PAN AFRICAN UNIVERSITY

INSTITUTE FOR WATER AND ENERGY SCIENCES (including CLIMATE CHANGE)

Master Dissertation

Submitted in partial fulfillment of the requirements for the Master degree in

WATER POLICY

Presented by

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The Socioeconomic Impact on the Water Management in Algeria: Tlemcen as a Case of Study

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Date: 6th October 2021

In Memory of my Mother
To My Father
To My Sisters
To My Grand-Mothers
To All the Ones Dear to My Heart

ACKNOWLEDGEMENTS

My foremost thanks and gratitude go to the Almighty God for his ever-present, guidance and favor throughout the journey of my postgraduate studies.

My sincere gratitude goes to my supervisor, Prof. Abdelghani Chiboub Fellah for his implication and assistance, his constructive criticism, and support during the research period especially during this Covid-19 period.

Special appreciation to the University of Tlemcen and the Pan African University Institute for Water and Energy Sciences (PAUWES) for tuition and academic exposure. I would like to thank the African Union Commission (AUC) for the scholarship and research fund. This work would not have been completed without their support.

I am also grateful to the Institute Director of PAUWES, Prof. Dr. Abdellatif Zerga and PAUWES staffs for their assistance and efforts for enabling learning environment while Covid-19 pandemic.

Deeply appreciation to the guest lecturers for their providing high quality courses, with whom I have learnt a lot.

Many thanks to l'Algérienne Des Eaux (ADE) and L'office National de L'Assainissement (ONA) for providing me the data that I needed for my thesis, I would also like to thank particularly Mme Amaria Slimani director of ONA who allowed me to make an internship at the WWTP of Ain El Houtz, Mme Nabila and Mr Khouani laboratory assistant at WWTP of Ain El Houtz who helped me during my internship, and Mr Choukri manager at ADE for providing me data for my thesis.

My great recognition to the inhabitants of Boujlida for their cooperation and comprehension, and for their time provided to respond to the survey.

Abstract

Water shortages experienced by the locality of Boujlida-Tlemcen are not only a consequence of the drought which has occurred in the city over the last decade, but also a delicate and difficult management issue due to the use of archaic investigative tools.
The main idea of the study is the analysis of data provided by l'Algérienne Des Eaux (ADE) about water production, distribution and consumption, in order to evaluate the efficiency of the water supply network, and on interviews to assess the role of water in the organization of the relationship between habitat and users.
The data analysis has shown that the water supply network of Boujlida is efficient at 55% meaning that about half of the volume introduced into the network is lost and that the water bill covers 92% of the total cost of water.
The survey highlighted the irregularity of water supply in the 160 households surveyed where the majority receives water 3 to 5 times a week, and use water only for cooking and not for drinking. The majority buys bottled water and/or fills water from fountains, and 55% had a water tank at home to satisfy their water needs during water shortages. Only 42% of the housings are connected to the sewage network.

Those results confirms that the water and sanitation management need a serious taking charge by decision-makers to improve its efficiency, where the water demand as much as on supply is of critical importance in a country with limited fresh water resources. Reducing water demand must be a major long-term challenge for the management of water resources that integrates sustainability issues in terms of environmental and economic dimensions. The ultimate aim is to consume less by consuming better.

Keywords: Locality of Boujlida; Water Management; Performance; Efficiency; Water Needs;

Résumé

Les pénuries d'eau que connaît la localité de Boujlida-Tlemcen sont non seulement une conséquence de la sécheresse qui s'est produite dans la ville au cours de la dernière décennie, mais aussi un problème de gestion délicat et difficile en raison de l'utilisation d'outils d'enquête archaïques.

L'idée principale de l'étude est l'analyse des données fournies par l'Algérienne Des Eaux (ADE) sur la production, la distribution et la consommation d'eau, afin d'évaluer l'efficacité du réseau d'approvisionnement en eau, et d'autre part, sur des entretiens pour évaluer le rôle de l'eau dans l'organisation de la relation entre l'habitat et les utilisateurs.

L'analyse des données a montré que le réseau d'approvisionnement en eau de Boujlida est efficace à 55%, ce qui signifie qu'environ la moitié du volume introduit dans le réseau est perdu et que la facture d'eau couvre 92% du coût total de l'eau.

L'enquête a mis en évidence l'irrégularité de l'approvisionnement en eau dans les 160 ménages enquêtés où la majorité reçoit de l'eau 3 à 5 fois par semaine, et n'utilise l'eau que pour cuisiner et non pour boire. La majorité achète de l'eau en bouteille et/ou remplit l'eau des fontaines, et 55% avaient un réservoir d'eau à la maison pour satisfaire leurs besoins en eau pendant les coupures d'eau. Seuls 42 % des logements sont raccordés au réseau d'assainissement.

Ces résultats confirment que la gestion de l'eau et de l'assainissement nécessite une prise en charge sérieuse par les décideurs pour améliorer son efficacité, où la demande en eau autant que sur l'approvisionnement est d'une importance critique dans un pays aux ressources en eau douce limitées. La réduction de la demande en eau doit être un enjeu majeur à long terme pour une gestion des ressources en eau intégrant les enjeux de durabilité en termes de dimensions environnementales et économiques. Le but ultime est de consommer moins en consommant mieux.

Mots-clés : Localité de Boujlida ; Gestion de l'eau; Performance; Efficacité; Besoins en eau ;

ABREVIATIONS

ABH: Hydrographic Basin Agencies

ADE: Algerienne des Eaux

AGID: National Agency for the Construction and Management of Hydraulic Infrastructure for Irrigation and Drainage

AGIRE: National Agency for Integrated Management of Water Resources

ANBT: National Agency of dams and transfers

ANRH: National Agency of Hydraulic Resources

APC: Popular Assembly communal

BOD_5: Biological oxygen demand

BV: Billed volume

CCNRE: National Consultative Council for Water Resources

COD: Chemical oxygen demand

D: Subscriber density

DAEP: Directorate of Drinking Water Supply

DHW: Wilaya Water Departments

DO: Dissolved oxygen

DRE: Water Resources Department

DREW: Water Resources of the Wilaya Department

DWS: Drinking Water Supply

EC: Electrical conductivity

EQH: Equivalent inhabitant

FAO: Food and Agriculture Organization

GDP: Gross Domestic Products

HDPE: High Density Poly Ethylene

IWMI: International Water Management Institute

IWRM: Integrated water resources management

LDLI: Linear Distribution Loss Index

LIPS: Loss Index per Subscriber

MDGs: Millennium Development Goals

MOA: Mestghanem-Oran-Arzew

MREE: Ministry of Water Resources and the Environment

$N\text{-}NH_4^+$: Ammonium nitrogen

$NO_3\text{-}N$: Nitrate-nitrogen

ONA: National sanitation office

ONID: National Office for Irrigation and Drainage

ONS: National Office of Statistics

PCCE: Program for the consolidation of economic growth

PCSC: Additional growth support program

PNE: National Exceptional Program

PO_4^{3-}: Phosphates

SEAAL: Algeria Water and Sanitation Company at Algiers

SEOR: Algeria Water and Sanitation Company at Oran

SS: Suspended Solids

UGT: Urban Group of Tlemcen

UN: United Nations

UNDP: United Nations Development Program

VAT: Value added tax

WHO: World Health Organization

WWTP: Waste Water Treatment Plant

Φ: Diameter

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CHAPTER I: GENERAL INTRODUCTION

I.1. Background

Water sustains life, it is therefore a vital human need and a right without which human beings cannot survive. A minimum of 20 to 40 liters of water per day per person is necessary for drinking and basic hygiene. However, the world's freshwater resources are facing increasing demand due to population growth, economic activity and, in some countries, improved living standards. Competing demands and conflicts over access rights arise because many people still do not have equal access to water and sanitation. There has been talk of an impending water crisis. According to the United Nations, access to drinking water and basic sanitation services is essential for achieving the Millennium Development Goals 6 (MDGs). This is a fundamental requirement for effective primary health care and a prerequisite for the success of the fight against poverty, hunger, child mortality, gender inequality and environmental damage **(Taylor *et al.*, 2008).**

Among the resources that contribute to the development of human activities, water has several characteristics that distinguish it from all others: it is essential for life; it is omnipresent (it makes up 65% of the human body, and covers 70% of the Earth's surface); it is available in strictly fixed quantities, dictated by conservation laws and the water cycle. The quantity useful for human activities is distributed extremely unevenly, where approximately 1,300 million km^3 of water that shelters the planet, 97.2% consists of salt water unusable for human activities; of the remaining 2.8%, 2.15% are “trapped” in the polar ice; remains 0.65%, of which 0.62% is underground. The water cycle provides a level of land precipitation of about 113,000 km^3 per year, from which 72,000 km^3 of evaporation must be subtracted to obtain the net available flow; of the remaining total, 32,900 km^3 are considered geographically accessible, but the timing of this precipitation must also be taken into account. Most are concentrated over short periods of time and result in flooding; 9,000 km^3 remain effectively accessible; if we add the precipitation water retained in dams, there are finally 12,500 km^3 of fresh water available each year for human use, which represents more than 5,000 liters per person per day worldwide, larger users (the Americans) withdrawing “only” 1,800 liters daily **(Baechler, 2012).** Currently, 1.1 billion people; (17 %) of the population lack access to safe water while 2.4 billion people (40 %) lack adequate sanitation. The majority of affected people live in Africa and Asia. Furthermore, population growth, rapid urbanization, and economic development weigh heavily on water resources **(Titi Benrabah *et al.*, 2013).** According to the Food and Agriculture Organization FAO, by 2025, 1800 million people will be living in countries or regions with absolute water scarcity and two-thirds of the world population could be under conditions of water stress. **(Naimi-Ait-Aoudia and Berezowska-Azzag, 2014)**

The scarcity of water in the world, and the management of water resources is one of the most crucial problems of the 21st century and remains the concern and interest of different organizations. In addition, water is essential for the functioning of terrestrial ecosystem, it is essential for human life ; for agricultural, industrial and domestic activities, and even, for political, social, economic and technical development. Currently, far from being available in quantity and quality, water remains the center of concern for the possibilities of development and human civilization **(Baghli *et al.*, 2012).** Over the past twenty years, the discourse on water scarcity has developed. It often conveys a vision that can be qualified as the security of the resource, in which fresh water, essentially referring to the hydrological systems of watersheds and aquifers, constitute strategic resources making it possible to meet the for water need for populations and activities, particularly industrial and agricultural. The lack of water is set to increase under the effect of a number of factors, which weigh on the compatibility in the near future of the quantity of quality water available with growing needs. It goes without saying that already today, water resources in many countries are at a critical level because demand exceeds the mobilized supply and the degradation of the quality of the resource is increasing and sometimes irremediable. While the results are already pessimistic, the projections are alarming. The scarcity of water, aggravated by demographic pressure and the intensive use of agriculture, poses very serious economic, food and health problems **(Boubou-Bouziani and Maliki, 2014)**

On a planetary scale, the water crisis continues to worsen, and now it threatens all technological and economic projects as well as the survival of the population. Therefore, trade-offs are thus necessary not only between users, but also between spaces. In an environment of deficit and conflict, the sharing of water resources, conditions the choice of development, which requires efforts and above all sacrifices. As a result, this situation accentuates territorial imbalances, and it establishes a spatial hierarchy, between the city and its periphery. The problem of drinking water supply is acute in a region with no resources and with significant population and urban growth. It combines physical scarcity and social scarcity **(Bessedik, 2019)**

According to FAO data, water uses are 70% for agriculture, 20% for industrial production (using water as process fluid or as inputs in products) and energy (hydroelectricity, thermal and nuclear energy), and 10% for domestic consumption. The water is therefore primarily used to feed humans. This is primarily due to the fact that it takes 2,000 to 5,000 liters of water to produce a person's daily food, compared to 2 to 5 liters for drinking and 25 to 100 liters for domestic use. If we focus on water consumption and not abstraction, agriculture even consumes 93% of fresh water, against 4% for industries and 3% for communities. Agriculture is therefore by far the sector which withdraws and consumes the most water in the world. Aquifers, which represent a volume 100 times greater than fresh surface water, also provide a good part of our needs and the increase in water demand has resulted since the second half of the twentieth century in a recourse growing to these underground basins. Globally, 65% of this resource is used for irrigation, 25% for drinking water supply and 10% for industry. In many countries, irrigation systems rely heavily on groundwater (90% in Libya, 89% in India, 84% in South Africa, 80% in Spain) **(Boubou-Bouziani and Maliki, 2014).** By improving the efficiency of water use in agriculture and the productivity of water, countries can lower the poverty rate and thereby reduce the percentage of the population that suffers from hunger. Likewise, by reducing the time to search for water, children will have time to attend primary education. According to WHO, access to safe water can reduce infant mortality rates and effectively combat water-borne diseases and other emerging epidemics where sanitation systems are lacking. So the link between access to drinking water and other MDG is well established. **(Kherbache and Oukaci, 2017)**

Today in the Mediterranean, 180 million people have less than 1000 m^3 of water. According to the forecasts of the Blue Plan (2007), the pressures on water resources will further increase significantly in the South and in the East and 63 million Mediterranean people will have less than 500 m^3 of water per capita per year in the horizon 2025. Climate change will reinforce the reduction of the resource.

