

# Water contamination of the dam at Hammam Boughrara in the North-West of Algeria, as sustainable development falters

## Poluição das águas da barragem de Hammam Boughrara no-noroeste da Argélia no contexto do desenvolvimento sustentável em dificuldades

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### Abstract

Water pollution in Algerian dams, primarily from urban waste and a lack of environmental awareness, poses a pressing environmental challenge. This study aims to highlight this critical issue within environmental science and geography. Dams' pollution threatens ecosystems, public health, and agriculture. Addressing this issue is crucial due to its wide-ranging impacts. Despite its significance, there is a research gap on dam pollution in Algeria. This study investigates Hamam Boughrara dam's pollution levels, contamination sources, and health risks from heavy metals. We employ a comprehensive approach, using digital and geospatial databases to define the study area and calculate measurements. Ecological data comes from accredited organizations and studies. Our findings reveal alarming pollution in Hamam Boughrara dam, with contamination spreading to nearby agricultural land due to heavy metals. This poses a significant threat to human health and the environment. Additionally, the study highlights Algeria's historical lack of environmental legislation, primarily due to prioritizing state matters. Addressing water pollution in Algerian dams is a collective responsibility demanding immediate action. This research stresses developing robust environmental legislation and international collaboration. Finding sustainable solutions is imperative for people and the environment's well-being. In summary, this study clarifies the severity of water pollution in Algerian dams and emphasizes the urgency of addressing it to protect the environment, public health, and agriculture.

**Keywords:** Environment, Sustainable development, Hammam Boughrara dam, Water pollution.

### Resumo

A poluição da água nas barragens argelinas, provocada principalmente pelo lixo urbano e pela falta de conscientização ambiental, apresenta-se como um grande desafio, pelo seu amplo impacto negativo. Este estudo visa sinalizar esta questão no seio da ciência ambiental e da Geografia, uma vez que a poluição das barragens ameaça ecossistemas, saúde pública e agricultura. Apesar da importância do tema, ainda há lacunas na pesquisa, daí que aqui se investiguem os níveis de poluição na barragem de Hamam Boughrara, as fontes de contaminação e os riscos de saúde decorrentes dos metais pesados. Através de uma investigação abrangente, procuramos mobilizar bancos de dados digitais e geoespaciais para definir a área de estudo e calcular medidas. Os dados ecológicos provêm de organizações credenciadas e de estudos já realizados. Os nossos resultados revelam índices de poluição alarmantes na barragem de Hamam Boughrara, com contaminação espalhando-se para as áreas agrícolas próximas, que representa uma ameaça significativa para todos. O estudo destaca também a histórica falta de legislação ambiental na Argélia, principalmente devido à priorização de questões estatais. Abordar a poluição da água nas barragens argelinas é uma responsabilidade coletiva que exige ação imediata. Esta pesquisa enfatiza a necessidade de desenvolver uma legislação ambiental robusta e a importância da colaboração internacional. Torna-se imperativo encontrar soluções sustentáveis que promovam o bem-estar das pessoas e do meio ambiente. Assim, pretendemos mostrar a gravidade da situação, enfatizando a urgência de abordar o problema para proteger o meio ambiente, a saúde pública e a agricultura.

**Palavras-chave:** Ambiente, Desenvolvimento sustentável, Barragem de Hammam Boughrara, Poluição da água.

## 1. Introduction

Pollution has affected various aspects of the environment and caused significant damage. The pollution is visible on land and in the sea, and it affects the air and water. There is no solution except to roll up our sleeves, mend and patch what can be mended, and try to reduce the factors causing pollution. This can be achieved through conferences and meetings to come up with agreements, or through the enactment of laws and directives. However, these directives are often not respected (UNEP,n.d). As a fundamental environmental element, water has not escaped the detrimental effects of extensive human activities on our planet. The impact of these activities extends across land and sea, with serious consequences for urban and rural areas alike. Hazardous substances have seeped into ecosystems, polluting water bodies and leaving no corner of the Earth's surface untouched. Dams in particular are highly vulnerable structures. Most, if not all, contend with the task of collecting water that may be contaminated. The Hamam Boughrara Dam is one of these stations that suffer from this problem. Officials have been unable to solve this problem because the mechanisms of the solution may go beyond the local legislative authority when contaminated water comes from a neighboring country, and the problem becomes regional. It is clear that the contaminated water came from the border of Oujda town through the Bounaim River (Abouelouafa et El Halouani, 2002). Even though this city has a filtering station at the level of this valley, it has not been able to limit the dangerous waste produced by this latter. Moreover, it has a population of more than one million inhabitants, and its craft and industrial units exceed 150

units. Algeria can work hard to reduce this pollution by completing an artificial barrier at the level of the Mouilah valley, near the border. This would be able to break the speed of pollution and reduce its impact, in order to contain the problem. Efforts must be joined, and the parties must come together to find a sustainable solution that can satisfy everyone and governs moral reason, by respecting legislation and charters, including local and international. The environment has become a more global issue than a regional one, and its preservation and attention have become not only a necessity but also an individual and collective obligation. Through this research, we have sought to review the state of pollution reached by the Hamam Boughrara Dam, how important this pollution is, and where it comes from and how it is caused ?.

