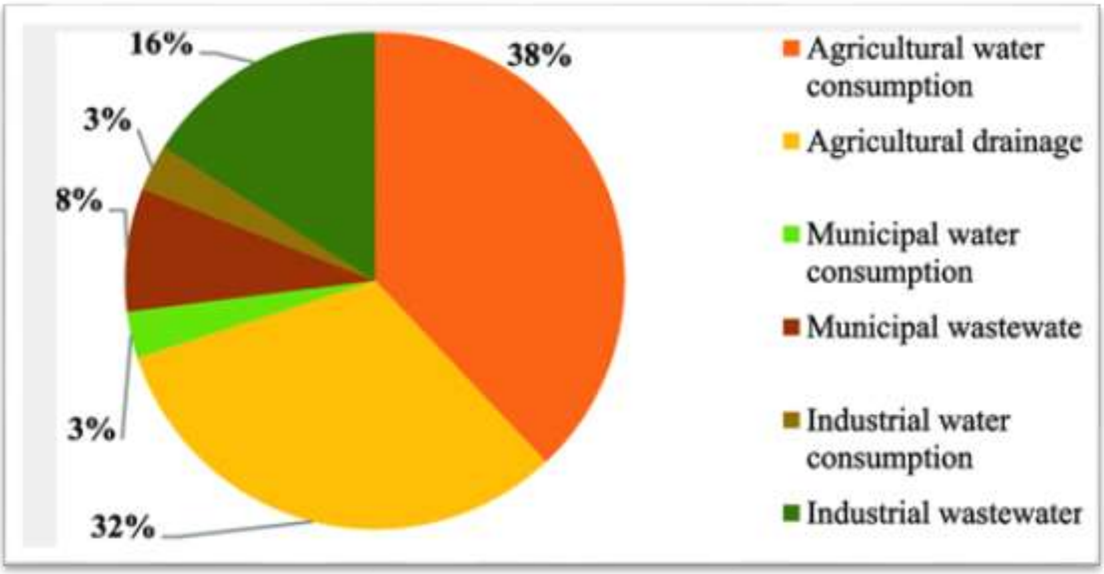


Figure 23: the World's water consumption and wastewater by sector 2020
Source:23

3.1.1. Irrigation techniques

Irrigation techniques that have been developed over time have largely evolved to provide higher yields, while the volumes of water consumed have decreased significantly. The use of old or traditional irrigation methods used by farmers in Algeria and the lack of modern water-saving irrigation systems (such as sprinklers and drip irrigation) are the main factors in water consumption

Several irrigation techniques can be distinguished:

- surface irrigation, which floods the entire cultivated area
- Sprinkler irrigation, which mimics rainfall, has certain disadvantages: it moistens plants, which encourages the establishment and proliferation of certain diseases, or affects the plant when the water used is of poor quality or saline.
- Drip irrigation, which distributes drops of water to the plants, but only above the rhizosphere.
- In-ground irrigation of the rhizosphere using pipes or porous containers placed in the soil.

Drip irrigation and in-ground irrigation are two advanced water distribution techniques that operate by delivering water at a very low flow rate, directly to the plant's root zone, often referred to as the rhizosphere. This localized watering method ensures that each plant receives the precise amount of water it requires, minimizing waste and improving water-use

efficiency. By targeting water application directly to the roots, both systems reduce evaporation losses that typically occur in traditional surface irrigation methods.
As a result, these techniques are particularly effective in water-scarce regions where maximizing every drop of water is critical to sustainable agriculture.

The benefits of drip and in-ground irrigation go beyond just efficient water use. They also lead to increased crop yields, as plants are provided with a steady and consistent supply of water, optimizing their growth conditions.
Moreover, the precision of these irrigation methods reduces the need for excessive fertilizer application. Since water is delivered directly to the root zone, the amount of fertilizer needed is minimized, and the risk of fertilizers leaching into the groundwater is significantly reduced. This not only helps to reduce pollution but also contributes to the protection of surrounding ecosystems and the environment, making these irrigation methods both economically and ecologically beneficial.