Population growth in the South and East of the Mediterranean will put 290 million people in a situation of water scarcity in 2050 **(Boubou-Bouziani and Maliki, 2014)**

Since the announcement of the eight objectives of the Millennium Development Goals, MDG, where the access to safe water is considered as an important part of the first objective linked to the elimination of the extreme poverty and hunger, water and poverty have become more integrated and put to the forefront in the public debate. The last report of the United Nations Development Programme UNDP 2006, entitled "Beyond scarcity: Power, poverty and the global water crisis" has come to confirm the necessity to take the water factor as a central element in combating poverty, particularly in Algeria. Actually, in terms of climate, Algeria is characterised by a semi-arid nature, the fact that brings a high degree of scarcity in water availability. In fact, the average theoretical availability of water has attained a critical threshold estimated at 500 m^3/capita/year, representing less than half the scarcity threshold fixed by the World Bank at 1000 m^3/capita/year, and less than the fifth of the threshold of 2000 m^3/capita/year. There is a general consensus that this critical issue may be caused by bad governance of water **(Maliki *et al.*, 2009)**. Access to safe drinking water, sanitation and hygiene is a key to sustainable development and for achieving a green economy is not possible without ensuring everyone has access to basic water and sanitation services. Across the world, access to these services has proved to be a critical step in lifting people out of the vicious cycle of poverty and environmental degradation. Furthermore, the wastewater infrastructure of many fast-growing cities required to ensure water efficiency is non-existent, inadequate or outdated. Water storage, treatment and distribution systems are also often poorly maintained. Besides, water losses, due to technical leakage and water theft, often exceed 40-60 per cent of total water distribution in many developing countries **(Tapio and Jarmo, 2015)**

I.2. Problem Statement

The alarming shortage of freshwater faced by certain countries requires urgent and immediate action, in particular, those in the arid and semi-arid areas of the globe, which do not have sufficient water and land resources to ensure the survival of the increasing population. In this regard, Algeria is among the most vulnerable areas of the world, based on the threshold of water scarcity fixed at 1000 m^3/inhab/year. Algeria belongs to countries with low hydraulic resources. During the last 25 years, the country went through a long period of severe and persistent drought, characterized by an important rainfall deficit, estimated at about 30 % for the whole country. During 2001–2002, this shortfall reached 50 %. Due to the low levels of precipitation, the west of Algeria will be most affected by water shortage. The drought which has prevailed for more than two decades has desiccated the subsoil, causing serious disruption of the 1,000-year-old water bearing layer **(Habi and Harrouz, 2015).** Algeria is also one of the countries where water availability is limited while needs are growing rapidly. This growth is due to the demographic explosion, to industrial and agricultural developments as well as to drought. To cope with this shortage, the construction of dams seems to be the most suitable solution to meet the various needs. If these structures are indeed a necessity to guarantee, in all seasons, the water supply essential to the country, it would be advisable to control and protect the quality of the water of the dams against various sources of pollution, particularly those due to human activities ; agricultural and industrial practices, and urban discharges **(Bouzid-Lagha and Djelita, 2012)**

The issue of water has always been a problem for Algerian users, and decision-makers. The importance of these drinking water needs is reflected in its demographic development. Indeed, between 1966 and 1998 and in the absence of a real policy of demographic control, the population of the North-West region of Algeria alone more than doubled, reaching 4.8 million in 1998 with a average annual increase of 2.5%, and the gross density increased from 61 inhabitants/km^2 in 1966 to 136 inhabitants/km^2 in 1998. If in 1962 the theoretical water availability per inhabitant and per year in Algeria was 1500 m^3, it was only 720 m^3 in 1990, 680 m^3 in 1995, 630 m^3 in 1998, 500 m^3 in 2000 and would represent only 430 m^3 in 2020. In the future, it is estimated that the drinking water supply needs will be multiplied by around 2.5 in 25 years and they will represent 40% of the resources that can be mobilized around the year 2025. Water needs will therefore increase, but the problem of availability of water will be of increasing concern, because, several factors will have to be taken into account, including global warming **(Bouziani-Boubou and Maliki, 2009)**

In Algeria, water is a major constraint and a limiting factor for agricultural production. The causes are essentially natural: irregularity and weakness of the rains, which are often stormy, and soil erosion. The scarcity of water is accentuated by an ever increasing demand. The climatic characteristics of Algeria imposed from the colonial era a policy of building large reservoir dams, and the postcolonial period saw the continuation of this policy. Water from annual precipitation is estimated at 12.4 billion m^3, most of which (8 billion m^3) will flow into the Mediterranean Sea. The Tell, with 7% of the total surface area of the country, receives 88% of surface runoff. Given the topographical conditions which do not always allow the establishment of large dams, Algeria has adopted a vast program of construction of hill reservoirs for the mobilization of water resources in order to fill the existing deficit, which is very interesting when the biophysical and socio-economic conditions allow it, is also suitable for arid or semi-arid areas characterized by torrential runoff as well as for humid regions. But their effectiveness and sustainability remain, however, dependent on many conditions ranging from the choice of site to the participation of local actors.

In the semi-arid north-west of Algeria, the problem of water scarcity continues to grow and hold the attention of planners and managers. In this region, which has always suffered from a lack of water, all possibilities for building large dams have been exhausted and the construction of small reservoirs has taken precedence over that of large dams. This area benefited from a construction program of 253 hill reservoirs during the 1985-1989 five-year plan. The last few years have seen the continuation of this policy, given the growing water needs and frequent droughts. The objectives are the satisfaction of the needs of the populations and rural development. Across Algeria, 1,237 small hill reservoirs have been built since the 1980s. Opinions remain divided on the success or failure of these developments, which undeniably play an important role in rural development. Most are silted or degraded. This situation amounts to posing the problem of the rigorous selection of potential sites for development as well as that of integrating the development into its environment. Other problems have arisen in terms of management, maintenance and the degree of ownership by the populations. With clearer objectives, a more detailed diagnosis of biophysical and socio-economic factors and the involvement of local residents, these developments could have had a more positive impact. It is therefore important to take stock of the current state of these reservoirs as well as their impacts and future developments. To this end, to better understand the main issues raised by these hill reservoirs and to draw lessons from the immense experimental field available to Algeria and to improve the design and management of future developments, an analysis a sample of around forty reservoirs was carried out in two representative areas from the Algerian north-west: the watershed of the Tafna wadi (Tlemcen) and that of the El Hammam wadi (Mascara). These two large watersheds are of great regional interest and constitute a water tower with 9 hydraulic dams **(Habi and Morsli, 2011)**

The creation and development of technical and technological means to escape the subjugation of local conditions and the vagaries of nature in the water sector is one of the prerequisites for the development of the economy and the cultural level. Science has always developed techniques (aqueduct, foggaras, dams, transfer, desalination, purification, water-saving devices, etc.) and know-how (management, human resources management, etc.) which make it possible to tame this resource. This is how water management has seen the birth of different types of water from: wastewater treatment plants, dams, seawater desalination, water treatment, boreholes, wells,… from several so-called "water" technologies. The issue of access to water is seen on two complementary axes. Upstream of consumption, it concerns: exploration (remote sensing), exploitation (desalination, dams, etc.) and the availability of water resources. Downstream, the central issue related to water remains that relating to consumption (economizing devices), pricing and wastewater treatment. Upstream and downstream, the common question remains that of mastering techniques and know-how **(Bouziani-Boubou and Maliki, 2009).**

The water supply in the Urban Group of Tlemcen is characterized by an insufficient production that cannot meet with current needs, mainly due to the reduced rainfall during last years. Most neighbourhoods are supplied once to twice a week for few hours. There is also a tremendous rate of water loss that exceeds 50%. This loss is the result of an advanced deterioration of pipes, poor workmanship quality, and a lack of maintenance and renewal of pipelines. The water supply system as a whole is poorly structured as a result of extensions made without basic design. **(Abdelbaki *et al.*, 2012).** The water shortage in Tlemcen has generated new practices. Citizens tired of the disorders of the drinking water distribution system, and in the absence of information on the genesis of the water shortage, are trying as best as possible to organize themselves to obtain supplies and ensure a minimum of water reserve. So, regulation and mobilization systems for domestic water storage were invented to deal with the disadvantages produced by the shortage. The urban water sector in the city of Tlemcen is in deficit. Drinking water is supplied sporadically. The limits of conventional water resources have been repeatedly reached due to the persistence of drought **(Bessedik, 2019)**

I.3. Importance of Water Management

Currently, there is awareness that the management of water resources has gone beyond the framework of engineering and economists and requires the implementation of new strategies to find solutions. Thus some recent suggestions propose to ; review the economic value of water, look for solutions to the problems of the scarcity of fresh water in terms of quality and quantity, address the communication gap between actors which perpetuates the same problems and the same errors to the detriment of the sustainability of water, and advocate for consultation between water stakeholders and emphasize the absence and / or insufficiency in the structuring and supervision of water users. Water management is generalized into watershed management in interactions with other water supply subsystems, ecosystems, irrigation, industries and humans **(Baghli *et al.*, 2012)**

Integrated water resources management (IWRM) can be defined as a systematic process for the sustainable development, allocation and control of the use of water resources in the context of social, economic and environmental objectives. It is cross-sectoral and therefore in flagrant contradiction with the traditional sectoral approach adopted by many countries. It was further broadened to include participatory decision-making of all actors. IWRM is based on a variety of uses of water resources which are interrelated. Failure to recognize the interdependence coupled with unregulated use can lead to negative consequences such as the waste of water resources and the unsustainability of water resources in the long term. Integrated management does not exclude water users or the use of sectoral approaches adopted in many countries. Rather, the allocation of water and decisions about its management take into account the impact of each use on the others. Thus, intersecting objectives of social, economic and environmental sustainability are considered as a whole, and cross-sectoral policies are examined in order to formulate more coherent and coordinated policies. **(Taylor *et al.*, 2008)**

The integrated and sustainable management of water resources goes hand in hand with the consultation of water stakeholders. Current management is inadequate and does not respond to the sustainability of this resource. Our modern societies seem to experience a decision deficit in integrated management. The consultation of actors advocated in sustainable management is weak if not lacking. To remedy this, we must improve the decision-making conditions, improve the decision-maker and improve the decision-making tools. The recommendations to remedy the deficit in decision-making in the water resource are to create back-and-forth exchanges of information between actors without reductionism and within a framework of cooperation. To do this, politicians who need accurate and reliable information cooperate with scientists. These should provide them with information in the form of scientific and socio-economic assessments converted into information for use in planning and thus engage in policy making **(Baghli *et al., 2012*)**. Different user groups (farmers, communities, environmentalists, and others) can influence water resource development and management strategies. This results in additional benefits, such as informed users who apply local self-regulatory systems to solve their problems of water conservation and protection of feeding areas, much more efficient than regulation and control. centralized can achieve. The term management is used in its broadest sense and emphasizes the need not only to focus on the development of water resources, but also to conscientiously manage the development of water that ensures sustainable use for future generations. **(Taylor *et al.*, 2008)**

I.3.1. Policy of Integrated Water Management in Algeria

Aware of the challenges to be taken up in the management of water resources and of the need to implement a new policy in this sector.

- In 1995 Algeria organized national water meetings for the first time, following this meeting, an inventory and diagnosis of water distribution and sanitation systems (dilapidated networks, leaks, illegal connections, inability to ensure full access to water for the populations, etc.) was established and a national strategy developed.
- In 1996, Algeria embarked on a new water policy, namely "Integrated management of water resources" to guarantee their development and sustainability. This new policy is based on a set of institutional reforms and new instruments which are the Basin Agencies and the Basin Committees.

- In 1999, creation of the Ministry of Water Resources, responsible for the implementation and application of the national water policy.
- In 2005 the water code was promulgated, defines water as property of the national community. According to this text, the first principle on which the use, management and sustainable development of water resources is based, is the right to access to water and sanitation to meet the basic needs of the population. , while respecting equity in public services. Its purpose was to improve the public water and sanitation service, to build skills, to improve management transparency, to facilitate access to water for the most disadvantaged, and to preserve and restore water quality.

The 2005 law complements that of 1983, providing it with a legal, institutional and financial framework to guarantee sustainable management of water resources (drinking water and irrigation), concerted planning and management of infrastructure and resources, efficiency of public services and sanitation, protection of water against pollution, waste and overuse and in order to prevent the harmful effects of water as a good of the national community.

The policy undertaken aims to create a medium-term decision-making tool, which can be updated subsequently without external intervention, for the development and management of water resources in Algeria. It revolves around the following concepts:
1. Specify the extent and quality of water resources including unconventional resources;
2. Evaluate water demands, now and in the future;
3. Draw up an inventory of existing and planned infrastructures, identify new potentials and initiate actions for their mobilization and transfer;
4. Dynamically confront resources and needs and quantify the costs and benefits of each variant as well as its impact on the national economy;
5. Examine the institutional framework and its suitability for the management and protection of the resource **(Chaib Draa Tani, 2019)**

I.4. Objectives

1.4.1 General Objective of the Study

The overall objective of the study is to assess the water management and sanitation in the city of Tlemcen, Boujlida as a case of study, and analyze its socio-economic impact.

1.4.2 Specific Objectives of the Study

- ✓ To examine the efficiency of the drinking water supply network of Boujlida;
- ✓ To evaluate the economic loss of water management;
- ✓ To analyse the efficiency of the WWTP of Ain El Houtz;
- ✓ To evaluate the rate of satisfaction of water needs at Boujlida;

I.5. Research Question

In order to assess the specific objectives specified above, our study examines the following questions:

1. What is the volume lost in the drinking water supply network in Boujlida?
2. Does the water bill cover the production, storage and distribution of drinking water?
3. Does the treated wastewater of the WWTP of Ain El Houtz conform to the norms of reuse?
4. Does the water supplied cover the citizens of Boujlida needs?
5. Does the frequency of the supplied drinking water satisfy the citizens?
6. What are the reasons of water shortages in Boujlida?
7. How the citizens of Boujlida evaluate the water quality and water management?