## 2. The study area

### 2.1. The geographical location of the dam

The Hamam Boughrara dam is situated in the extreme northwest of Algeria, precisely in the region of Tlemcen. It is located 50 km west of Tlemcen, and 10 km east of the city of Maghnia. Specifically, it is situated on the southern side of the urban center of the Hammam Boughrara municipality, touching the 35th parallel. Its astronomical position is between 1.38° and 1.40° west longitude and between 34.26° and 34.42° north latitude.

The Hammam Boughrara Dam is a strategically important regional achievement, dedicated to fulfilling the water and irrigation needs of the area.

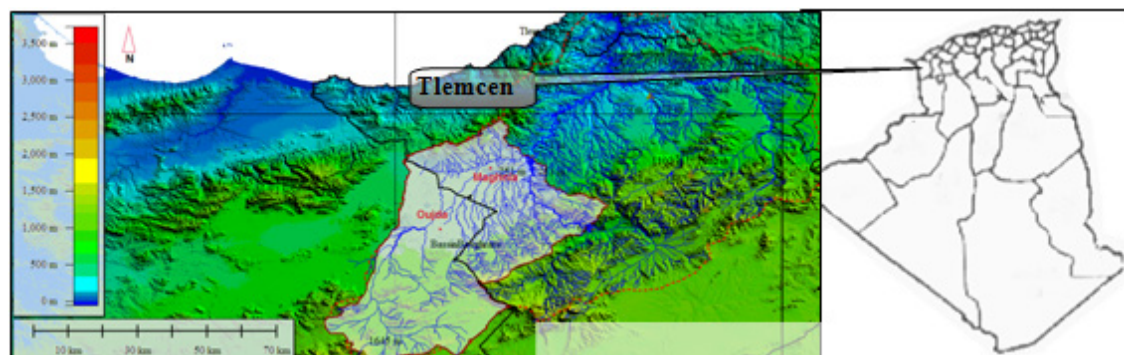


Figure 1  
Boughrara watershed Site.

Table 1

*Trend The characteristics of the Hammam Bouhrara catchment area*

Tub	Area in km <sup>2</sup>	Perimeter in Km	Height	3D	Shape coefficient
Bouhrara	2242,7	253,7	737,744	2268,6	1,50

With a capacity of 177 million m<sup>3</sup>, It is considered the mouth of a small basin known as Mouilah, which belongs to the Tafna watershed.

The catchment area of the dam extends up to the Algerian-Moroccan border and may include a portion of the region around the city of Oujda, forming a new network of sub-watersheds, it appears that the Hammam Bouhrara catchment area is considerable in size, covering 2242.7 km<sup>2</sup> and measuring a perimeter of 253.7 km (Table 1). Further analysis of the basin's dimensions allowed us to calculate its shape coefficient, which stands at 1.50, indicating an elongated form where the length is 1.5 times greater than the width. This characteristic has the potential to affect the hydrological processes in the area, such as the time of concentration, the rate of surface water runoff, and soil erosion.

## 2.2. The hydrographic network provided for the dam

At the location of the Hamam Bouhrara dam, a simple hydrographic network is observed in one of the valleys of the region, specifically the Mouilah and Tafna valleys.

### 2.2.1. UpperTafna

The river originates in the Tlemcen Mountains and its source and tributaries descend from the edges of the Sebdo Mountains, specifically at the Boumaza cave. As the river flows from south to north, its branches diminish until they reach an altitude of 670m where they meet the Beni Bahdel dam. The river then enters the Tlemcen Mountains and flows through rugged straits before reaching the central Tafna plains. Finally, the river reaches the Hamam Bouhrara dam at an altitude of at least 250m.

### 2.2.2. Central Tafna

The plains of Maghnia are renowned for their remarkable fertility, which is attributed to the confluence of the Tafna and Mouilah Rivers. The Mouilah river is considered the natural boundary that

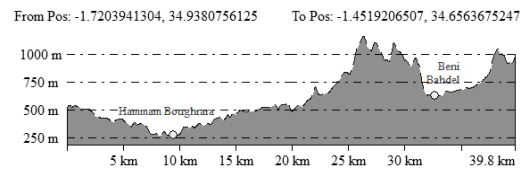


Figure 2  
Topography of the Tafna Region.

separates the two communes of Hamam Bouhrara and Maghnia. The river flows towards the dam at an average altitude of no more than 285 meters, and it is the primary component of a sub-basin covering an area of about 2,242 km<sup>2</sup>. The Mouilah river is a major contributor to the Hamam Bouhrara dam.

## 3. Sources of dam water pollution

There are two types of pollution: local and external.