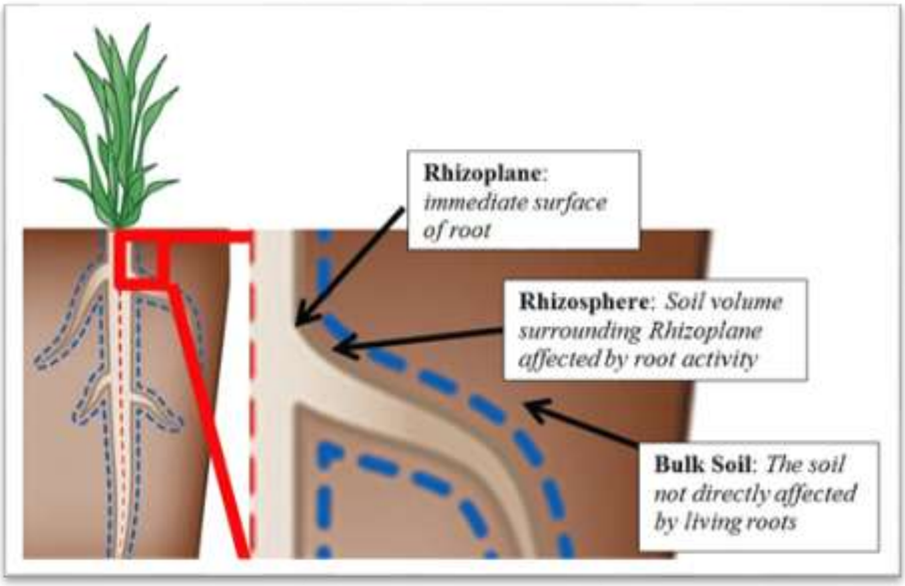


Figure 24: the location of rhizosphere in roots. Source: 24

3.2. <u>Domestic use</u>

Domestic water is conventionally clean, free from harmful elements. It is estimated that 20 to 40 liters of fresh water per person per day is the minimum required to meet drinking and sanitation needs alone. If we add the needs of hygiene and meal preparation, this figure varies between 40 and 200 liters on average, depending on local water availability.

It should be noted that the more water is available, the more it is used. Barely a century ago, most of the world's population (90%) lived in rural areas, whereas today around half live in cities. Water use differs according to whether people live in urban or rural areas.

Populations without access to drinking water are mainly located on the Asian and African continents, with rates of 65% and 27% respectively, compared with only 6% in Latin America and 2% in Europe. Ethiopia offers access to drinking water to only 22% of its inhabitants, the lowest rate in the world.

Access to drinking water close to the consumer has stimulated consumption, which has increased considerably with installations such as washbasins, showers, bathtubs, toilets, washing machines and dishwashers. The following figure shows the average water consumption of these sanitary installations

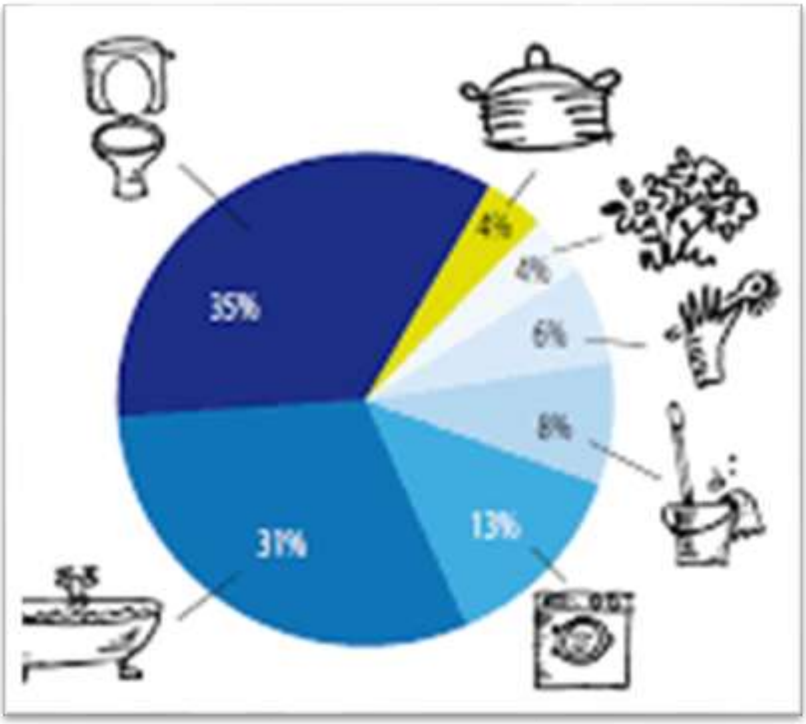


Figure 25: Water consumption by domestic activity. Source: 25

Worldwide consumption of bottled water has grown steadily over the past thirty years, averaging 12% a year. Europeans are the main consumers. In the United States, 57% of Americans regularly drink bottled water.

In Algeria, mineral water is defined by the Executive Decree of July 15, 2004, as water from an underground aquifer, distinguished by its purity and specific content of mineral salts and other constituents. Spring water, on the other hand, is defined as exclusively underground water, suitable for human consumption but microbiologically sound and protected against the risks of pollution.

3.3. Industrial use

The relationship between industrial development and water consumption is undeniable, with the industrial sector being a major consumer of freshwater worldwide. As countries become more developed and industrialized, the demand for water from industries such as manufacturing, energy production, and mining increases substantially.

On a global scale, the industrial sector accounts for approximately 22% of all freshwater withdrawals. However, there is a notable disparity in water usage across different levels of development. In highly industrialized countries, the industrial sector can consume up to 59% of the total available water resources, reflecting the crucial role water plays in sustaining modern industries. In contrast, underdeveloped nations rely far less on industrial water consumption, with the industrial sector in these countries typically using only about 8% of their total water supply.

In Algeria, the situation is unique. As of 2002, the industrial sector accounted for just 6% of the nation's total water consumption. A significant portion of this water is used in the oil extraction industry, which remains a dominant sector of the country's economy.

The oil and gas industry requires substantial amounts of water for various processes, including cooling, drilling, and refining. While this relatively low industrial water consumption rate might suggest a lesser burden on water resources, it also highlights the country's reliance on its non-industrial water uses, such as agriculture and domestic needs.