I.6. Limitation of the Study

The challenge encountered during the study revolves mainly around the effects caused by the ongoing Pandemic situation (Covid-19). There was limited movement of people during this period, which delayed me on the field survey that I had to postponed which lead to not having enough time to question all the inhabitants of Boujlida.

Access to data took a lot of time because of the administrative procedure. For that reason the area of the study planned at the beginning has changed and lessened and not all the parameters have been studied, due to the lack of time.

CHAPTER 2: Literature Review

II.1. Introduction

Demographic growth and the more urbanized population make access to the water service difficult and expensive, especially for cities which, given the total exploitation of nearby resources. In this context, transfer and interconnection projects, covering hundreds of kilometers, have been carried out. Among these major projects in Algeria, there is the In Salah-Tamanrasset transfer (received in 2011, it consists of taking 100,000 m^3 per day and bringing it back from In Salah to Tamanrasset over a distance of over 750 km); the transfer from Koudiat Acerdoune (Bouira) to Tizi Ouzou, Médéa and M'sila; the transfer of the high Sétifian plains; the Mestghanem-Oran-Arzew (MOA) transfer; the Beni Haroun dam, etc. These achievements were accompanied by an accelerated process of institutional reforms in the water sector, particularly after the promulgation of Law No. 05-12 on water. All of these efforts came up prematurely with major constraints in the field due to a concentration on the mobilization of water upstream (supply policy) without valuing the resource downstream by management of water demand. However, Algeria was able to achieve the MDG targets related to access to water well before their deadlines set by the UN in 2015. In fact, the country provides access to drinking water to the majority of the population with a connection rate of 98% in 2015, against 78% in 1999. And it was able to achieve the objective linked to sanitation where the rate of connection to sanitation networks was evaluated in 2015 at 90% while it was 73.2% in 2000 **(Kherbache and Oukaci, 2017)**

In Algeria, the systematic inventory of water resources, in spite of many studies carried out during the last century is not completed yet, but its broad outline is known, where water consumption is not measured and if it is, data are rarely reliable due to water meter degradation. Few attempts have been made to characterise and quantify actual water consumption **(Habi *et al.*, 2016).** These resources are not well distributed, in space, quantity and nature (surface or underground). The major part of the country (87%) corresponds to a desert, where precipitations are quasi null but which conceals important fossil underground water resources. The Northern part of the country is characterised by a Mediterranean climate, with renewable surface and underground water resources. Ninety percent of the surface water is located in the Tell area which covers about 7% of the territory. Another characteristic is the strong disparity between the West and East of the country. Plains are reaching on the poorly sprinkled Western area. The Eastern part of the country is a mountainous area where the principal rivers run out. The Western basins receive only 10% of the flow with a surface representing the third of that of the North of the country. Those of the East drain 40% with only 20% of the total surface and the Centre basins drain 50% of the flows with 50% of the remainder of the surface. One estimates nearly 1.6 billion the volume regularised by year. The numbers of dams reach 110 of which 45 have a capacity higher than 10 millions m^3 and 65 of lower capacity. The total of surface and underground water resources are estimated at 19.2 billion of m^3.

In Algeria, underground water is an essential capital in regard to the water reserves. The repeated dryness of these last decades clearly put forward the weaknesses of balance between

need and resources regarding the surface water. The advantages of underground water, as a resource, result from the characters of their occurrence, their distribution and their regime in the natural environment. One can say: Underground water does not require installations similar to regulating equipment and surface water transfer; underground water is often accessible and exploitable using simple means without requiring an excessive investment, in wide territories; underground water often offers natural characteristics in conformity with the standards required by many uses, in particular the drinking water.
Taking into account the diversity of the formations and geological structures as well as the importance of feeding the underground water reserves, all types of aquifers are represented in Algeria. It results from this point of view that the underground water potentialities and their exploitation could be radically different. A classification based on geological and morphological criteria made it possible to determine levels of much diversified resource and their exploitation. The strong potentialities allowing an intensive exploitation are localised in two principal types of aquifers:

- The large karstic, free or captive aquifers: mounts of Tlemcen, table land of Saida, karsts of Zibans.
- The large plains formed by subsidence and filled by an important alluvial filling, well fed as well by precipitated as by the rivers which cross them: plains of Sidi Bel Abbes, Mitidja, Mascara, Annaba.

The rate of renewal of these aquifers is rather appreciable. Considering the geological environment and particular climatic conditions, one can say that in many areas of Algeria, the use of the underground water resource is limited by various factors:

- The parcelling out and the partitioning of the reservoirs as well by erosion as by tectonics ;
- The morphology accentuated on a large part of the North ;
- The limited power of the aquifers is a real constraint for intensive exploitation ;
- The weakness of the unit flows of drillings which involves an exaggerated number of drills.

To this quantitative limitation of the reserves available, one can add the deterioration of the chemical quality of water. This is particularly true in the aquifers coastal (plain of Andalouses, Mitidja Eastern, plain of Annaba- Bouteldja, ... and the aquifers of the semi-arid areas, in particular those in the vicinity of the closed depressions (Chotts and Sebkhas).
Excessive extraction from these aquifers often involves a fast increase in the water mineralization. For these reasons, real and direct exploitable volumes of underground water, by well and drillings, can differ notably from the values of the annually infiltrated water.
(Bouchekima *et al., 2008*)

Considering potentialities, mobilization, organization, and utilization we put forward that water in Algeria is a major constraint to development, and this is in association to other fatal and undoubtedly insurmountable vulnerabilities due to the current economic performance. It is considered that remediation to water scarcity remains the economic adaptation of investments and funding. **(Bouchentouf and Benabdeli, 2021)**

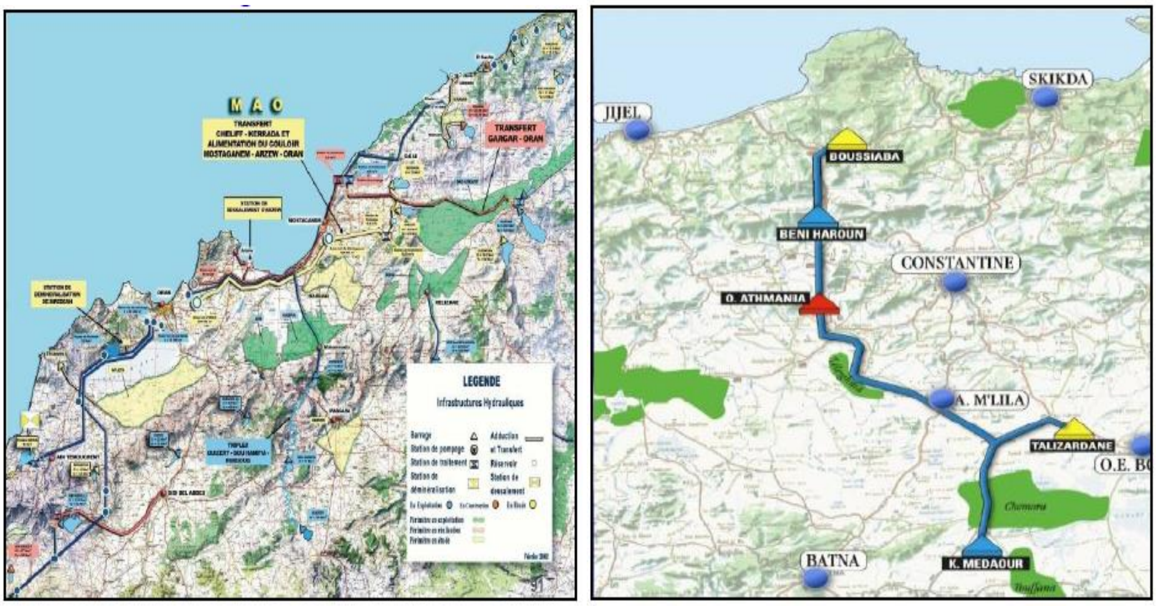

Figure 2.1 : The Mestghanem-Oran-Arzew (MOA) transfer (left), The Beni Haroun Dam Transfer (right) **(Chareb-Yssaad)**

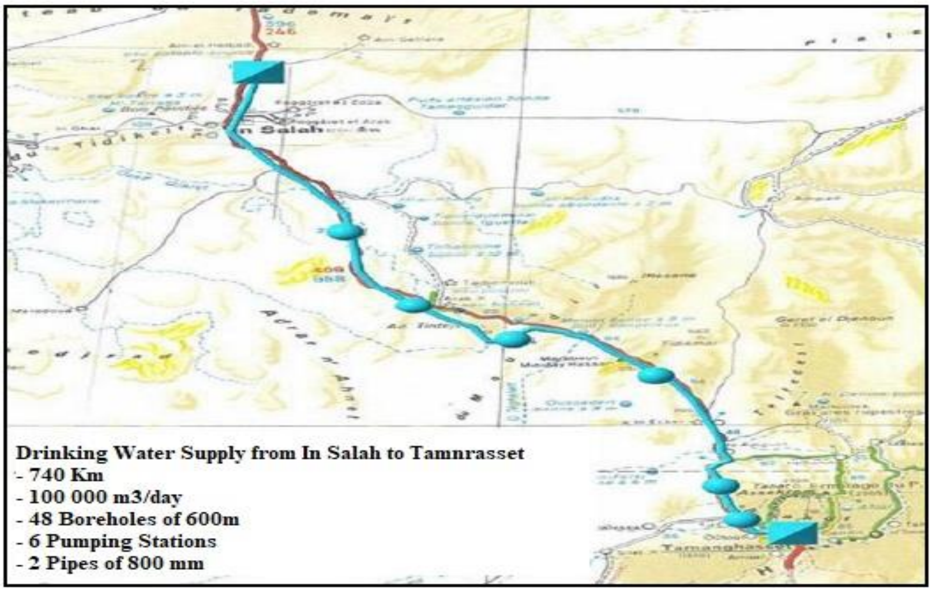

Figure 2.2 : In Salah to Tamanrasset Transfer **(Chareb-Yssaad)**

II.2.Algeria Water Resources

Algeria, with a surface of 2.4 millions km^2, is the largest country of northern Africa. Most of this surface is occupied by the Sahara, unfit to agriculture, but rich with mineral resources. More than 90 % of the population lives in the North, that includes a coastal band along the Mediterranean Sea, plains, mountains and high lands. The annual amount of rain, in the North, varies between 300 and 1000 mm. In the Sahara and south the Saharian Atlas, the annual amount of rain is below 100 mm. Algeria has 17 major hydrographic basins and shares the Medjerda basin with Tunisia, and Tafna, Draa, Guir and Daoura basins with Morocco. The annual amount of rain is 100 billion m^3, of which 80 % evaporate into the atmosphere

(**Bouchekima *et al., 2008***). Algeria has five watersheds comprising 19 catchment area. The renewable surface water resources are estimated in total of 13.2 km^3/year across the country. Water contained in the renewable groundwater aquifers in north of the country are estimated at nearly 1.7 km^3/year, and these sheets are fed mainly by rainfall where the distribution is irregular in both space and time (**Titi Benrabah *et al.*, 2013**)

Algeria is considered as an arid region with irregular poor water resources that are geographically wrongly distributed. Theoretically, it has been shown that water availability was about 1770 m^3/habitant/year in 1955, 680 m^3/habitant/year in 1995, 500 m^3/habitant/year in 2000, and averagely 430 m^3/habitant/year in 2013. Increase of demography will affect negatively and significantly the ratio since plans reaching 51 million habitants by 2030 leading dropping water resources availability until esteemed alarming level of 320 m^3/habitant/year (**Bouchentouf and Benabdeli, 2021**)

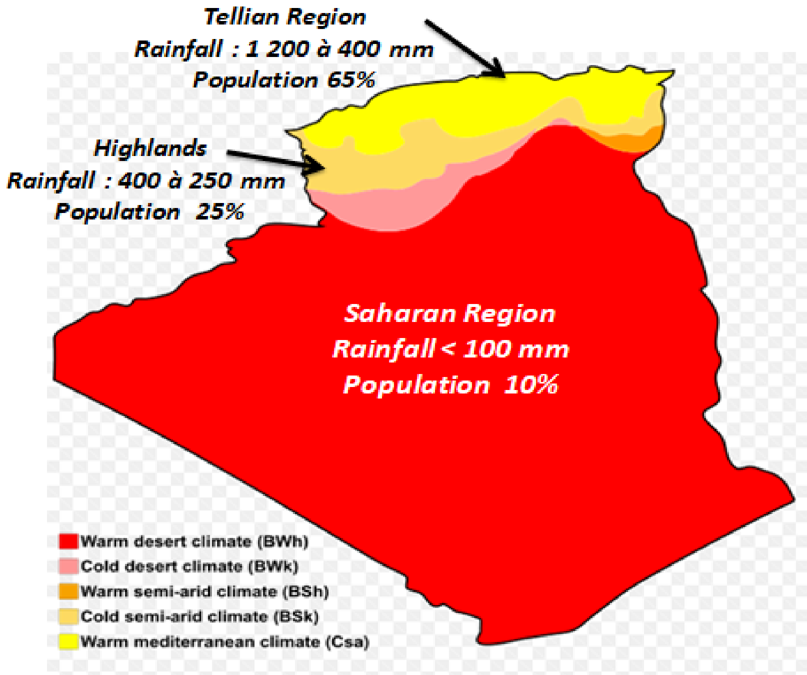

Figure 2.3 : *Aridity Level in Algeria* (**Djelouah, 2018**)

The water resources are estimated at 19.3 billion m^3/year, of which 12.4 billions of surface water and 6.9 billions of underground water. Only 6 billions could be mobilized by dams. For now only 4 billions are mobilized by nearly 110 dams.