### 3.1. Challenges in Controlling Pollution from External Sources

The Bounaim River in Morocco has been identified as a potential external source of organic and physico-chemical pollutants originating from urban and industrial pollution in the city of Oujda. (Bouزيد-Lagha et al., 2012), which pose a challenge to control due to the complexity of the factors involved. The effluent discharges contaminate the receiving water-courses and cause serious nuisance to local residents, users and wildlife. (Rassam et al., 2012). Numerous studies have unequivocally demonstrated a significant level of pollution in Bounaim river, surpassing the prescribed limits. The observed standards categorize the water quality in Bounaim river as C4-S2, indicating a classification of poor quality (Abouelouafa et El Halouani, 2002). Oujda is Morocco's fifth most populous city.

### 3.2. Multiple internal sources and varying risk

The Hammam Bouhrara dam is subjected to several local sources of water pollution, with numerous valleys and streams that collect pollutants from nearby and distant villages and towns. The

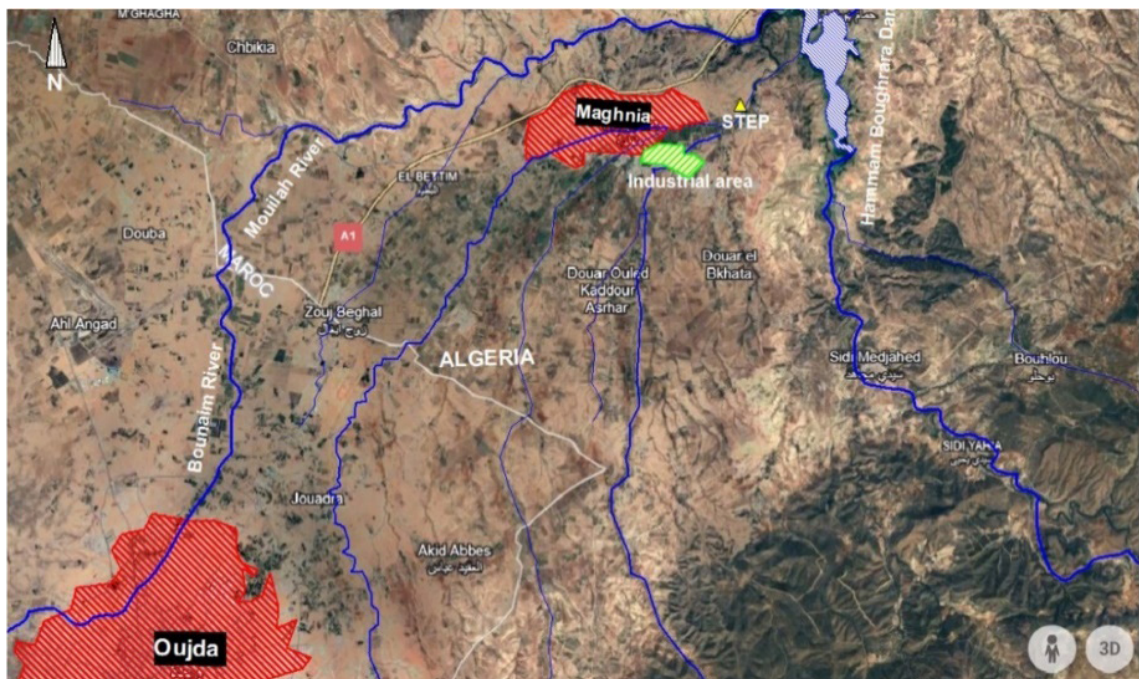




**Figure 3**  
Plants and algae indicate the trophic level of Waste Water.



**Figure 4**  
Very high levels of eutrophication at the dam.



**Figure 5**  
Transboundary Hydrographic Network.

collected pollutants are then transported to the dam, which can lead to water contamination (Bouزيد-Lagha et al., 2012).

### 3.2.1. Upper Tafna river

The river originates from the Tlemcen mountains and is intercepted by the Bani Bahdel dam. It flows close to the village of Sidi Mjahed, which is home to approximately 8,000 residents, and the village of Bouhlou, with more than 7,000 inhabitants.

### 3.2.2. Abbas river

The river flows alongside the town of Maghnia, coming into contact with the active industrial area and carrying pollutants produced by industrial units, such as the ENCG oleo-chemical plant, which emits more than 200,000 (eq/inhabitant) of pollutants, the CERTAF ceramics unit, which produces water containing heavy metals, and the MAÎSERIE maize unit, which generates 40,000 (eq/inhabitant) of pollutants. These substances can remain in the soil

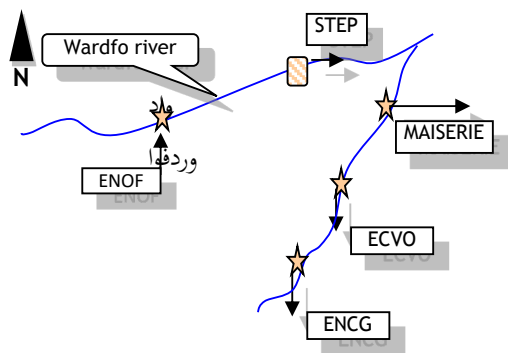


Figure 6  
Geographical map of the locations of industrial plants in Maghnia.  
Source: researcher's achievement.

or are deposited in the groundwater, which is particularly concerning since agricultural land is located next to the industrial zone.