As Algeria continues to develop its industrial sector, managing water resources efficiently and sustainably will become increasingly important to ensure a balance between economic growth and environmental preservation.

The most water-hungry industries are processing plants. The El Hadjar industrial complex (Annaba, Algeria), for example, requires a flow rate of 700 l/s at full capacity, roughly equivalent to the AEP needs of the city of Annaba.

Water is an essential element involved in industrial production processes, as it participates in :

- Production as a thermal fluid (production of steam, hot water, cooling water, chilled water, etc.). For this purpose, water conveys and exchanges heat and cold within an industrial site.

- Water is used for washing and transporting raw materials.
- Water is used as a solvent, raw material, manufacturing agent or cleaning fluid for equipment or manufactured products.

Water consumption in industry varies from country to country and from sector to sector. The quality of industrial water depends on the activity, e.g. the food industry needs drinking water, whereas the electronics, medical and biotechnology industries require ultra-pure water.

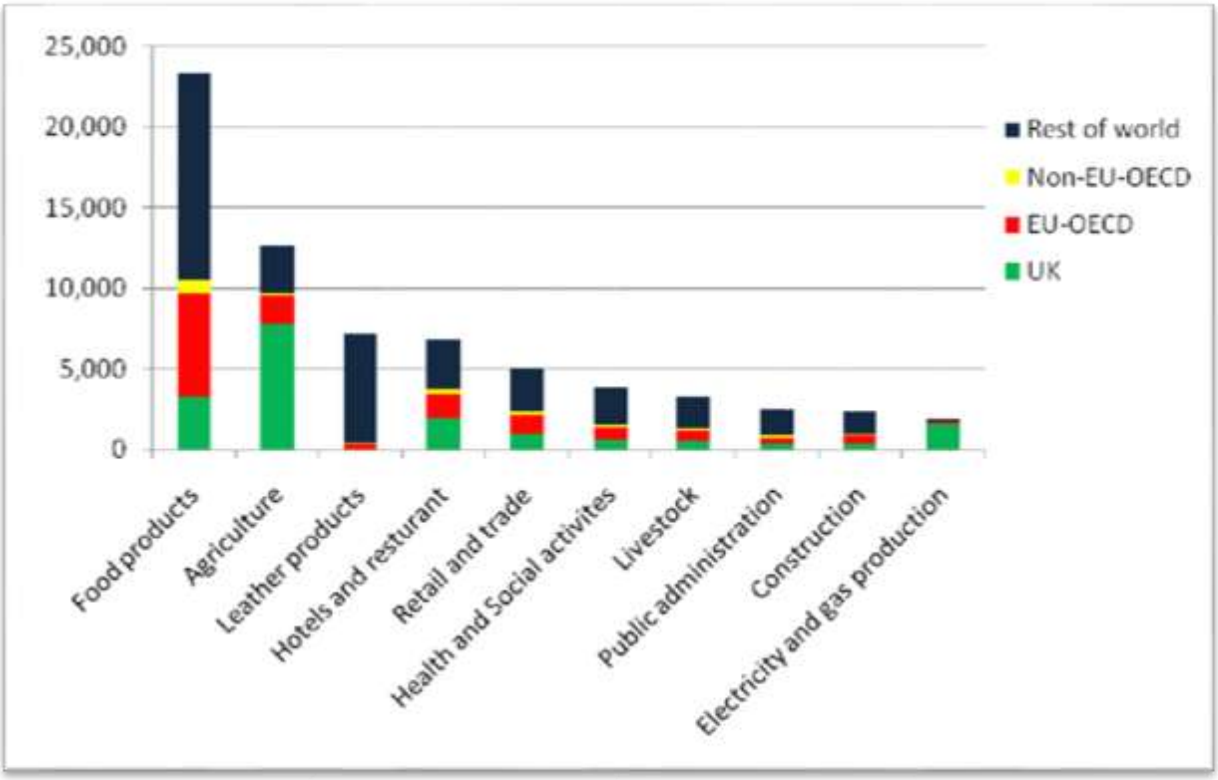


Figure 26: A classification of Water consumption by economic sector in worldwide. Source: 26

4. International water law

The right to water is a fundamental human right, ensuring that all individuals, regardless of their economic status or origin, have access to a minimum quantity of fresh, clean water. This concept recognizes water not merely as a resource but as an essential requirement for life, health, and dignity.

The European Charter of 1968 was one of the first international documents to establish water rights, acknowledging the importance of access to water for all people. However, despite its broad endorsement by 146 states that have ratified the International Covenant, the right to water remains a legal ambiguity, as it is not legally binding in many jurisdictions.

This legal uncertainty surrounding the right to water raises several complex questions, particularly regarding the nature of water itself. One of the central debates is whether water should be treated as a marketable commodity that can be bought and sold, like any other product. In many regions, water is managed and distributed by private companies, prompting concerns over its accessibility and affordability for marginalized communities.

The question of whether water can be considered a market commodity, subject to supply and demand dynamics, contrasts sharply with the view that it is a shared resource meant to be freely available to all.

At the heart of the debate is the distinction between goods and things. Goods are objects that can be privately owned and provide utility to individuals, while things, by contrast, are seen as resources that cannot be commodified in the same way.