From the 6.7 billions of groundwater resources, 5.1 billion are located in Sahara. The rest, i.e. 1.6 billion m^3, is already mobilized at a rate of 80 %, principally by wells and boreholes.

The National Plan for the potable water consisted on a large project, launched in 1990, financed by the European Investment Bank and given to an association of European consultants, had to elaborate a data bank, the more complete as possible, about surface waters, underground waters, on the urban, industrial, and agricultural water demand and to define the major axes of investment in water for the twenty next years. The study, which is nearly done, had been cut into the five grand hydrographic basins, which are the territories of the basin agencies ; Oranie (Chott Chergui), Cheliff (Zahrez), Algérois (Hodna- Soummam), Constantinois (Seybousse – Mellegue), and Sahara (**Bouchekima *et al., 2008***)

Table 2.1: *Water Resources in the Hydrographic Basin in Algeria*

Hydrographic Basin	Oranie (Chott Chergui)	Cheliff (Zahrez)	Algérois (Hodna - Soummam)	Constantinois (Seybousse - Mellegue)	Sahara
Area (Km²)	76 000	56 200	47 431	43 000	225 200
Population (Million inhab)	3.8	3.8	9.5	5.5	5.5
Rainfall (Billion m^3/yr)	23.5	20.5	21	25	95
Surface Water Resources (Hm^3)	958	2 000	4 304	5 600	/
Underground Water Resources (Hm^3)	309	245	130	337	/
Total Water Resources (Hm^3)	1 267	2 245	5 049	5 937	600
Water Availability (m^3/inhab)	220	300	320	500	1 120

Source **: (Boubou-Bouziani and Maliki, 2014)**

Algeria, which has 1,200 km of coastline, adopted seawater desalination (three quarters) or brackish water (one quarter) as alternative to supply drinking water to cities and localities in the coastline, and up to 60 km further from the coast. In 2013, Algeria had nine large desalination plants in operation capable of producing up to 1.4 million m^3 of desalinated water per day. The commissioning of other stations will bring the total production capacity to more than 2.5 million m^3/day. In addition to these large stations, there are around twenty small mono-block stations (with capacity range from 2,500 to 7,000 m^3/day); some of these have been relocated to reinforce water deficiency in other localities. The most important constraints of water desalination are; on the one hand, the energy consumption per cubic meters of water and on the other hand the effects on the environment due to discharge of brine, significant greenhouse gas emissions and, chemicals in the natural environment **(Bouchentouf and Benabdeli, 2021)**

Figure 2.4 : The Five *Hydrographic Basin in Algeria* **(Chareb-Yssaad)**

II.3. Algeria National Water Development Strategies and Policies

Algeria is one of the countries with the most water deficit. Indeed, the average theoretical availability is estimated at 500 m^3/inhabitant/year which is a critical threshold, where the actual data report a value of 383 m^3/inhabitant/year. It represents less than half of the scarcity threshold set by the World Bank at 1000 m3/capita/year and a quarter of the comfort threshold which is 2000 m^3/capita/year. The primary culprit for this critical condition and repeated shortages is poor water governance.

At the beginning of the 1990s, a new water policy based on the uniqueness of the resource, integrated management at the hydrographic basin scale, concerted, economic and environmental management was put in place and several institutions in particular, the higher water council and the river basin agencies were created. However, despite the emergence of this institutional framework allowing for integrated management, intersectorality and the participatory approach are far from being really applied. On the contrary, Algeria is starting to completely free the management of public water services and applies a new pricing according to the new water code which can negatively influence the underprivileged segment of the population, namely the poor **(Maliki, 2006)**

Since the beginning of the 2000s, the Algerian government has taken important measures to get out of the situation of water scarcity that affected the country. The hydraulic issue has been placed high on the political agenda and big resources have been put in place to mobilize new conventional and unconventional water resources and develop hydraulic infrastructure:

dams, transfers, seawater desalination plants, purification plants etc. **(Bouchentouf and Benabdeli, 2021)**

National strategies have always favored supply policies by increasing the number of retaining structures and boreholes (approach in terms of supply: quantitative approach). The Algerian dam park (which reaches a little more than one hundred), mobilizes on average 5,500 billion m3 (since the year 2000), while Morocco, with its 33 dams, totals 1,010 billion m3, and that Tunisia reaches 2,410 billion m3 with its 28 dams. Regarding boreholes, in 1989, it was already indicated that 80% of the groundwater potential in northern Algeria, then estimated at 1.8 billion m3, was overexploited **(Bouziani-Boubou and Maliki, 2009)**

The new water sector policy in Algeria aims to centralize water management activities and gradually increase the involvement of the private sector. Within the new institutional framework, the Ministry of Water Resources and the Ministry of Environment and Land Use Planning will be responsible for water, wastewater and irrigation planning, management, monitoring, and pollution control. The two most important instruments in the legal and regulatory framework are ; Environmental Protection Law No. 83 – 03 of 1983. which specifically mentions water pollution, and Water Law No. 83-17 "Le Code des Eaux" (revised in 1996 under law No. 96-13) which includes several articles related to wastewater discharge, pollution abatement, the protection and preservation of water bodies and wastewater reuse for agricultural and industrial purposes **(Bouchekima *et al., 2008*)**

Providing access to safe water, disposing of wastewater and providing sanitation systems are three of the most fundamental foundations of human progress. Access to an improved water source and sanitation facilities are among the Millennium Development Goals.

So if there is a lack of water, an essential element for economic, social, agricultural or even ecosystem life; it can also have an impact on productivity: the water and sanitation crisis is slowing countries' economic growth. Sub-Saharan Africa is thus losing 5% of its annual Gross Domestic Products GDP.

Analysis of the demographic data of Algeria, reported in the literature, reveals that this country occupies the third place on the African continent, the seventh position compared to the Arab countries and the thirty-fourth place in the world. This reflects the importance of drinking water needs. The demand for fresh water therefore grows each year by 4 to 5%, while natural resources remain invariable **(bouziani-Boubou and Maliki, 2009)**

The principles of law relating to water are :

- *Uniqueness of the resource*: Unit management at the level of the Hydrographic Basin. This management will be ensured by the Hydrographic Basin Agencies.
- *Consultation*: Consultation takes place through hydrographic basin committees.
- *Economy*: This economy is achieved by combating leaks and wasting water with objectives based on systematic metering and the rehabilitation of networks as well as by sensitizing users to the use of this resource.
- *Ecology*: Water is a scarce resource and a collective good to be protected against any Form of pollution.
- *Universality*: Water is the concern of all users.

In February 2007, the National Water Plan, spread out until 2025, was adopted, this flexible and evolving planning tool has as its main objectives:

- Ensure the sustainability of the resource.
- Create the dynamic of territorial rebalancing.
- Create and strengthen attractiveness and competitiveness.
- Guarantee good water governance. **(Chaib Draa Tani, 2019)**

II.3.1. Political Will and Basin Management Systems

Setting up basin management requires political will, high-level commitment and dialogue between water users. Basin management is governed by national legislation and policies as well as by international agreements. Basin organizations are part of a three-dimensional framework: a favorable environment, institutional arrangements (roles and responsibilities) and management mechanisms. For the establishment of IWRM in hierarchical societies, it is necessary to proceed in stages, starting by bringing together the water stakeholders and identifying common concerns. This political will makes it possible to include the gathering and exchange of information, and then the presentation of proposals to the government for its approval.

In Algeria, the IWRM approach is being integrated into plans and strategies at the national level. However, the current challenge is to ensure that these plans are implemented effectively and over the long term. To do this, the managers at the basin level will be the major players in the articulation between the national policy development and planning processes on the one hand, and basin management on the other. This will help reduce risks, enhance sustainability and facilitate economic growth and more equitable development, while preserving the environment.

Due to the inherent and multiple links between the different uses and users of water, water management at the level of a basin has a direct impact on the communities, administrative regions and political territories of this basin. Communities that share a basin are particularly interdependent. Basin managers must identify ways to address water-related challenges in order to avoid problems such as social unrest, conflict, economic downturn and degradation of vital resources.

II.3.2. Strategic Axes of The National Water Policy

Like other countries, Algeria has enriched its national water policy by adapting it to all the changes arising from climate change, evolution, social and economic challenges and needs as well as a perception of the real cost of water and the economic consequences.

In the early 2000s, the government decided to make the water issue a top priority. This priority has resulted in a strong impetus for intervention by the State on two major strategic axes:

- 1st axis: The development of hydraulic infrastructure as part of national programs to revive and support economic growth.
- 2nd axis: Institutional reforms as part of the national approach to strengthening governance.

The major projects implemented since the beginning of the 2000s have five strategic objectives:

- Increase and secure the mobilization of conventional (renewable and fossil) and unconventional (desalination and purified wastewater) water resources to ensure that domestic, industrial and agricultural water needs are met.
- Guarantee access to water and improve the quality of service through the rehabilitation and modernization of drinking water supply and distribution infrastructure to minimize losses and improve service quality.
- Ensure access to sanitation and protect water ecosystems through the rehabilitation, modernization and extension of sanitation and wastewater treatment infrastructure to preserve and reuse a limited water resource.
- Support the food security strategy with the modernization and extension of irrigated areas.
- Ensure good water governance and improved management indicators. This governance is based on ; economy and preservation of water, protection against major risks, progressive and inclusive pricing system, and participatory management **(Chaib Draa Tani, 2019)**

II.3.3. Importance of Development Policies

From all given data, it should be noted that Algeria is in a situation of water scarcity where the scale of the challenge can be met only if the water mobilization reaches 18 km^3 in order to ensure food self-sufficiency. Major studies on climate risks on agriculture in the region highlight shortfalls in yields of rainfed crops up to 50% during 2000-2030 periods. The rainfall deficit calculated between 1974 and 2010 is around 33% in the west, 20% in the center, and 17% in the east of the country, which is considered as another factor limiting the increase of irrigated area. The yield of strategic crops remains depending on irrigation and limited, since only 800,000 ha are currently cultivated with average yields lower than those of countries with the same soil, climate condition, and water resources **(Bouchentouf and Benabdeli, 2021)**

Several factors are contributing to the worsening of the water crisis, among the most important are:

- **Increase in demand**

The rapid increase in the world's population has enormous implications for all resources including water. If the demand for this resource increases, in parallel People will face the shortages of fresh water which will seriously hamper food production and economic development. Although there are differences of opinion, the worst-case scenarios suggest that almost seven billion people in 60 countries will lead lives characterized by one of the water crises in 2050. Even under optimistic assumptions.

- **Urbanization**

At the start of the 20th century only a small percentage of the population lived in cities in most parts of the world. The urban population increased steadily during and reached 47% by the millennium. Projections indicate that it will reach 58% in 2025. Historically, the majority of this increase has been recorded in developed countries. Algeria, for its part, suffered the same fate, since the last decade was characterized by an urbanization never seen since independence, which further complicated water management in our country.

- **Globalization**

Water consumption has almost doubled in the past 50 years. A child born in the developed world consumes 30-50 times the resources of water compared to one born in the developing world. These lifestyle choices are at least as important. A demand for better water services and new uses such as washing machines for households in developing countries will have a negative impact on the water crisis.

- **Agricultural development**

The irrigated land area had doubled during the first half of the 20th century, reaching almost 100 million hectares in 1950. From the 1970s onwards irrigation declined markedly. However, most of the agricultural land in the world will continue to be watered through rain in the future. It is estimated that the use of water in agriculture by 16,000 km^3 annually.

- **Climate change**

The world is experiencing quite significant climate change accompanied by an increase in temperature on earth, which leads to a decrease in water resources through vaporization. The worst will obviously be for arid and semi-arid countries such as Algeria. Another major problem related to water management concerns access to this scarce resource **(Maliki, 2006)**

Since 2000, Algeria, has been trying to catchup by intensifying investment in water sector and considering a long-term strategy between 1999 and 2019. Significant public funding has been allocated to the water sector to carry out the structural reforms launched in 2001-2002. The government and policymakers have adopted several urgent approaches concerning national water policy, development, planning, preservation and treatment. Public investment in the water sector rose from 34.8 million Euros (28.5 billion Algerian dinars) in 1999 to 738.4 million Euros (594 billion DA) in 2006. The adopted strategy is based on improving water supply resources by rational use consisting in construction of dams, construction of desalination stations and, wastewater treatment plants. Algeria has undertaken big water resources projects to guarantee sustainable development and reduce dependence on food security but it was without success. The development of strategic agricultural production for an arid country like Algeria necessarily requires an optimal and rational use of water resources. The availability of water reserved for irrigation remains whatever the mobilization programs badly exploited and cannot include increasing irrigated areas. The uses of water-saving techniques remain beneficial, since they make doubling of irrigated lands surface easily possible. The methods of supplying water by moistening through a porous pipe buried in the soil at different depths depending on the type of crop constitute an interesting solution.