3.2.3. Wardfo river

It flows alongside the city of Maghnia, collecting wastewater and water from several industrial activities, including the ENOF bentonite production unit located on the city's outskirts. The river then joins the Abbas River before ultimately emptying into the Mouilah River, which originates in Morocco.

3.2.4. Maghnia

Maghnia is a small city compared to Oujda, with a population of 116,340 according to the latest statistics from 2008, compared to 52,000 in 1987. However, it is predicted that Maghnia will only reach the current population of Oujda in 2070. Currently, the population of Maghnia is estimated at 134,000, which is one fifth the size of Oujda. This large difference in population is accompanied by other factors, such as the impact on the environment. Maghnia discharges more than 7,603 cubic meters of wastewater into the Wardefou River every day, and despite these large quantities of residential discharges, Maghnia only produces one fifth of the pollution that Oujda produces (Step, 2007).

The water in this valley is heavily polluted due to its high concentration of organic matter, as well as large amounts of mineral salts and heavy metals from the nearby industrial area. These pollutants have significantly increased the mineral content in the water (Tidjani et al., 2006).

4. The pollution of dam water that exceeds all specifications

As water has no taste or smell, it is not always possible to judge the drinkability of water by its appearance, and it is necessary to refer to other criteria and physical-chemical indices to recognise the level of pollution affecting the waters of the hydrographic network in general and dams in particular. The data obtained from the National Dams Agency (April 2015) illustrate the concerning state of the Hammam Bouhrara dam, emphasizing the significant pollution (Table n° 2).

The water quality in the Hammam Bouhrara dam is of growing concern due to low oxygen levels, high biological oxygen demand (DBO5) and chemical oxygen demand (DCO). In addition, the dam contains high levels of residues (RS) and oxidizable matter (MO), indicating a particularly worrying presence of organic matter that stimulates bacterial activity and thus poses a threat to human health. The presence of traces of ammonium (NH4+) in the dam's water already justifies such bacterial activity. According to WHO guidelines, water intended for human consumption should not contain organic matter, even in small quantities. Furthermore, water rich in organic matter leads to the depletion of the water in the reservoir and the proliferation of algae, resulting in water pollution, a reduction in oxygen levels and a disruption of the ecosystem, which can ultimately lead to the death of fish and other organisms. The presence of high levels of chlorophyll A in the dam during spring and summer, with a concentration of

Table 2										
Physicochemical parameters for the water of the Hammam Bouhrara dam (National Dams Agency, April 2015)										
Dam	RS	PO <sub>4</sub> <sup>3-</sup>	DBO <sub>5</sub>	DCO	MO	O2	NH <sub>4</sub> <sup>+</sup>	NO <sub>2</sub> <sup>-</sup>	NO <sub>3</sub> <sup>-</sup>	pH
Concentration (mg.L <sup>-1</sup> )	890	0.960	7.1	39	7.9	74.4	1.380	0.400	6	7.6
WHO standards(mg.L <sup>-1</sup> )										
No guidelines (NG)	NG	NG	NG	NG	/	NG	0,3	≤ 3	≤ 50	≥ 6.5 and ≤ 9.5
Source: National Dams Agency (April 2015).										

33.8 mg.L<sup>-1</sup>, indicates excessive algal growth and further highlights the poor water quality in the dam (El Haouati et al., 2013).

#### 4.1. Mineral salt contamination

While water can naturally have some level of salinity, domestic wastewater can significantly increase its salinity when mixed together. The high level of chlorine in the water of the Hammam Boughrara dam is also an indicator of domestic pollution, as this substance is commonly used as a disinfectant and can be combined with other insecticidal elements, such as chlorinated hydrocarbons (CHCs). The concentration of chlorine in the dam water reached 443mg.L<sup>-1</sup>, which is more than twice the permitted level. In contrast, in 2002, the level of chlorine near the sources of Tafna did not exceed 15 mg.L<sup>-1</sup>. This demonstrates the extent of the domestic pollution problem in the dam (Dahmani et al., 2002).

The Mouilah river is a significant source of salts, with salinity levels in the valley reaching 1000 mg.L<sup>-1</sup> (Belaidi, 1992). Salts in water and soil can be detrimental to living organisms. An increase in the concentration of the medium in relation to the concentration of the cell can lead to the phenomenon of osmosis. This can impact small organisms more severely than larger ones, as the exchange volume is more significant for smaller organisms (Belaidi, 1992).