This philosophical and legal discussion has profound implications for how water is governed and accessed. Is water a "Good" that can be privatized and sold, or is it a "Thing" that belongs to all and should remain under collective stewardship? This ongoing debate continues to shape policies and legal frameworks around the world, as societies grapple with the balance between the commercialization of water and its recognition as a basic human right.

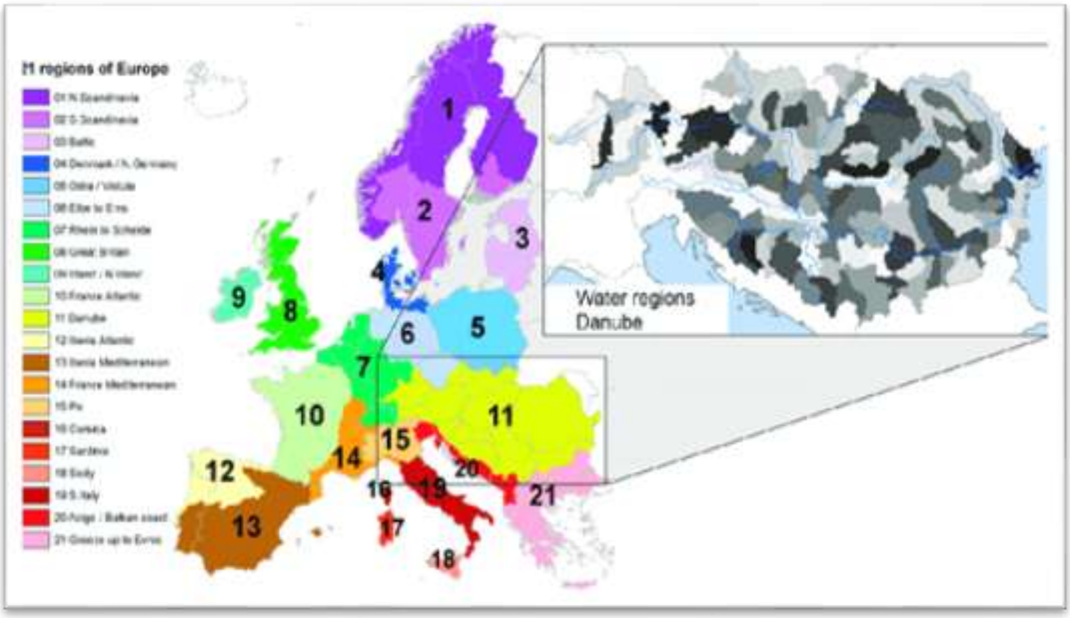
4.1. Shared water

One of the most significant challenges in global water management is the fact that two out of every three major rivers and aquifers—over 300 in total—are shared between multiple countries. These shared water resources often span political borders, and their management requires cooperation, negotiation, and sometimes even compromise.

Rivers and aquifers that cross national boundaries do not adhere to the artificial divisions created by human-made borders, making their use and conservation far more complex. Countries must work together to balance competing demands and ensure the sustainable management of these vital resources, which are crucial for drinking, agriculture, industry, and overall economic development.

The impact of shared water resources is far-reaching, as roughly two out of every five people on the planet rely on water that originates outside of their own country. This creates a delicate situation where the actions of one country can directly affect the water security of its neighbors. For example, upstream countries that control the flow of a river or the extraction of groundwater can have a significant impact on the availability of water for downstream nations.

In some cases, this has led to disputes and conflicts over water allocation, as nations vie for their share of limited resources. Managing these shared waters requires not only technical solutions but also diplomatic negotiations, ensuring equitable access and fair distribution for all parties involved.



Moreover, the fact that 155 countries depend on upstream water sources for more than 50% of their water needs further complicates the implementation of the right to water.

The right to access clean, safe, and sufficient water is enshrined in international law, yet the realities of shared water resources often make it difficult to achieve. The legal and logistical challenges of coordinating water use across borders, addressing pollution, preventing over-extraction, and ensuring long-term sustainability require comprehensive and collaborative approaches. These complexities highlight the importance of international agreements, treaties, and cooperative frameworks that can help resolve conflicts and ensure that water remains a shared resource that benefits all.

The 1997 New York Convention (Convention on the Law of the Non-Navigational Uses of International Watercourses) has not been ratified, as its article 7 on financial compensation posed a major problem of application. For example, the Danube flows through seventeen countries, and the Nile through ten. There are, however, agreements on inter-state management of watercourses, for example between India and Pakistan (Indus Water Treaty).

In Europe, the United Nations Economic Commission for Europe (UNECE) negotiated the Convention on the Protection and Use of Transboundary Watercourses and International Lakes, signed by the European Union at "Helsinski, 1992" and adopted at "London, 1999" by other European Union states, including the Russian Federation.