The contribution of water to food security and nutrition constitutes a crucial point of interaction between policies of different economic concerned sectors and even within the same sector. Despite the 16.6 billion USD (1200 billion dinars) spent in 20 years, the real impact is only 830 USD (60,000 Algerian Dinars) per agricultural plot; the constraints hampering self-sufficiency or food security still remains at the level of the risky policies adopted which have-not taken into account the basic factors of population growth, climate change, modern irrigation techniques, agro-ecology, and agro-forestry **(Bouchentouf and Benabdeli, 2021)**

II. 4. Algeria Water Management

One of the main indicators of well-being and human development is incontestably adequate fresh water access. In the second edition of the World Water Development Report, "Managing Water under Uncertainty and Risk" (UNESCO, 2012), UN-Water stressed that water underpins all aspects of human development, and that a coordinated approach to managing and allocating water is critical. The major water concern in many regions is insecurity about the adequate water supply in the face of rising population demand. According to the United Nations Organization FAO (2007), by 2025, 1800 million people will be living in countries or regions with absolute water scarcity and two-thirds of the world population could be under conditions of water stress (**Naimi-Ait-Aoudia and Berezowska-Azzag, 2014)**

The worsened situation of the bad water governance is due to certain inadequate practices resulting from lack of coordination and the almost absolute marginalization of the role of the citizens. Good water governance can be applied by coordination between sectoral policies (environment, energy, trade, food and agriculture, including fisheries, forestry, and industry) to avoid repercussions on water resources **(Bouchentouf and Benabdeli, 2021)**

Since the mid-1990s, the interest - and the obligation - to measure performance has grown in the majority of public bodies; the latter have embarked on the identification of management indicators with a view to improving the quality of their services. According to the International Water Association, "A performance indicator is a quantitative measure of a specific aspect of an operator's performance or level of service. This type of indicator is most often used to monitor and assess the efficiency and effectiveness of a water and sanitation service ". In drinking water supply, performance measurement by indicators relating to the qualitative results of the service appears to be a tool suitable for improving this management control. The implementation of this methodology seeks “to constitute a common panel of indicators covering all the missions of the drinking water supply services. These indicators, in limited number and often quite simple to calculate, are ranked in order to guide the choice of the local authority, without however depriving it of the possibility of adapting the list to the particular context of its service ” **(Abdelbaki *et al.*, 2012)**

To face the water resources problems and in a preoccupation with a better management, it was adopted an integrated approach of protection and rational use of the water resources by:

- The creation of the Water National Council and five watershed agencies was adopted, whose statute specifies that the agencies manage the contributions of all nature granted by the State and intended to promote and support the projects and actions aiming at the water economy, the safeguard of its quality and the protection of the receiving mediums against the pollutant emissions; the five agencies are: Oranie-Chott Chergui, Cheliff-Zahrez, Algiers Zone-Hodna-Soummam, Constantinois-Seybouse–Mellegue and the Sahara.

- The creation of the watershed committees at the level of the five agencies made up of the representatives of the State, the local authorities and the users; they have role of formulating opinions on all the questions related to water and in particular about the appropriateness of projects and installations under consideration of the level of the influence zone of the watershed.
- The distribution of the water resource mobilised between the various potential users.
- The intervention programmes of the watershed agency.
- The revision and adoption of a new water code.
- The realisation of new stations for waste water treatment to protect water quality.
- The establishment of the national quality chart of the surface waters.
- The establishment of a cleansing tax fixed at 20 % of the invoice of consumption out of drinking water and industrial.
- The institution of a royalty of saving water whose rate varies from 2 to 4% depending on the areas.
- The creation of national funds for integrated management of water resources.

In 1993, the Ministry of Equipment, after an analysis on the situation of urban water and sanitation, initiated a large process of changing in the sector. After a large concertation with the main concerned sectors (Agriculture, Industry, local collectivities), a New Water Policy was adopted, based on four main principles:

- Water must be protected, in quantity and in quality.
- Water is a collective resource, whose use is subject to an agreement between all the users.
- Water must me managed inside a natural hydrological unit, the hydrographic basin

In 1996, five Hydrographic Basin Agencies were created, first tools of this new water policy. They are responsible for:

- Collecting data, particularly relative to hydrology and hydrogeology, to the use and quality of water, and to the existing infrastructures of the basin.
- Participating to the elaboration of regional plans for allocating the water resources.
- Sensibilisation of the consumers.
- Participating, with the help of the National Fund for Integrated Resources Management, in financing projects aiming at protecting the water resources, in the country, in quantity and in quality **(Bouchekima *et al., 2008*)**

The water crisis is essentially a crisis of governance. The causes include the absence of institutions adapted to water problems, the fragmentation of structures, divergent interests upstream and downstream with regard to the rights of riparians and access to water, and the transfer illicit public resources for private interests, as we see in our country for mineral water companies. There is as yet no agreed definition of water governance - the ethical implications and political dimensions still under discussion - but many issues affecting water management need to be taken into account. The principles of effective water governance (UNESCO, 2003) include the participation of all parties, transparency, equity, resilience, integration and ethical issues. The adoption by governments of a commercial approach similar to that of the private sector, without consulting users and without implementing measures adapted to public participation in the decision-making process, contributes to the lack of knowledge of the real demand of this vital resource. The public authorities, after having organized a national water conference in 1995, realized the need to extend the concession to the national or foreign private sector. With regard to the Water Code as amended by Ordinance No. 96-13 of June 15, 1996, five basic principles underpin the New Water Policy ; integrated management, economical management, decentralized, coordinated and unified management within the framework of the hydrographic basin, user participation in managementand and the principle of compatibility of water management with regional planning policy and environmental protection **(Maliki, 2006)**

II.5. Algeria Water Sector Actors

Main tasks of the water sector can be stated as; Knowledge of water resources and needs at different horizons; planning the development of water infrastructure necessary to meet the needs; mobilization and integrated conventional resources (surface water, groundwater) and unconventional (desalination of seawater, reuse of treated wastewater); drinking water supply and industry; irrigation in large areas and facilities for small and medium hydropower; urban sanitation and protection against flooding; and adaptation of the legal and institutional framework. The structure of the water sector falls under three categories; the Central Administration; the Authority devolved (Water Resources of the Wilaya Department (DREW)); and the public trust **(CEDARE, 2014)**

For efficient governance of the water sector, it is necessary to identify the various water stakeholders, essential tools necessary for the sustainable development of this sector through its planning institutions and information system, but also by the recognition of political, legal and financial frameworks.

The water administration, characterized by the decentralization and regionalization of public services, is summarized in an organization chart comprising:

- A central administration comprising 9 departments responsible for planning, development, regulation, general administration, regulation and human resources.
- A decentralized administration made up of 48 Wilaya Water Departments (DHW) currently Water Resources Department (DRE).
- Public institutions under supervision whose mission is to implement national water resources assessment programs and integrated water management systems at the hydrographic basin scale ; National Agency of Hydraulic Resources ANRH, Hydrographic Basin Agencies ABH and National Agency for Integrated Management of Water Resources AGIRE.
- Agencies whose mission is to develop infrastructure and manage water, sanitation and irrigation services ; National Agency of dams and transfers ANBT, Algerienne des Eaux ADE, National sanitation office ONA, National Office for Irrigation and Drainage ONID,

Algeria Water and Sanitation Company at Oran SEOR, Algeria Water and Sanitation Company at Algiers SEAAL, etc..
- Local authorities (Communal Popular Assembly APC) playing a role in the operation of granting concessions and partnership between the public and private sectors. **(Chaib Draa Tani, 2019)**

II.5.1. Regulatory actors

The regulatory actors in the water sector correspond to the central administration made up of the Ministry of Water Resources and the Environment MREE, the Ministry of the Interior and Local Communities, the Ministry of Regional Planning and environment, the Ministry of Agriculture and Fisheries, the National Consultative Council for Water Resources and the various departments (planning, regulation and human resources). However, the MREE remains primarily responsible for water policy, which it is responsible for developing and implementing. Its competence extends to all activities relating to research, operation, storage, distribution of water for all uses, and sanitation. It ensures, with the other ministries, the preservation of the quality of water resources. The National Consultative Council for Water Resources (CCNRE), within which must organize and develop consultation and coordination relations with other administrations, various economic sectors and more generally, all users **(Chaib Draa Tani, 2019)**

II.5.2. Decision-maker-operator actors

Decision-maker-operator actors are those who make decisions at the regional level of hydrographic basins and wilayas. They are appointed as managers at the level of public establishments with national competence:

- National Water Resources Agencies (ANRH): is a public administrative establishment with a scientific and technical vocation. It is placed under the supervision of the ministry in charge of water resources, and its head office is located in Algiers **(Chaib Draa Tani, 2019)**

- -Hydrographic Basin Agencies (ABH): whose mission is to implement the policy of integrated water management at the scale of large river basins. Committees attached to these agencies comprise representatives of the Administration, local and of water users. These committees are consultative bodies on all matters related to water regionally **(CEDARE, 2014).**

- Integrated Water Resources Management Agencies (AGIRE): is responsible for planning the development of water resources, collecting fees **(Chaib Draa Tani, 2019)**

- Algerienne des Eaux (ADE): is a national public institution created by Executive Decree No. 01-101 of April 2001. Its role is to ensure throughout national implementation of the national policy on water through support management activities of production operations, transport, treatment, storage, supply, distribution and supply of drinking water and industrial as well as the renewal and infrastructure development related thereto. The responsibilities can be stated as; standardization and quality monitoring of the water supply; initiate any action to save water, including; improving the efficiency of network transfer and distribution; the introduction of any technical water conservation; the fight against waste in developing information campaigns, training, education and awareness towards users; design, with public educational curriculum disseminating the culture of water conservation **(CEDARE, 2014).**

- The National Dams and Transfers Agency (ANBT): created by decree n ° 85 - 163 of 11 June 1985 with EPA status, has twenty years of experience to its credit, particularly in monitoring and implementing implementation of plans and programs decided in terms of the realization of structures for mobilization and transfer of surface water resources (Dams, Reservoirs, Large Storage Structures and Transfer Infrastructures). By virtue of article 2 of the aforementioned decree, the statute of the National Dams Agency by abbreviation "ANBT" establishment of an administrative nature, created by decree n ° 85.163 of June 11, 1985, is reorganized in its legal nature into a public establishment of an industrial and commercial nature called “Agence Nationale des Barrages et Transfers” by abbreviation “ANBT” by executive decree No. 05-101 of 23 March 2005. **(Chaib Draa Tani, 2019)**

- National Sanitation Office (ONA): is a national public institution created by Executive Decree No.01-102 of April 2001. The office aims at protection of the water environment and the implementation of the national sanitation policy in consultation with local communities. It is responsible for management and operation of sanitation facilities within its field of competence, including; any work for the sanitation of towns and particular, networks of wastewater collection, pumping stations, sewage treatment plants, sea outfalls in urban perimeters and communal areas as well as in industrial and tourism development; developing and implement integrated projects on the treatment of wastewater and stormwater drainage; manage subscribers utility sanitation; establish the cadastre sanitation facilities and ensure its updating; and develop master plans for the development of sanitation infrastructure within its field of activity **(CEDARE, 2014).**

- National Office for Irrigation and Drainage (ONID): National Agency for the Construction and Management of Hydraulic Infrastructure for Irrigation and Drainage (AGID) is reorganized in its legal nature into a public industrial and commercial establishment endowed with legal personality and of financial autonomy, called the “national office for irrigation and drainage” (ONID). Created by executive decree n ° 05-183 of 9 Rabier Ethan 1426 corresponding to 18 May 2005. The establishment is placed under the supervision of the minister responsible for agricultural hydraulics and its head office is located in Algiers **(Chaib Draa Tani, 2019)**

Table 2.2*: Summary of Water Sector Actors and Their Missions*

Water Sector Actors	Mission
DRE	-Propose, Study, Develop, evaluate and implement the national policy on water production and storage. -Initiate and oversee, within the framework of the national plan, the study and construction of structures and equipment for the mobilization and transfer of surface and groundwater. -Propose standards, regulations and operating conditions for equipment, structures and water resources (Water Code). - Initiate and carry out any action aimed at the development of unconventional water resources.
ANBT	-Provide water to distribution establishments and municipal boards in accordance with agreements made with these water distribution organizations within the framework of distribution programs set by order of the Minister in charge of water resources (ADE). -Carry out all auscultation and technical control interventions and the upkeep, maintenance, clearing and repair of water resources mobilization and transfer works in operation, according to operating instructions and standards (DRE, ADE). -Ensure the application of the water tariff to establishments responsible for the distribution of drinking, industrial and agricultural water, and to those responsible for the production of electrical energy as well as to municipal boards. -Study and develop protection, upkeep, maintenance and intervention systems on works in operation. -Maintain the state of exploitable water reserves and carry out periodic water quality control measures, as part of the management of the water resource for which it is responsible.
ADE	-Ensure throughout the national territory, jointly with the DRE, the implementation of the national drinking water policy through the support of management activities of production, transport, treatment, storage, drinking and industrial water supply, distribution and supply as well as the renewal and development of related infrastructure. -Standardization and monitoring of the quality of distributed water. -Initiate any action aimed at saving water -Plan and implement annual and multi-year investment programs (DRE).
ONA	-Ensure throughout the national territory, the protection of the water environment and the implementation of the national sanitation policy in consultation with the local communities (DRE, APC). -Project management and the operation of sanitation infrastructures that fall within its area of competence. -Fight against all sources of water pollution in the areas of its field of intervention as well as the management, operation, maintenance, renewal, extension t of any work intended for the sanitation of agglomerations and in particular, wastewater collection networks, lifting stations, treatment plants, outlets at sea, in urban and municipal perimeters as well as in tourist and industrial development zones.