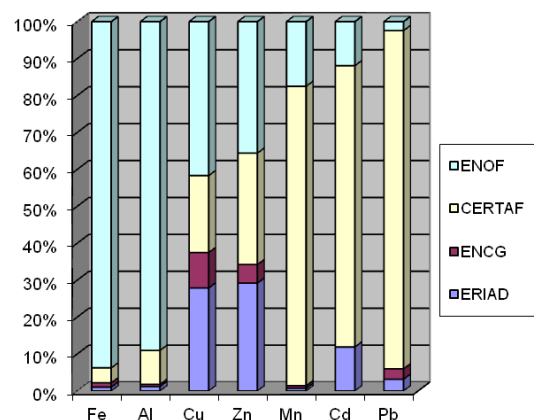
Salts can accumulate in soil as water evaporates, and plants will only absorb what they need to grow. However, if these salts continue to build up, the soil can become toxic. Historians attribute the extinction of the Mesopotamian civilization to salinity. Six thousand years ago, the Sumerians drained the waters of the Euphrates to irrigate their land for two thousand consecutive years. This led to the poisoning of the soil, ultimately resulting in the decline and disappearance of their civilization (Gleick, 2001).

#### 4.2. Heavy metal pollution is the most dangerous type of pollution

Mineral salts can be accompanied by other dangerous pollutants such as heavy metals, which can harm human and animal health, as well as plants. The soil near the city has been found to be rich in heavy metals, including copper, zinc, iron, aluminum,

and even lead. The concentration of these heavy metals is particularly high in the soil on the outskirts of the industrial area along the Abbas River (Belhadj, 2002). For example, zinc concentration in the soil reached 103 mg.kg<sup>-1</sup>, which is relatively low compared to the amount found in the Mouilah River, where the zinc concentration was approximately 137mg.kg<sup>-1</sup>.

A more recent study has revealed even higher levels of these substances near the Hammam Boughrara dam, with levels exceeding 987mg.kg<sup>-1</sup> at one point (Benseghir, 2012, p. 77). This suggests that the industry is releasing significant amounts of toxins into the river system as a whole, and into the Mouilah River in particular.



**Figure 7**  
Ranking of industrial establishments according to pollution rates.  
Source: Bensaada (2006).

The soil is also not free from dangerous metals, such as lead and cadmium. Although the level of lead is below the established standard of 100 mg/kg, it is still present in small quantities. In contrast, cadmium is not found in the soils of the Abbas River, but it is highly concentrated in the river itself due to the strong acidity of the medium that dissolves it. Soils that are saturated with metals are washed towards the dam, particularly in winter, and this has become a major source of pollution. Heavy metals, including manganese, iron, cobalt, nickel, and copper, have been found in the water of the dam (Mahi, 2015), with varying levels that in some cases exceed the standards set by the World Health Organization (WHO, 2011). This poses a significant threat to aquatic organisms, humans, and animals alike.

Heavy metals can accumulate in the tissues of living organisms, leading to serious health problems and even death. For example, high levels of lead in the body can damage the nervous system and cause developmental delays in children. Cadmium exposure can cause kidney damage and increase the risk of cancer. Therefore, it is crucial to monitor and control the levels of heavy metals in water and soil to prevent their harmful effects on the environment and human health.

## 5. Water pollution in light of faltering environmental development

Throughout history, mankind has frequently disregarded the environment in all areas of development, and the concept of sustainable environmental progress has been postponed and sidelined in favor of technological and urban expansion. Consequently, the environment has been overlooked in many aspects of life, and the threats and issues it poses have only increased. Humanity has experienced the devastating consequences that can endanger the lives of all nations. As a result, many international organizations and countries have implemented laws and regulations to manage and limit the causes of environmental degradation. The first initiatives emerged in the first half of the twentieth century, with the most significant being the Clean Air Act in England. Prior to that, similar initiatives were undertaken in Italy, Austria, and Germany in 1909 and 1920, and in France in 1932.

However, these laws did not solve all environmental problems caused by human activities such as industry, agriculture, and urbanization. Industrial zones are usually located on the outskirts of cities or urban areas, which means that the environment receiving the waste resulting from these activities is not included in urban development programs, due to the neglect of decision-makers. Furthermore, the arrogance of the industrial lobby, which prioritizes profit over the environment, has led to the neglect of the environment, which has only recently gained its independence from urban centers (Berrue & Bertrand, 1997). Unfortunately, this is still the prerogative of certain developed and wealthy countries that support environmental projects by possessing all the means and technologies.

The search for environmental liberation through environmental awareness was the result of elitist movements. One of the first international non-governmental organizations to focus on this issue was the International Rights Association, which adopted a set of principles called “Helsinki Rules” at the Helsinki Forum in 1966 (Kiss & Beurier, 2000). These rules made man responsible for the destruction of the environment and numerous catastrophes resulting in the deaths of many people due to pollution that affected various elements of the environment. Water was one of the most important elements studied, and legal texts were formulated to protect it from pollution. Unfortunately, the Stockholm Declaration in 1972 did not give water enough attention and only classified general discharges in a category that would harm the environment (Kiss & Beurier, 2000).