5. Prospects for mobilizing and protecting water resources

The mobilization and protection of water resources are major concerns on a global scale, given the vital importance of water for humanity and ecosystems, and the outlook for water resource mobilization and protection:

- Integrated water resource management (IWRM): IWRM is an approach that aims to coordinate water management across different sectors (agriculture, industry, urban planning) and to involve all stakeholders, including local communities, it promotes sustainable water use by taking into account socio-economic and environmental needs.
- Investment in water infrastructure: The construction and maintenance of infrastructure such as dams, irrigation systems and wastewater treatment plants are essential for the efficient mobilization and management of water resources.
- Use of innovative technologies: Technologies such as desalination, reuse of treated wastewater, rainwater harvesting and intelligent management of water networks can help increase water supply in areas where resources are scarce or under pressure.
- Watershed protection: Watersheds are crucial areas for regulating water quality and quantity. Protecting watersheds from deforestation, soil erosion, pollution and other threats is essential to ensure the continued availability of fresh water.
- Managing water-related risks: Extreme weather events, such as droughts and floods, are becoming increasingly frequent as a result of climate change.
- Strengthening international cooperation: As many water sources cross national borders, international cooperation is essential to effectively manage transboundary water resources.

5.1 Critical zones

Critical water zones are regions where water resources are scarce, threatened or poorly managed, creating significant challenges for local populations, ecosystems and economic activities. These areas are often confronted with problems such as water scarcity, degradation of water quality, conflicts of use and risks linked to climate change:

- Arid and semi-arid regions: Deserts and semi-arid regions, such as Algeria and the Sahel in Africa, the Middle East, and parts of Central Asia and South America, face chronic water shortages due to low rainfall and high evaporation. These regions often face challenges such as desertification, soil degradation and competition for water resources between agriculture, cities and ecosystems.
- Overexploited river basins: In many parts of the world, river basins are overexploited due to the growing demand for water for agriculture, industry and domestic needs. For example, the Colorado River basin in the USA and the Indus River basin in South Asia are facing problems of overexploitation, degradation of water quality and declining flows.
- Coastal zones threatened by sea-level rise: Sea-level rise due to climate change threatens water resources in coastal zones, increasing the risk of saltwater intrusion into coastal aquifers and disrupting freshwater and saltwater ecosystems. Regions such as the Nile, Ganges-Brahmaputra and Mekong deltas are particularly vulnerable to these impacts.
- Cross-border conflict zones: Watersheds shared by several countries can be the scene of tensions and conflicts linked to the management and use of water resources. For example, the Nile basin in East Africa and the Jordan basin in the Middle East face challenges related to the equitable distribution of water between riparian states.

Effective management of these critical water areas requires an integrated and sustainable approach, involving cooperation between governments, local communities, private sector players and international organizations.

5.2 Increasing tensions

There are several aspects to the growing tensions surrounding water:

- Geopolitical conflicts: Water resources can be a source of conflict between countries or regions. For example, tensions exist between Egypt, Ethiopia and Sudan over the construction of the Renaissance Dam on the Nile, as this would affect the distribution of water resources.

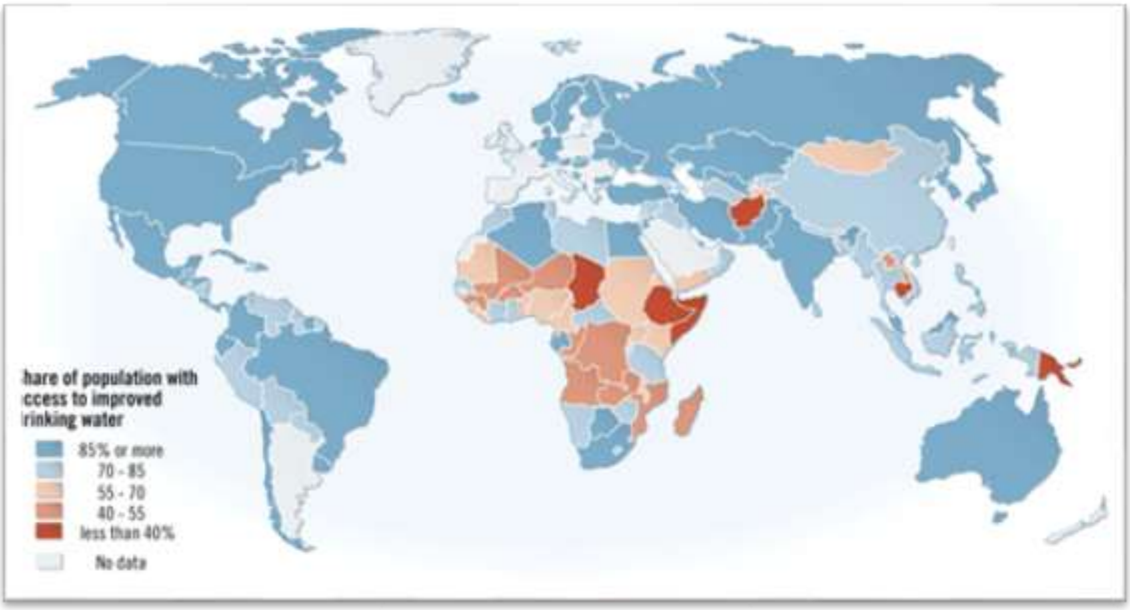


Figure 28: Access to safe drinking water worldwide. Source: 28

- Water stress: In many parts of the world, demand for water is outstripping supply, leading to local and regional tensions. Prolonged drought, overexploitation of water resources and population growth exacerbate this water stress.
- Climate change: Climate change is disrupting precipitation and evaporation patterns, which can exacerbate water shortages in certain regions and increase tensions.
- Water pollution: Water pollution by chemicals, industrial, agricultural or domestic waste can lead to conflicts of interest between different stakeholders, such as industries, farmers, governments and local communities.
- Migration: In regions affected by water shortages or water-related disasters such as flooding or desertification, migration can increase social and economic tensions in host areas.
- Water trade: The commercialization of water and private control of water resources can also lead to tensions, particularly in regions where water is an essential public good.