	-Develop and carry out integrated projects on wastewater treatment and rain drainage. -Carry out studies and works projects on behalf of the State and local communities (DRE, APC). -Draw up master plans for the development of sanitation infrastructure falling within its field of activity.
ABH	-Manage the information system at the watershed level through the establishment and updating of databases and geographic information tools. -Contribute to the preparation, assessment and updating of medium and long-term sector development plans at the river basin level. -Collect the fees established by the laws and regulations in force. *Surface water domain: -Design, install and manage a national hydro climatological network, intended for the development of the national water balance Process, format, archive and disseminate hydro climatological data. -Conduct general methodological studies on hydro climatological regimes for the inventory of surface water resources. -Study the hydrological phenomena on the experimental basins such as erosion, runoff, infiltration and evapotranspiration. -Set up and manage a flood forecasting network. -Water resources mobilization domain. -Monitor the qualitative and quantitative evolution of resources for all of the Tafna basin. -Inventory of hydraulic structures. -Monitor hydraulic structures (collection of drilling and wells). *Field of irrigation and drainage: -Carry out an inventory of soil resources intended to be developed by irrigation and Drainage. -Determine and map, in collaboration with the National Institute of Cartography, the hydrodynamic characteristics of irrigable soils. -Study the water needs of crops as well as the irrigation and drainage perimeters intended for the development of development, irrigation and drainage projects. -Study the evolution of soil and surface water salinity in irrigated areas and provide information relating to their protection and safeguard.
AGIRE	-Carry out all surveys, studies and research related to the development of integrated water resources management. -Develop and coordinate integrated water information management systems at the national level. -Contribute to the preparation, evaluation and updating of medium and long-term sector development plans. -Contribute to the management of incentive actions for water saving and the preservation of the quality of water resources. -Carry out technical operations to delimit the natural hydraulic public domain, particularly wadis and natural water bodies.

II.6. Algeria Water Supply

The evaluation of the quantities of water to be made available to users is often set by the objectives of water endowment per inhabitant. On the other hand, the quality covers two aspects, the axis of the water itself and that of the quality of service to convey the resource according to the expressed needs. In the Algerian context, the quality of service is often measured by the distribution frequencies. However, other additional and crucial indicators could be more relevant, such as the water supply per capita, without incorporating the rates of physical losses in the networks, which remain high, or carrying out surveys among users, particularly households, because the quality of service can only be measured in terms of user satisfaction. In reality, the surveys are little used, not to say unused, which led us to take the estimates of the ADE and the delegated companies consolidated by the executives of the Directorate of Drinking Water Supply (DAEP) at the level of the MREE. At first glance, we notice a favorable evolution in the frequencies of distribution of drinking water. Thus, the daily distribution goes from 693 municipalities (45%) in 1999 to 1,156 municipalities in 2015 (75%); Within this rate, 38% of municipalities benefit from a 24-hour service and the rest benefit from a discontinuous service. The MRE (2008) exposed some examples of improvement such as the wilaya of Tlemcen (increased from 1 day / 5 to daily), Annaba (from 1 day / 2 daily) and Djelfa (from 1 day / 5 to day-to-day). Despite these improvements, the distribution of water is characterized by cuts and hourly rationing policies of the distribution which often lead to increases in household consumption. When the water service becomes irregular, the use of storage means becomes a means of dealing with the fear of water, under these conditions some users have cisterns and they carry out storage even in cities served 24 hours a day, which explains the social perception of water scarcity and the search for methods of individual adaptation to scarcity. **(Kherbache and Oukaci, 2017) (Kertous, 2010)**

The water distribution pipeline networks in Algeria extend to more than 105,000 km, with a capacity to transfer 3.3 billion m^3/year. The capacity of water storage tanks exceeds 0.7 billion cubic meters. It is worth noting that most of the water distribution network is old thus causes a high level of wasted potable water.
The Government is aware of the need to allocate adequate funding to renew and modernize the distribution systems in the country. The drinking water average connection rate is estimated as 95% (max 100% and min 80%) with per capita share of 175 L/day (max 518 L/day and min 74 L/day) **(CEDARE, 2014).**

The quality of the distributed water is another axis of the quality of service. It constitutes a black spot in the drinking water policy in Algeria. The quality of the water supplied is a major concern of subscribers who are reluctant to consume tap water. They have developed a capacity for individual adaptation. In Bejaia for example, while users are reluctant to pay for water distributed by ADE and heavily subsidized, they find themselves forced and forced to look for water vendors who roam the neighborhoods and sell water so-called from Toudja of better quality than that delivered in their taps **(Kherbache and Oukaci, 2017)**

The water services are financed by two main means; the State grants for new investments and infrastructure development, user fees paid directly to ADE, which, in turn, distributes it back to the different public companies involved in the water sector to cover operation and maintenance costs. The water pricing is set by the state. A decree (Decree 05-13 of January the 9th, 2005) determines the rules for pricing of public services of water supply and sanitation and related prices. Drinking water pricing are set according to public service costs of water supply and its distribution among different categories of water consumers. Categories of users include: - Households (Category I) - The government, artisans and services sector (Category II) - The industrial and tourism units (category III).
Price in DA/m^3/trimester for Category I is 6.3 (for up to 25 m^3/month), 20.48 (from 26 to 55 m^3/month), 34.65 (from 56 to 82m^3/month), and 40.95 (more than 82 m^3/month), Category II is 34.65, and Category III is 40.95 $1 US Dollar equals 79 Algerian Dinar, DA in 2005 **(CEDARE, 2014).**

II.7. Algeria Sanitation

The volume of wastewater discharged currently is estimated at more than 750 billion m^3 and will exceed 1.8 billion m^3 by 2030. In order to deal with purification wastewater potential, the water resources sector started an ambitious construction program of wastewater plants treatment WWTP. Exploited wastewater plants are actually divided on 50 WWTP and 50 lagoons with capacity of about 570 hm^3/year. In 1999, 128 WWTP were identified with treatment capacity of 98 million m3/day. The program underway includes 176 treatment plants (87 WWTP and 89 lagoons). The installed capacity is about 355 hm^3/year. The total installed capacity after the completion of this program will be 925 million m^3/year, which is equivalent to 10 medium dams. The treatment and quality of water in Algeria is closely related to socio-economic and sustainable development. Reliable identification of water treatment problems and reuse can better protect this resource and integrate it effectively into the food safety agricultural production process **(Bouchentouf and Benabdeli, 2021)**
The length of the sanitation national network is experiencing a significant improvement; due to the implementation of the sewerage network program of achievement throughout the country. Sewerage networks evolved from 21,000 km in 1995 to 41,000 km in 2010 with branching ratios/rates of connections increasing from 79% to 86% from 1995 to 2010. With the achievement of approximately 1,500km of collectors per year, the national total sanitation network by 2020 will be 54,000 km. The annual volume of wastewater discharged is estimated at about 1.2 billion m^3. The water resources sector has launched a very ambitious program for wastewater treatment plants. Several stations are currently underway or being rehabilitated and others will be launched. Sewage treatment plants are managed for two years by the building operators and by ONA with a training program to ensure continuity of service **(CEDARE, 2014).**

Reuse of wastewater is an essential element of development, as it provides a sustainable alternative water resource, the reduction of pollution of the environment and the protection of public health. The main motivation for several countries to embark on wastewater reuse projects is recycling for a quantitative purpose, particularly in arid and semi-arid regions.

Algeria's interest in the reuse of wastewater in irrigation is due to the sharp rise in water requirements. Rains and dam's waters and boreholes will no longer suffice for the satisfaction of needs, which explains today, the ambition of Algeria to treat one billion cubic meters of wastewater for the irrigation of 100,000 hectares **(Chikh *et al.*, 2018)**

The reuse of treated wastewater, especially for agricultural purposes, has become one of the main strategic axes of the water resources sector in Algeria. Recognizing the urgency in construction and renovation of sewerage networks and wastewater treatment infrastructure, a council of ministers was consecrated in 2004 exclusively to discuss sanitation which has been seriously considered. It was decided to launch 158 new wastewater treatment infrastructures projects in different integrated programs for a total amount exceeding 2.8 billion USD. Since then, 134 treatment plants has been built with an installed capacity of about 12 million Equivalent inhabitant EQH or 800 hm^3/year compared to a volume of discharged water estimated at 1.4 billion m3/year. A consequent part of the purified volume is reused for irrigation. By 2025, 56 other stations will be received, which will bring the number of treatment plants to more than 200, including 12 intended to coastal protection. As an example, we can cite the El-Karma station in the region of Oran (administratively named Wilaya) planted on an area of 8,100 ha, whose treated waters are used in agricultural irrigation of the Melata plain located in the south of Oran region.

In fact, national strategy in terms of treated wastewater exploitation for irrigation purposes consists in contributing to extension of irrigated lands, increase of agricultural production, and preservation of surface and underground water resources. Reuse of treated wastewater constitutes a priority axes in water sector strategy. The objective would be to irrigate more than 100,000 ha lands by treated wastewater over 2030 horizon. It should be noted that National Exceptional Program PNE estimates reuse of treated wastewater in 2030 at 600 hm^3 as a weak hypothesis and 1.2 km^3 as strong hypothesis **(Bouchentouf and Benabdeli, 2021)**

The wastewater services are financed by two main means; the State grants for new investments and infrastructure development, user fees paid directly to ADE, which, in turn, distributes it back to the different public companies involved in the water sector including ONA to cover operation and maintenance costs. The Sanitation price is set on the basis of public service costs of sanitation and its distribution among different categories of users and water consumption bands corresponding to the volume of water supplied to public service users of drinking water. In general, sanitation is included in water bill as 80% of bill and the basic price in DA/m3 is 6.3 in Algiers, Oran, Constantine, 6.1 in Chlef, and 5.8 in Ouargla, (1 $Dollar equals 79 Algerian Dinar, DA in 2005) **(CEDARE, 2014).**

II.8. Algeria Water Financing

For a long time now, investments in the water sector have been financed by final state aid due to lack of user participation. In fact, the debt financing of local authorities was stopped in the late 1960s. Algeria has experienced a real "Marshall plan for water" since 1999, to the point that some have announced that the battle for water has been well won, thus making it possible to overcome the economic water scarcity that Algeria has experienced for long decades. Note that the concept of economic water scarcity is an indicator used by the International Water Management Institute (IWMI) to measure water scarcity.

Today, Algeria's water sector takes the lion's share of all public development and equipment programs. It should be noted that the financing of infrastructure and water mobilization works in Algeria comes from the state equipment budget. This has two elements namely the investment budget and the capital operations. For each specific development program, a Special Treasury Accounts is attached. We have distinguished five Special Treasury Accounts which participate, or have participated, in the financing of water in Algeria, which we have drawn from the nomenclature of the treasury accounts (2012):

•Account No 302-108: "Account for the management of public investment operations registered under the economic support and recovery program (PSRE) (2001-2004)" with an envelope allocated to the water sector of 4.386 billion DZD (equivalent to US $ 57.52 million).

• Account No 302-120: "Management account for public investment operations registered under the additional growth support program (PCSC 2005-2009)". This account managed more than 13% of the resources allocated to the water sector of this program, ie 1,820 billion DZD (approximately 25.92 billion US $).

• Account No. 302-116: “Special Fund for the Economic Development of the Highlands (FSDRHP)” with an envelope of 43.2 billion DZD (594.87 million US $) dedicated to the sector.
• Account No. 302-089: "Special Fund for the Development of Southern Regions (FSDRS)" with an amount for the water sector 80 billion DZD (1.152 billion US $).

• Account No. 302-134: "Fund for the management of public investment operations registered under the program for the consolidation of economic growth (PCCE) 2010-2014 "with more than DZD 2,000 billion for the water sector (or US $ 26.731 billion). **(Kherbache and Oukaci, 2017)**

It is therefore easy to understand why we are talking about a "Marshall plan for water" in Algeria during the period 1999-2012. The improvements, although significant in terms of infrastructure and project achievements, remain mixed and far from commensurate with the financial effort made. Indeed, budgetary authorizations have evolved remarkably to reach a peak of US $ 7.333 billion (DZD 535.5 billion) in 2011.
The period from 1999 to 2012 has been qualified as a period of "hydraulic catching up" in Algeria given where it has been observed an increase in budgetary authorizations for the water sector, a favorable evolution of connections to the networks of the drinking water and sanitation, an increase in equipped and irrigated areas and the equipped agricultural area reached 230,000 ha in 2015 while it was 156,000 ha in 1999 (an increase of 47.43%), the number of wastewater treatment plants increased from 12 stations in service in 1999 to 177 in 2016, the number of dams reached 75 dams in operation at the start of 2016 against 47 dams in operation in 1999 , institutional reform and reorganization of water institutions, etc.
The diversification and redistribution of investments in the agricultural sector will result in a significant increase in agricultural products transformed into differentiated products with high

added value. Investment in the agricultural sector also improves agricultural productivity and relates to the development of agriculture business and agro-industries. In case of Algeria, a quota of 35% is recommended for water resources mobilization, 20% for extension of orchards and vineyards, 10% for the development and renovation of productive potential, 15% for intensification of strategic crops, 10% for agricultural land development and lastly 10% for training, research and vulgarization actions. Additionally, the primordial element which is at the base of the development of agriculture is Man. Thus, development can only be achieved through the strengthening and consolidation of human potential. Therefore, investments in various fields, health and education are the best guarantees of increasing the real potential of the rural population. **(Bouchentouf and Benabdeli, 2021)**

The improvements that were observed in water and sanitation services in Algeria were the result of a proven effort in terms of financing and equipment and investment projects. Thus, within the framework of this largely budget-intensive policy, priority sub-sectors have benefited from significant envelopes including the Drinking Water Supply DWS / adduction which is positioned at the top throughout the period of the study (between 1999 and 2012). With the objective of detecting the place of this segment and the economic cost of the favorable development of drinking water indicators, we highlight the annual distribution of payment credits, absorption rates and the share of sub-sector in relation to total budget allocations. The right of access to water and sanitation is enshrined in Law No 05-12 (article 3). From this principle results an objective of prioritizing domestic needs. In other words, the water supply through the mobilization and distribution of water in sufficient quantity and in the required quality is done as a priority for the needs of the population and the watering of the livestock. To achieve this, the commitment of a large-scale investment policy is of colossal importance. Most of the budgetary allocations allocated to the sector have been allocated primarily to the mobilization of drinking water and the extension of water distribution networks **(Kherbache and Oukaci, 2017)**

II.8.1. Pricing System for Water Supply and Sanitation Services

The state-regulated tariff system is based on three principles :

- The principle of tariff escalation according to consumption brackets;
- The principle of selectivity of tariffs according to the categories of users (service households, industries and tourism);
- The principle of solidarity between users to guarantee access to water corresponding to the basic needs of households (social section invoiced at the basic rate).