However, the Rio summit in 1992 rectified this situation by contributing to chapter eighteen of the twenty-first memorandum, which focused on the protection and quality of freshwater resources. The summit did not introduce legal texts but instead limited itself to providing simple directives (Kerdoun, 2000). At the end of the last century, meetings and conferences continued to emerge, and a new term for the interface took dimensions beyond the classic unilateral terms to achieve effective strategies that can satisfy all members. Conferences such as the Johannesburg Conference in 2002 and Milan in 2003 aimed to reconcile sustainable development and economic growth while preserving natural resources. In a world where the population is growing exponentially, demand for food, water, shelter, health services, energy, sanitation, economic security, and other needs closely related to the environment is increasing rapidly, making it imperative to protect and manage natural resources for future generations.

### 5.1. Delayed legislative mechanism for water protection in Algeria

The first Algerian constitution did not explicitly address the protection of the aquatic environment or even the protection of the environment in general, as the legislature was focused on establishing the principles of the rule of law immediately after independence (Brady et al., 2020). However, Algeria hosted its first national meeting on the environment



in 1974, and as a result, the National Committee for the Protection of the Environment was created by Law 74-165 on July 12, 1974 (Kerdoun, 2000).

There were indications of interest in the 1976 constitution, which defined state property and considered surface or groundwater, and whatever it contained, to be state property, stipulating that these public properties should be protected without separation. Based on this, it took eight years for the Water Law of February 5, 1983 to be added to the dictionary of laws. Despite the new legislation, similar decrees were not accounted for, and the legislative mechanism remained incomplete. The Algerian standard for environmental protection has not seen the light of day until today (Kerdoun, 2000).

The 1989 constitution built upon the 1976 constitution and expanded the scope of legislation to the National People's Congress by integrating environmental issues into areas of legislation where necessary. However, this expansion did not bring about significant change, and the constitution remained ineffective in terms of environmental legislation, even after the 1996 constitution. The promulgation of decrees continued to be subject to reports by national bodies, as in the past. A report on the central importance of the environment published in June 1989 revealed that industry operated on a large scale under conditions that did not allow for the care and concern of environmental protection (Kerdoun, 2000).

## **5.2. Legal mechanism to protect water from residential and industrial waste**

The industry is a crucial component of human activity, urban prosperity, and development. However, it can lead to significant environmental problems due to its hazardous chemical residues. Urban areas also play a role in this issue because of their residential effluents. As urban areas become more active and larger, they produce large quantities of effluents, which further complicates the matter. Therefore, it is crucial to establish standards and laws to control pollution and mitigate its adverse impacts.

### **5.2.1. Residential waste**

Over the years, the Algerian government has sought to improve the legal system pertaining to environmental issues, particularly after realizing the negative impact of mistakes made by planners and

entrepreneurs during the planning process. The Water Law, initially issued on February 5, 1983, prohibited the discharge of any kind of polluted water into nature without adhering to specific conditions and criteria in order to prevent harm to the sewage system. Ministerial Circular No. 380, issued on October 19, 2002, provides additional clarification and supplement to the February 5, 2002 law on the protection and assessment of the coast. On page 7 of the circular, a special procedure is explained in regards to sewage that could affect the coastline. The circular stipulates that each city with a population of over 100,000 must be connected to a STEP (Sewage Treatment and Effluent Plant) filtration station, while smaller centers are limited to a simple filtration system.

### **5.2.2. Industrial companies**

The second chapter of the February 5, 1983 law is devoted to the protection of water. Article 36 specifies the objectives of combating water pollution in general. According to the same article, any direct or indirect flow, discharge or accumulation of substances that pollute surface, ground or coastal waters and that can change the physiological, chemical, biological or bacteriological properties of these waters is prohibited. Articles 39 and 40 require institutions of all types to take appropriate measures so that their wastes conform to prescribed specifications and standards.

Article 61 places full responsibility on owners or facilitators of enterprises whose remains and discharges do not meet the stipulated criteria. Article 63 contributes to freezing the organization's activity if it is found to be contrary to that, and Article 60 fines anyone who is responsible for operating such polluting establishments. Meanwhile, Article 37 provides for periodic analysis of all water areas and valleys to identify violations. The governor and the president of the Municipal People's Assembly may follow the preparation steps and procedures stipulated in Article 61 that authorize them to do so. In this regard, Al-Riyadh Corporation or the Corn Factory has suspended its activities several times by state decision due to the significant pollution it causes, and it is now dumping its residues in bentonite pits near the Boughrara Dam.

Although authorities have the power to regulate and reduce pollution within their geographical boundaries, it becomes challenging when institutions



responsible for pollution are located outside these borders. It is crucial to establish a common mechanism to address such situations and find a solution to the problem. Cooperation and coordination between different authorities and institutions are necessary to tackle transboundary pollution effectively. Moreover, international conventions and agreements can be utilized to enforce pollution control and management measures in a coordinated and effective manner.

### 5.3. Common environmental interests in place of the extension of agreements

Valleys are often shared between two or more countries, or used as borders between them, since waterways do not adhere to political boundaries. Globally, there are 261 rivers that cross multiple countries, many of which are tributaries and valleys (Gleick, 2001). The idea that water has no borders has become a central focus of European agreements.