5.3 Major environmental and health challenges

Major environmental and health challenges are increasingly interconnected, as the degradation of natural ecosystems directly impacts human well-being. Deforestation, pollution, and climate change contribute to a deteriorating environment, exacerbating issues such as air and water contamination, soil erosion, and the loss of biodiversity.

These environmental shifts result in a host of health problems, including respiratory diseases, waterborne illnesses, and heat-related illnesses, which disproportionately affect vulnerable populations. In urban areas, rapid industrialization and population growth lead to higher concentrations of pollutants, further compromising the quality of the air, water, and food supply, with serious implications for public health.

At the same time, environmental destruction exacerbates existing health inequalities, particularly in regions already struggling with inadequate healthcare infrastructure and limited access to clean water and sanitation. For instance, polluted water sources are a breeding ground for pathogens that cause diseases such as cholera, dysentery, and typhoid, while the loss of biodiversity can reduce the availability of medicinal plants and resources that communities rely on for traditional medicine.

The ongoing impacts of climate change also pose significant threats to health, as rising temperatures and extreme weather events, such as floods and droughts, increase the risk of malnutrition, infectious diseases, and mental health issues. These intertwined environmental and health challenges demand urgent action to mitigate their effects and build resilient communities for the future.

There are several aspects to the growing tensions surrounding water:

- **Geopolitical conflicts**: Water resources can be a source of conflict between countries or regions. For example, tensions exist between Egypt, Ethiopia and Sudan over the construction of the Renaissance Dam on the Nile, as this would affect the distribution of water resources.
- **Water stress**: In many parts of the world, demand for water is outstripping supply, leading to local and regional tensions. Prolonged drought, overexploitation of water resources and population growth exacerbate this water stress.
- **Climate change**: Climate change is disrupting precipitation and evaporation patterns, which can exacerbate water shortages in certain regions and increase tensions.
- **Water pollution**: Water pollution by chemicals, industrial, agricultural or domestic waste can lead to conflicts of interest between different stakeholders, such as industries, farmers, governments and local communities.

- **Migration**: In regions affected by water shortages or water-related disasters, such as flooding or desertification, migration can increase social and economic tensions in host areas.
- **Water trade**: The commercialization of water and private control of water resources can also lead to tensions, particularly in regions where water is an essential public good.

The commercialization of water and the privatization of water resources have become increasingly controversial, particularly in regions where water is considered a fundamental public good. As water becomes a commodity, private companies often take control over its extraction, distribution, and pricing, which can lead to unequal access and exploitation.

This shift from a public resource to a privatized one may prioritize profit over the needs of vulnerable populations, especially in areas where water scarcity already presents significant challenges.

In such regions, the most marginalized communities may struggle to afford basic water services, exacerbating inequality and undermining the idea of water as a human right.

The control of water resources by private entities can also lead to tensions between local governments, businesses, and citizens. In many cases, privatization has sparked protests and public backlash, as communities demand that water remains a publicly managed resource, accessible to all, regardless of socioeconomic status.

In regions where water is essential not only for survival but for agriculture, industry, and sanitation, conflicts can arise over ownership, pricing, and the management of these resources. The growing push for the privatization of water highlights the need for transparent and inclusive policies that protect the rights of communities while balancing the demands of economic growth and environmental sustainability.

5.4 Major environmental and health issues related to water

Water-related environmental and health issues are among the most pressing global challenges today, directly impacting food security, economic stability, and human well-being. As the global population continues to grow, so does the demand for food. To meet this demand, farmers have increasingly turned to intensive irrigation techniques, especially since the 1960s. Irrigation now accounts for a staggering 70% of the world's total freshwater consumption. In arid and semi-arid regions, the reliance on irrigation is even more pronounced, with up to 90% of available water resources being diverted to agricultural use.

This high consumption rate places immense pressure on already scarce water supplies, threatening both food security and the sustainability of water resources.

The issue of water wastage exacerbates these challenges, especially in developing countries where infrastructure is often outdated or poorly maintained. In these regions, water leakage from pipes can account for up to 50% of total drinking water losses. This is not only a waste of valuable resources but also a significant economic burden. In agriculture, intensive irrigation practices also contribute to substantial water losses, with up to 40% of pumped water being lost due to evaporation, inefficient irrigation systems, or poor water management. Such inefficiencies increase the pressure on existing water supplies and make it harder to ensure access to clean, potable water for growing populations.

The disparity in water consumption between regions further highlights the global water crisis. A family living in arid regions of Africa typically uses between 10 and 40 liters of water per person per day for basic needs like drinking, cooking, and washing. This is a stark contrast to urban dwellers in Europe and North America, where daily water consumption can range from 300 to 600 liters per person.