The pricing of the public drinking water supply service is based on the principle of escalation of tariffs according to user categories and consumption brackets in order to, on the one hand, to ensure to domestic users the supply, at a social rate, of volumes sufficient to meet basic needs and, on the other hand, to regulate demand corresponding to high consumption.

The application of this principle results in the establishment, for each tariff zone, of progressive scales by categories of consumers **(Chareb-Yssaad)**

The water law in Algeria establishes the principles, legal regimes and applicable rules for the use, management and sustainable development of water resources, as a good of the national community. This law also specifies the management methods as well as the pricing of water, sanitation and agricultural water services. The 48 wilayas (departments) in Algeria are divided into five tariff zones and each zone has its basic tariff for drinking water and sanitation (Table II.3.) (Art. 137). Zones 1, 2 and 3 bring together the departments of northern Algeria; they have the same basic tariff for drinking water and sanitation. Zone 4 includes a few departments in the West which have a lack of water resources, on the other hand, the departments of the South (Sahara) are grouped in zone 5.

The water distributed to subscribers is billed according to a progressive tariff schedule with several quarterly water consumption brackets (Table II.4.). According to Table II.4, the pricing of drinking water and sanitation in Algeria is based on two principles: i) the definition of three categories of users (domestic, industrial, commercial) and four consumption brackets water for domestic users, ii) progressive pricing for households according to the quantities of water consumed **(Boukhari and de Miras, 2019)**

Table 2.3 : *Water Tariff Scale According to Territorial Zone in Algeria* **(Executif Decret n°05-13 of 9 January 2005)**

Territorial Tariff Zone	Covered Wilayas	Basic Water Tarrif DA/m^3	
		Potable Water	**Sanitation**
Algiers	Algiers-Blida-Médéa-Tipaza-Boumerdes-Tizi Ouzou-Bouira-Bordj Bou Arreridj-M'sila-Bejaia-Sétif	6.30	2.35
Oran	Oran-Ain Temouchent-Tlemcen-Mostaghanem-Mascara-Sidi Bel Abbes-Saida-Naâma-El Bayadh	6.30	2.35
Constantine	Constantine-Jijel-Mila-Batna-Khenchela-Biskra-Annaba-El Taref-Skikda-Souk Ahras-Guelma-Tebessa-Oum El Bouaghi	6.30	2.35
Chlef	Chlef-Ain Defla-Rélizane-Tiaret-Tissemsilet-Djelfa	6.10	2.20
Ouargla	Ouargla-El Oued-Ilizi-Laghouat-Béchar-Tindouf-Adrar-Tamanrasset	5.80	2.10

In Algeria, the billing is established on the basis of the tariff schedule by tariff zone territorial. It consists of two elements: **(Boukhari and de Miras, 2019)**

- A variable part, in an amount proportional to the volume consumed during a given time and measured at particular counter;
- A fixed part known as the fixed subscription fee, of a amount covering all or part of the maintenance costs of the particular connection, rental and maintenance of the water meter and commercial management of users, whose rates are as follows: 240 DA per quarter for drinking water and 60 DA for sanitation.

Added to this is :

- The management fee set at 3 DA/m^3 consumed;

- The "water saving" and "protection of the water quality ": the rate is 8% for the wilayas of North (4% for each fee) and 4% for southern wilayas (2% for each royalty);
- Value added tax (VAT): 9% applied to "water" products.

ADE only benefits from almost 60% of the water bill, and the 40% is for to ONA and other water bodies in the form of royalties.

Table 2.4: *Water Tariff According to Categories* **(Executive Decree n°05-13 of 9 January 2005)**

Users Categories	**Quarterly Tranche Consumption**	**Multiplying Coefficient**	**Applicable Tariff (North Zone)**	
			Water DA/m^3	**Sanitation DA/m^3**
Category I : Households				
1st Tranche*	< 25 m^3/trimester	1	6.30	2.35
2nd Tranche	From 26 to 55 m^3/trimester	3.25	20.48	7.64
3rd Tranche	From 56 to 82 m^3/trimester	5.5	34.65	12.93
4th Tranche	> 82 m^3/trimester	6.5	40.95	15.28
Category II : Administrations, Artisans, and Services of Tertiary Sectors	Uniform	5.5	34.65	12.93
Category III : Industrial and Tourist Units	Uniform	6.5	40.95	15.28

*1st Tranche = Social Tranche (≤ 25 m^3/trimster) billed as the base tarriff 100 DA = 0,62 €

The gradual shift towards integrated water resources management during the 2000s strengthened the role of River Basin Agencies. They are responsible, among other things, for setting up "information and awareness-raising actions for domestic, industrial and agricultural users with a view to promoting the rational use and protection of water resources"

The role of ABHs should be strengthened in this area in order to give them clear and strong powers on this subject.

Fair pricing of water seems to be an effective way to encourage users to adapt their consumption to their needs. The decrees of 2005 and 2007 underline that the new water pricing is now based on the principle of covering the real costs of the water service by charges paid by users. In reality, this requirement is difficult to apply and the Ministry of Water Resources is slow to reassess the tariff bases in this direction, both for domestic and industrial uses, but also for agricultural use. The lack of social acceptability by users of an increase in the tariffs for access to the water service partly explains this situation. Several specialists recognize that water sold at 10% of its price does not lead to rational use of the resource. If in the collective unconscious it is often admitted "that water is a gift from the sky", the mobilization, storage, transfer, production of drinking water and the distribution of water nevertheless require significant financial commitments.

Algerian national law defines water as a "good of the national community" and its management is a legally framed public service regardless of the strategies developed for one or another mode of exploitation or governance. The declared desire for a progressive tariff system (progressive scales per bracket and per user18) and unified across the whole of the national territory raises the question of financing, long eluded because of resources from hydrocarbon exports. Water officials believe that users will not pay the right price for water until the services are qualitatively and quantitatively satisfactory.
In terms of managing the demand for agricultural water, Algeria is struggling to put into practice the discourses developed on the issue and to fit into the dynamic spurred by international meetings and recommendations. Among the 400 or so hill reservoirs in the country, only one (in Constantine) has an association of irrigators. Most often, farmers refuse to participate in the collective management of water resources because of the cost involved. This limitation of the participation of farmers and cooperatives in resource management does not encourage responsible and participatory practice **(Mozas and Ghosn, 2013)**

II.9. Water and Food Security

Water controls food security and good nutrition in a variety of ways. It is the lifeblood of ecosystems, including forests, lakes, and wetlands which represents basis of food security and nutrition to the present and future generations. Water is necessary for all activities and processes related to the food system. According to Codex Alimentarius (CODEX Committee on Food Hygiene, 2000), drinking water is considered as food. For food self-sufficiency, about 2.5 m^3 per inhabitant per day is needed; representing 912 m^3 per inhabitant by year, which is not the case with Algeria since the average endowment is only 400 m^3 per inhabitant per day. Looking to this chronic deficit, Algeria imports more than 17.31 billion m^3 per year as virtual water through food products which would also exceed potentials and exploitable volumes. Algeria displays in particular a desire to better exploit its agricultural potential to reduce dependence and food bill of the country while adapting to hydro climatic constraints.

In the context of food security, Algeria adopted The National Agricultural and Rural Development Plan, giving priorities to the reconversion or adaptation of cropping systems to pedoclimatic conditions. The Algerian policy to improve agricultural production is also based on the development of land, increase of the useful agricultural surface and the reinforcement of investments which still remains poorly supported and thought.
Algeria imported during the last ten years more than 4 million tons of food products, mainly cereals, milk, juices and fruits. The average amount of this bill is about 9 billion USD. The average moisture content of these products fluctuates between 15 and 20%, which represents an average of 600,000 tones. In multiple reports, the World Bank has shown that more than half of the food calories consumed in Algeria are imported **(Bouchentouf and Benabdeli, 2021)**

II.10. Sumary of Literature

In Algeria, even when not taking global climatic change into account, water scarcity is an important problem with acuity in many areas of the country. Since the seventies, dryness prevails in an intense and persistent way. The impact on the water resource already appeared through, the reduction in the rivers flow, the low level of filling dams and the global fall of the piezometric level of the principal country aquifers. In the future, the current deficits of the water resources will increase. This will lead to obvious problems of management and strategy to ensure a durable development for the country.

In the Sahara region, i.e South of Algeria, there is a large amount of groundwater. It represents non-renewable resources of brackish waters, which are contained in huge reservoirs of the two sedimentary basins: the Continental Intercalary and the Complex Terminal aquifers.

The need for good water governance will be essential if we really want to effectively manage this scarce resource while protecting poor households who do not have the financial means to pay an increasingly expensive bill.

The new water policy in Algeria focuses only on a market model which only privileges cost coverage. It is important to acquire a true understanding of the particular problems in this sector, which supposes the realization of a certain number of surveys at the household level in order to accompany this new water code by strategies to fight against poverty and ensure coordination of social policies. The Algerian paradox states that even non-poor households encounter difficulties in accessing, supplying and billing water, which raises the problem in a more global context.

Finally, it should be noted that water is not only the question of today but it is the first question of tomorrow!

CHAPTER 3: Study Area

III.1.Presentation of the Urban Group of Tlemcen

The wilaya of Tlemcen is located in the far west of Algeria, it is limited geographically in the North by the Mediterranean Sea, in the West by the Kingdom of Morocco, in North-east and east by the wilayas of Ain-Témouchent and Sidi Bel-Abbès, and to the south by the wilaya of Naâma. The wilaya of Tlemcen currently includes and since the division administrative office in 1991, twenty daïras and fifty-three communes including the capital of the wilaya is Tlemcen. It extends over an area of 9061 km². The territory of the wilaya of Tlemcen is made up of a set of natural environments that follow one another roughly parallel way. We distinguish from North to South: the mountain range of Traras, the plains and plateaus limited to the south by the mountains of Tlemcen and finally the area steppe that extends to the borders with the wilaya of Naâma **(Kherbouche and Soufi**, **2016)**

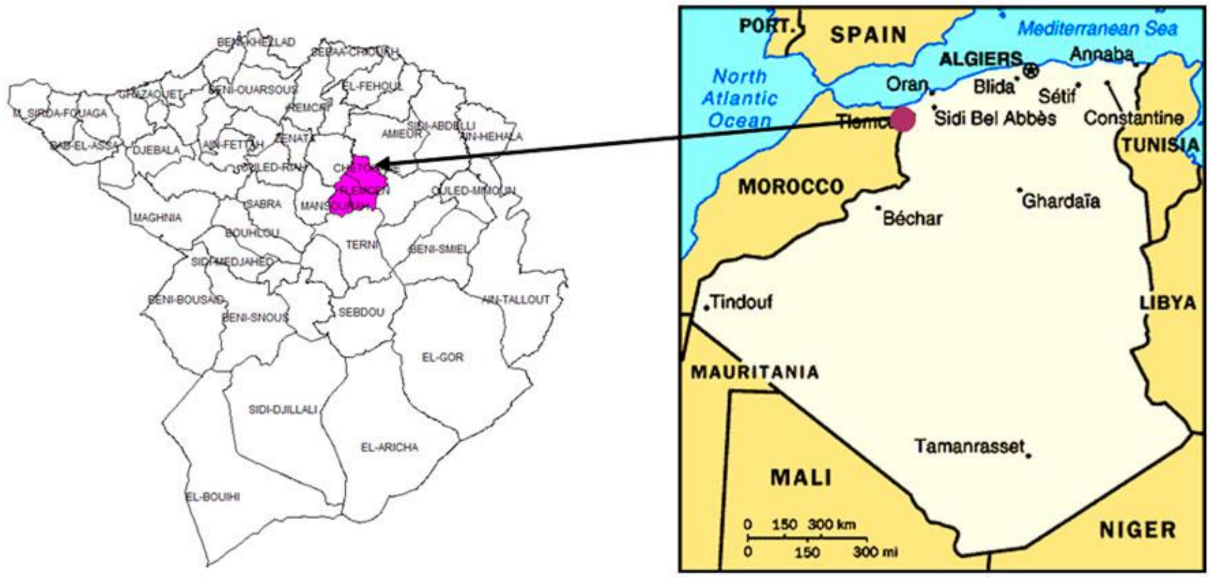

Figure 3.1: *Urban Group of Tlemcen (Tlemcen, Chetouane, Mansourah)* **(*Abdelbaki, et al., 2014)***

The grouping of communes of Tlemcen, Chetouane, Mansourah, occupies approximately 11,220 hectares constituting the interior basin of Tlemcen. It is defined by the limits of the commune of Hennaya to the north, and of Amieur to the north-east, to the east by the commune of Ain Fezza. In the South by the municipality of Tirni Beni Hadjel, In the South-West by the municipality of Sabra, The West by the municipality of Ouled Ryah, and In the North-West by the municipality of Zenata.