No country can exist in isolation from its neighbors. China's disregard for its neighbors' warnings during the collapse of a natural dam in Tibet in 2000 serves as an example. The disaster resulted in few casualties but destroyed important Indian installations along the Tibetan border.

The Nile River serves as a shared point between three countries Ethiopia, Sudan, and Egypt. The issue of water allocation could have easily led to war, but shared points between countries often provide grounds for bilateral and collective agreements. For instance, the 1987 Syrian-Turkish agreement over the Tabqa Dam, built by Turkey in 1973, allowed Syria a share of 500 cubic meters per second of water. Other examples include the 1990 Syrian-Iraqi agreement, with Iraq receiving 58% of the water level, and the 1996 agreement between India and Bangladesh over the Ganges River, as well as the agreement between India and Nepal over the Farakka Dam in India (Lamballe, 1999; 2017).

In the context of efforts by the International Rights Committee to address environmental issues, the United Nations General Assembly convened in New York on May 21, 1997, and enacted several significant environmental laws. The main focus of this forum was on the "just and rational use of shared

water", and as such, Article 5 of the second paragraph obligates countries to conserve these waters (Kiss & Beurier, 2000).

Water knows no borders, and this is especially true for Algeria and Morocco, which share many natural characteristics and even some topographical phenomena. The lower basin of Hammam Bouhrara is a shared point of interest between the two countries. However, pollution is a major concern affecting not only the environment as a whole but also the receiving environment in particular. Algeria receives significant amounts of pollutants shed by the Moroccan city of Oujda through the Abu Naim valley (Mouilah river), which then flow into the Hammam Bouhrara dam, collecting only polluted water that may harm the entire ecosystem. This situation is dangerous and requires a solution that satisfies both parties through a bilateral or collective agreement. To this end, a regional workshop was held, bringing together Algeria, Morocco, and Tunisia, with the World Bank in attendance, to study strategies for combating pollution on September 23-24, 1996, in Morocco.

### 5.4. Bilateral or collective agreements

One of the pioneering initiatives for bilateral or collective agreements to preserve the waters of swamps and waterways from pollution between neighboring countries was the creation of a global mixed international commission between Canada and the United States of America on January 11, 1909. The committee consists of six members from the two countries, and its most significant findings include the Ottawa Agreement of April 15, 1972, on the protection of swamps and dams, and the second agreement on November 22, 1978, on the protection of water from pollution in general (Kiss & Beurier, 2000).

However, Europe is a leader in regional agreements or treaties, such as the agreement on water adopted by the European Council. The idea that water has no borders was emphasized during the negotiation of these agreements. The members of the council concluded another agreement just a month after the first one on September 16, 1968. The second agreement focused on reducing the use of non-biodegradable detergents.

Europe continued to work towards more such agreements and adopted the Helsinki Accord in New York on May 21, 1997, soon after North America joined the European side on March 17, 1992, at the European track. The aim of this accord is to protect waterways and ponds from the effects of geographical boundaries caused by neighboring countries (Kerdoun, 2000).

The concept of sustainable development has been gaining momentum since the Rio Forum in 1992. The idea behind sustainable development is to utilize natural resources in a rational and responsible manner, without depleting them, and to preserve them for future generations. This is achieved by respecting ecological principles and promoting sustainable economic growth. The spatial conception of the environment also fits into this context, as the environment is considered a common human heritage that should be preserved by everyone (Kiss & Beurier, 2000). The slogan "Think globally, act locally" reflects the idea that environmental protection requires individual actions that collectively make a difference.

To enforce the idea of sustainable development and protect the environment, various agreements have been established, such as Article 10 of the Helsinki rules, which prohibits neighboring countries from causing any form of pollution to the shared waters between them. The United Nations has also codified some articles in its assemblies since 1997, particularly the fifth and sixth, which may impose compensation for the injured party in case of environmental damage (Kiss & Beurier, 2000). These agreements serve as a framework for promoting responsible environmental practices and preserving the environment for future generations.

## **6. Sustainable development in light of economic disparities**

Indeed, the link between environment and development is a complex and challenging issue, with different perspectives and priorities among developed and developing countries. Sustainable development aims to reconcile these two issues and promote a balanced vision that considers both the environment and the economic and social needs of society.

Developing countries often argue that they should not be limited in their development by environmental concerns, while developed countries

emphasize the importance of protecting the environment in the pursuit of sustainable development. The fourth principle of the Rio Declaration highlights the need to integrate the concepts of environment and development for sustainable development.

The issue of North-South cooperation and the balance between the economies of different nations is also crucial in this context. The Rio Forum and other international agreements have focused on subsidies and the polluter pays principle, which aims to ensure that those who cause pollution are responsible for its consequences. Finding a balance between the needs of different countries and promoting sustainable development for all remains a significant challenge for the global community.

Nearly 400 experts gathered at a resort overlooking the Baltic Sea to propose recommendations for the United Nations conference in the same year. The delegates concluded that the world's environmental problems cannot be solved unless the gap between rich and poor countries is bridged. Poor countries have no choice but to exploit the ecosystem in order to survive, and developing countries require the establishment of a green fund to support sustainable development. Economic differences may be a reason why a country fails to fulfill its environmental conditions. For example, in France, there are 16 methods to protect waterways, including plans, maps, legal materials, institutions, and organizations (Bourgoin-Barreilles, 2000).