This disparity not only reflects differences in lifestyle and infrastructure but also underscores the unequal access to water resources around the world. As water becomes scarcer in many regions, these imbalances are likely to worsen, leading to heightened tensions over water access and distribution.

The impacts of climate change are adding a new layer of complexity to water scarcity issues. Many climate scientists predict that global temperatures will rise by one to two degrees Celsius by 2050, contributing to shifts in precipitation patterns.

In arid regions, this warming trend could lead to a 10% decrease in rainfall, further exacerbating water shortages. Additionally, the increased evaporation rates caused by higher temperatures could lead to a dramatic reduction in the volume of freshwater stored in lakes and rivers—by as much as 40-70%. These changes threaten both the quantity and quality of available water, increasing the risks of droughts, crop failures, and water shortages.

Another significant factor contributing to water scarcity is the demographic explosion. The world’s population is projected to reach 8.7 billion by 2025, with the majority of this growth occurring in regions already struggling with water scarcity.

At present, three-quarters of the global population lives in areas that consume just over 20% of available water resources. As these regions continue to grow, the demand for water will intensify, further straining local water systems that are already under pressure. This demographic shift is expected to create an even greater imbalance between water availability and consumption, leading to more frequent water shortages and conflicts over resources.

Furthermore, rapid urbanization is playing a significant role in exacerbating water challenges. As more people move into cities, the demand for water in urban areas increases sharply. Cities often rely on distant water sources or underground aquifers to meet their needs, putting additional strain on already overextended water supplies.

The expansion of urban infrastructure—such as wastewater treatment plants, roads, and buildings—also requires vast amounts of water. In many cases, cities that face the most severe

water scarcity are the very ones experiencing the fastest growth, making it increasingly difficult to ensure that all residents have access to clean, safe water.

Ultimately, the interconnected issues of water scarcity, waste, climate change, and demographic growth require coordinated, global efforts to address. Effective water management strategies must incorporate sustainable agricultural practices, improved infrastructure, and innovative technologies to reduce waste and enhance water conservation.

Moreover, tackling the root causes of climate change and ensuring equitable access to water resources are critical steps in securing a future where everyone has access to this essential resource. Without such concerted action, the challenges of the global water sector will continue to grow, threatening food security, health, and economic stability worldwide.

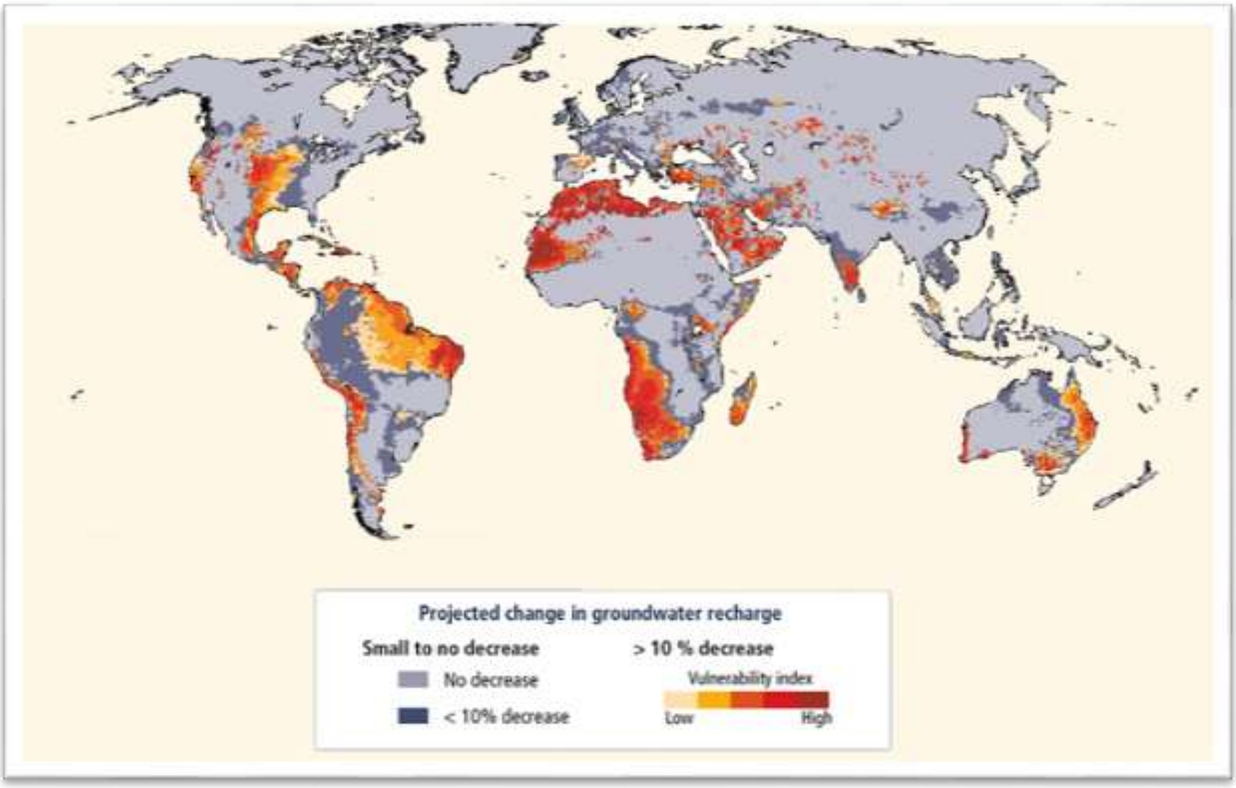


Figure 29: Projected change in groundwater recharge worldwide Source:29

Conclusion

The global water sector faces increasingly complex and interconnected challenges driven by population growth, rapid urbanization, and the demands of economic development. These pressures place immense strain on freshwater resources, which are already limited in many parts of the world. In Algeria, water is a particularly precious and finite resource, made even more vulnerable by the country's arid climate and uneven distribution of water supplies. This scarcity affects not only access to drinking water but also the agriculture and industry sectors, which are vital to the nation's economy and food security.

Algeria's water resources are divided between surface and underground sources, with significant regional disparities in availability. In the northern regions, where rainfall is more abundant, rivers and dams provide a more reliable supply of water for domestic, agricultural, and industrial needs.

However, the situation in the vast Saharan regions of the south is markedly different. Here, water supplies rely heavily on underground aquifers, such as the intercalary continental and terminal complex aquifers, which are often tapped to meet growing demands. Rainfall in Algeria varies significantly, with the coastal areas benefiting from more frequent precipitation, while the desert regions receive little to no rainfall, highlighting the stark contrast in water availability across the country.

Algeria's chronic water scarcity is exacerbated by several factors, including low and irregular rainfall patterns and a growing demand for water across all sectors. The pollution of water resources further compounds the crisis, with industrial discharges, untreated domestic wastewater, and unsustainable agricultural practices contaminating vital supplies.

This degradation not only reduces the quantity of usable water but also poses significant health and environmental risks. Additionally, global climate change is intensifying these challenges by disrupting precipitation patterns, causing prolonged droughts in some areas and severe flooding in others.

These extreme weather events further strain Algeria's already limited water resources, underlining the urgent need for sustainable management and innovative solutions to address the country's water crisis.At the same time, water pollution resulting from industrial, agricultural and urban activities is compromising the quality of available water resources. In the face of these challenges, sustainable and equitable water management is becoming increasingly crucial. This requires enhanced international cooperation, effective policies, investment in water infrastructure and integrated management practices, while taking into account the needs of all sectors, including agriculture, industry, the environment and local populations.

Water scarcity is a critical global challenge, but science and technology provide a wide array of innovative solutions to address this pressing issue. Effective strategies range from reducing water losses to developing advanced purification systems and adopting sustainable practices. These solutions aim not only to alleviate the immediate scarcity of water but also to promote long-term resource sustainability for future generations.

One of the simplest yet most effective approaches is reducing water losses in distribution systems and agriculture. Repairing leaks in pipelines and replacing traditional intensive irrigation methods with efficient drip irrigation systems can conserve substantial amounts of water. Drip irrigation delivers water directly to the roots of plants, minimizing evaporation and runoff, thereby optimizing water use in agriculture, which is often the largest consumer of freshwater globally.

Rainwater harvesting is another vital solution, particularly in areas prone to seasonal rainfall. By collecting runoff from roofs, roads, and other flat surfaces, rainwater can be stored in tanks or reservoirs for later use. This method not only supplements traditional water supplies but also reduces the strain on local water sources during dry periods. It is a cost-effective and environmentally friendly practice that can be scaled for both urban and rural applications.

Industrial water use is another area where significant improvements can be made. By reserving purified or treated water for industrial processes, freshwater can be prioritized for drinking and agricultural purposes. Many industries are now exploring closed-loop systems that recycle water within their operations, dramatically reducing the overall demand for freshwater while minimizing waste and pollution.

Reforestation plays an essential role in combating water scarcity by addressing broader environmental issues. Trees and forests help reduce the greenhouse effect by absorbing carbon dioxide, while also improving the local water cycle. Forests enhance soil water retention, reduce surface runoff, and contribute to the replenishment of groundwater reserves. In addition, they help moderate local climates, promoting more consistent rainfall patterns over time.

Urban and industrial water purification is critical to reducing pollution and ensuring the availability of clean water. Advanced treatment plants can remove harmful contaminants from wastewater, making it safe for reuse or safe release into the environment. This reduces the impact of industrial and urban activities on local water bodies and promotes the sustainable use of available resources. Encouraging the adoption of these technologies is essential for protecting water quality, particularly in highly industrialized and densely populated areas.

Finally, innovative technologies such as desalination and groundwater recharge are providing transformative solutions to water scarcity. Desalination, which involves removing salts and impurities from seawater or brackish water, has become an increasingly viable option for coastal regions facing acute freshwater shortages. Similarly, groundwater recharge techniques, which involve injecting or infiltrating treated water back into aquifers, help replenish underground reserves and prevent overextraction. These methods represent the cutting edge of water management, offering sustainable alternatives to meet the growing demands of a thirsty world.

In this course we established some links between a functional water management policy and preserving water resources as a sustainable solution to future generations also we discussed the critical situation that Algeria's suffers from when it comes to the water availability, later on we expended the discussion to international scale where we mentioned some facts about the water laws and the tensions raised by water sharing problems.

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