Even though these means exist in Algeria today, it can still be difficult to enforce the law, as stated in a report: "... indeed, it is sometimes difficult to enforce the law." (Perenne, 1991). For instance, this was the case with the Riyadh institution, MAISERIE, when the decision was made to close it.

### **6.1. Polluter pays principle**

The OECD established the polluter pays principle as an economic principle to direct funds towards environmental preservation and control, as well as to encourage the rational use of ecological resources. The principle was adopted at the European Union summits in Maastricht on February 7, 1992, and Amsterdam on October 2, 1997 (Kiss & Beurier, 2000). The principle states that the expenses of monitoring and preserving the environment are paid by the polluter. The Helsinki Agreement also incorporated this principle in its articles. For example, Articles 3

and 5 of Chapter two of the Helsinki Rules stipulate the principle of the pollutant driving force (Kiss & Beurrier, 2000). However, the formulation was cautious due to regional and international economic differences. The principle can be applied in the European Union but not in developing countries.

The Rio Summit disrupted the scales and introduced the concept of sustainable development, which has both north-south dimensions. A kind of reconciliation emerged between rich and developing countries, as the environment must be combined with the concept of development according to the new perception (Kerdoun, 2000). In this case, the issue of subsidies became the focus of discussion at the New York Forum in March 1992 and the Rio Forum in June 1992. Even developing countries are calling for the creation of a “Green Fund” as a special mechanism for promoting sustainable development (Kerdoun, 2000).

## 7. Conclusion

Located at the point of confluence of the Tafna and Mouillah rivers (North West Algeria), the hammam Boughrara dam is in an alarming situation from an ecological point of view. This pollution is nothing but excessive and irrational human activity exceeding any standard prescribed by international bodies. Based on the findings of our present research, the dam is subject to unprecedented pollution due to urban discharges (domestic and industrial) from various adjoining regions. The dam ecosystem has continued to deteriorate and the levels of heavy metals have increased significantly. Various studies show that this development is linked to industrial zones and intensive agriculture. The massive presence of pollutants in the Boughrara dam is the most complex problem to deal with on several levels. Taking into account the delay in realizing the need to manage this problem and also the slowness in setting up a sustainable development program, in fact Algeria has introduced legislation (National Committee for the Protection of the Environment in 1970) in order to protect and preserve the environment of the industrialization policy of the 1970s. Without any law implementing this legislation, the environment suffers still of massive degradation. It

took 10 years for a directive to establish a framework for the protection of this environment in general and groundwater in particular.

The steps taken by the Algerian state are not paying off given the complexity of the situation at the regional level of the dam. The deterioration of the waters and the consequences of this degradation have their source outside our borders (oued Mouillah). The economic disparities between the two sides and the failure of diplomacy make the situation more and more inextricable depending on an environmental status quo. The gap that is widening between the north and the south endangers any national or local initiative for an effective and efficient protection of the environment, for that the developing countries request a Green Fund to better manage this spectrum which is in progress to threaten the planet. We note a progressive awareness of the responsibility of the countries of the North in the degradation of the planetary environment in the form of the Rio summit (1992) where the problems of subsidies were at the center of the debates. In this regard, it is necessary to go beyond the notion of responsibility and move on to more concrete things.

Located at the confluence of the Tafna and Mouillah rivers in northwestern Algeria, the Hammam Boughrara dam is in a dire ecological state due to excessive and irrational human activities that exceed international standards. Our research shows that the dam is facing unprecedented pollution from urban discharges, both domestic and industrial, from surrounding regions. This pollution has led to the deterioration of the dam's ecosystem and an increase in heavy metal levels. Studies indicate that this pollution is linked to industrial zones and intensive agriculture.

The massive presence of pollutants in the Boughrara dam is a complex problem that requires attention on several levels, including the delay in realizing the need to manage this problem and the slow implementation of sustainable development programs. Algeria introduced legislation in 1970 (National Committee for the Protection of the Environment) to protect and preserve the environment during the 1970s industrialization policy. However, without effective implementation, the environment continues to suffer from massive degradation. It took 10 years to establish a framework for the protection of the environment in general and groundwater in particular.

The steps taken by the Algerian state have not been effective in addressing the situation at the regional level of the dam. The degradation of the waters and its consequences have their source outside Algeria's borders (Oued Mouillah). The economic disparities between the two sides and the failure of diplomacy make the situation more and more inextricable, further endangering any national or local initiative for effective protection of the environment. Developing countries need a Green Fund to manage this issue and prevent it from threatening the planet. The Rio Summit (1992) marked the beginning of a progressive awareness of the responsibility of countries in the North for the degradation of the planetary environment, and subsidies were a central topic of discussion. It is crucial to move beyond the notion of responsibility and take concrete actions to address this issue.

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