The mountains of Tlemcen correspond to a vast area of 300 km^2 where very karstfied carbonate rocks emerge (80%). They are sufficiently watered (500 to 800 mm / year) and infiltrate 200 to 400 mm / year. These groundwater constitute the main underground reservoir in western Algeria **(Benladghem, 2017) (Abdelbaki and Boukli Hacène, *2007)***

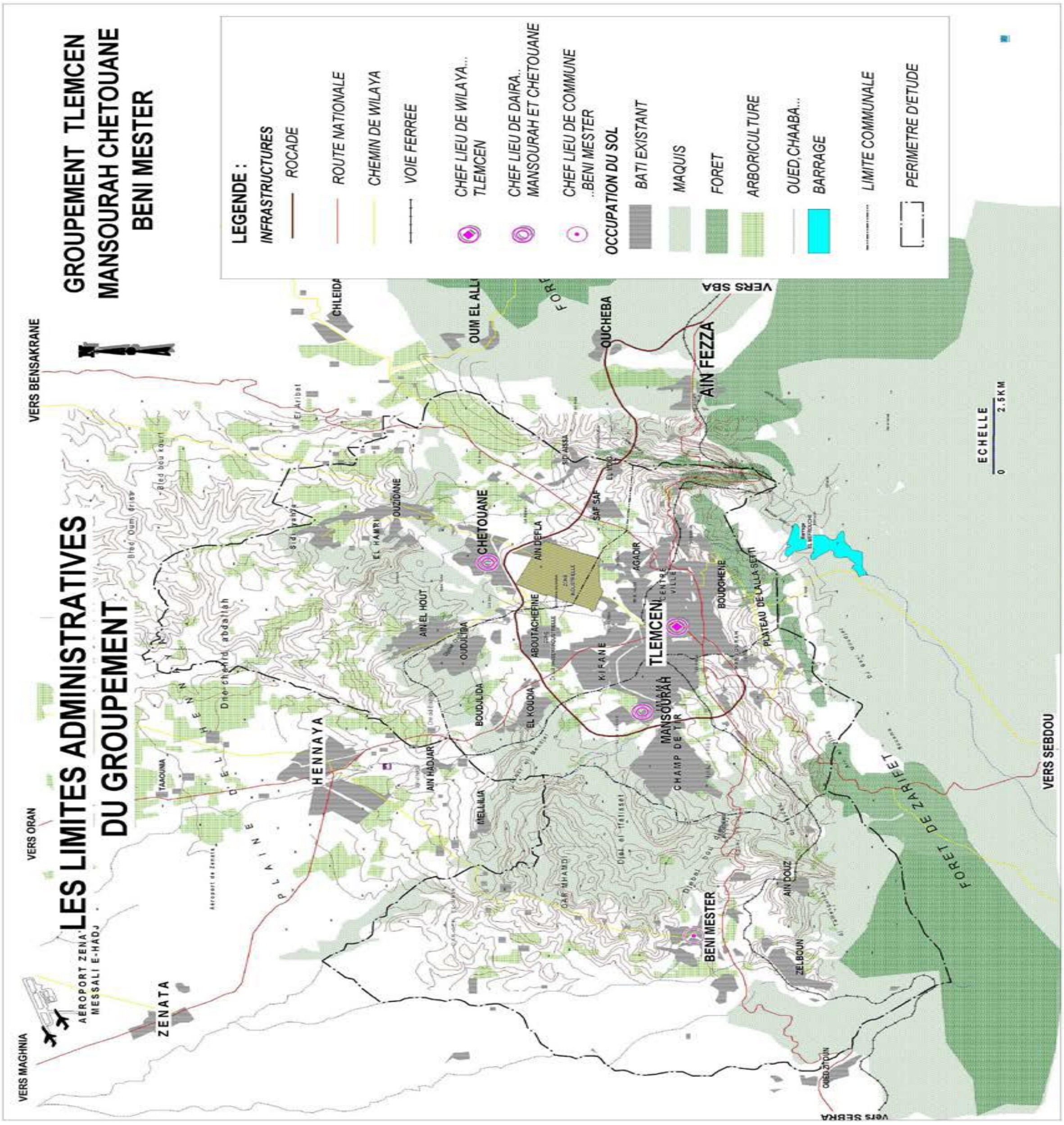

Figure 3. 2: *Actual Limitation of the Group* ***(Smail, 2017)***

Chetouane is located in the center of the wilaya of Tlemcen about 5km northeast of the city center, the town represents the northern part of the agglomeration of Tlemcen, it is made up of the following localities: Ouzidan - Ain El hout - Ain defla - saf-saf - Medigue - Sidi Aissa - Oudjlida - Boudjlida - Koudia - Domaine Hamadouche **(Mestar and Benaouda, 2018)**

The study area is the locality of Boujlida which is located north of Kudia, south of Ain El Hadjar, and east of Oujlida. It constitutes a new urban center established over a total area of 105 hectares and endowed with major housing projects, necessary amenities and green spaces. It is an urban pole which is an expansion of the city of Tlemcen. The Boujlida region is a fairly rugged region with very steep slopes ranging up to 20% (ADE Tlemcen), its altitudes vary between 550 m to 620 m.

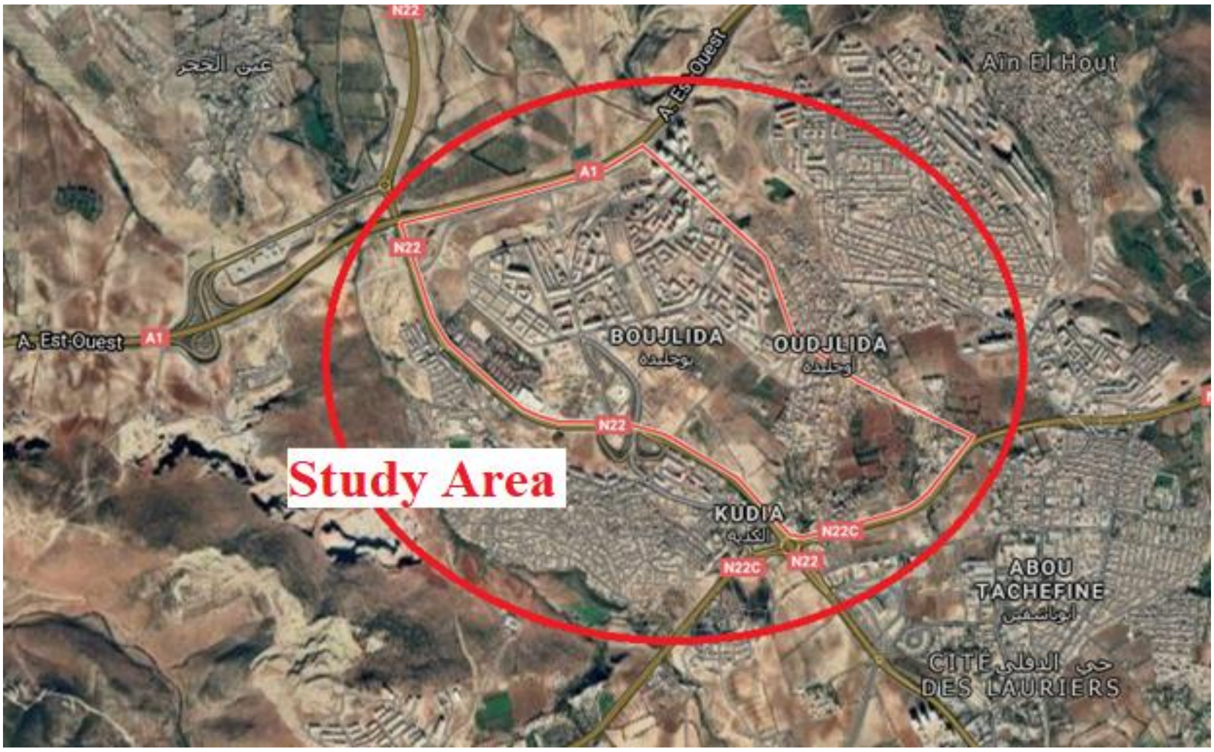

Figure 3.3: *Study area of Boujlida*

III.2. Climatology

Algeria's climate is sub-humid Mediterranean characterized by a rainy period ranging on average from September to May and a dry and sunny summer (ranging from May to September). Thus, the Urban Group of Tlemcen (UGT) belongs to this semi-arid climate zone **(Bouanani, 2004)**. The annual precipitation distribution shows a period of rain that extends from October to April with a peak in January. Annual precipitation fluctuates between 500 and 800 mm. The average rainfall calculated is 560 mm / year, temperatures averages vary between 5 ° C in January and 34 ° C in August **(Bensaoula, 2007)**

Rainfall varies greatly from one year to another and subsequently complicates the management of this resource. The Tlemcen, Mansourah, Chetouane and Béni Mester group enjoys a complex rainfall regime influenced by the Mediterranean climate characterized by a rainy season (September to May) and a dry summer. The rainfall is a function of the altitude; it is relatively abundant with a significant inter-annual variation. The potential evapotranspiration is very important. The amount of water that remains available for runoff and deep infiltration reaches 100 m/year. Winters are therefore quite severe with wind, snow and frost and also precipitation in the form of snow is frequent at the altitudes **(A.N.A.T., 2016).** Each year, Tlemcen Mountains receive the heaviest rainfall in western Algeria, enabling them to supply drinking water to a number of towns in the region. On the other hand, precipitation decreases when heading south **(Berrahma, 2009).**

III.3. Geology and Hydrogeology

The Urban Group of Tlemcen is located at the foot of mountains of Tlemcen, it is characterized by a complex and diverse geology. So there observes a succession of formations dated from Primary to Quaternary. It is between the horsts of Ghar Rhoubane in the west and the Tiffrit Pier to the east. It is made up of lands of Upper Jurassic and Eo-Cretaceous age. The Lias and the Middle Jurassic only outcrop in the western part, on the other hand the Triassic appears only in favor of dia pyric structures. North of the mountains of Tlemcen, the Jurassic is very quickly buried under thicknesses important mainly marly Miocene **(Bensaoula *et al.*, 2005).**

In the mountains of Tlemcen, the Plio – Quaternary deposits are only present in the ditches collapses and depressions, such as the Sebdou ditch and the Terni plateau. In the Miocene basin, only Tortonian sandstones and Plio-Quaternary conglomerates are aquifers and feed a few low flow sources. The only levels interesting are the calcareo dolomitic formations of Tlemcen and Terni **(Abdelbaki, 2014)**

According to **A.N.A.T (2016)** The Tlemcen Mountains and their foothills constitute the main mountainous relief in western Algeria. Fairly well exposed to maritime influences. Their surfaces are largely made up of outcrops of limestone and especially dolomite from the Upper Jurassic. These are well karstified and the volumes of water that infiltrate them are therefore quite considerable, constituting the main underground water resource in western Algeria.
The many tectonic episodes that have followed one another since the end of the Cretaceous have led to the fragmentation of the rigid ensemble of Jurassic rocks determining a set of horsts and grabens with North 50 ° to 70 ° East orientations.
The rejection of large faults which delimit them is often sufficient to isolate aquifer compartments from one another. The setbacks (North 20 °, East and North 100 ° East) and that of erosion have further accentuated the fragmentation of hydrogeological units and we are thus in the presence of a multitude of independent aquifers drained towards very many sources and which are therefore most often difficult to identify and map.
However, among all the geological formations characterizing the grouping, only the following formations are considered to be permeable:

- The dolomites of Tlemcen and the limestones associated with them
- The tortonian sandstones
- The sandstones of Boumèdiene to a lesser extent. **(Benladghem, 2017)**

The limestones and dolomites of the Kimmeridgian and Tithonian form the largest part, in the North and in the South, these formations are masked by a thick Neogene sedimentation represented by Miocene marls and the continental deposits of the middle and upper Eocene. Large accidents favor a structure in panels particularly arranged in horst and graben (example: zone of Tlemcen), the contacts between Jurassic and Neogene are made by fault particularly in the northern limits **(Bensaoula, 2006).** The existence of marl-limestone from Raourai (above the formation in process of karstification) prevents the water from going deeper and favors the establishment of a system of underground drains **(Benladghem, 2017)**

The tortonian sandstones admit a permeability of cracks and interstices, from these rocks emerge a few small sources some low importance sources (**Bouazzi, 2016)**

Boumèdiene sandstone does not drain much water. However, they present sandstone beds which are quite powerful interspersing in the marls and are considered interesting because these rocks have joints which increase their permeability.
Thanks also to fault sets, they can apparently give rise to large sources which are in fact fed by calcairo-dolomitic impluviums. The sandstones only play the role of a filter screen.
In fact, the role of these sandstones is to maintain, thanks to the marly levels, the acquired level of the Upper Jurassic **(A.N.AT 2016)**

The Tlemcen Mountains are often called the natural water tower of Western Algeria. They occupy the central part of the wilaya and represent 28% of the total area. These formations are largely karstified and constitute the most important aquifers of the wilaya of Tlemcen. The karst water resources of the Monts de Tlemcen constitute the most mobilized water resource, which largely supplies the population of Tlemcen. In fact, the municipalities with the best drinking water supply are those fed from the karst resources in question. The municipalities of the central part of the wilaya, for example, the UGT which includes a population of more than 230,000 inhabitants, is supplied by water resources which are 65% of karst origin **(Bensaoula *et al.*, 2012).**

III.4. Drinking Water Supply

Tlemcen's water supply depends on the water extracted from 20 groundwater wells, eight natural founts and the three reservoirs Meffrouche, Sekkak and Béni Bahdel. For 25 years, rainfall has been decreasing significantly leading to a diminished inflow to the reservoirs. Consequently the city's water supply heavily depends on groundwater resources. Constant overexploitation over the past few years is evidenced by sinking groundwater levels. The extracted water is stored in more than 37 water tanks. The distribution network is divided into 24 sectors but connections between sectors exist **(Cembrowicz *et al.*, 2004).**
Several underground sources are captured and many boreholes have been drilled to meet UGT's drinking water needs. Groundwater is exploited in order to increase the volumes of surface water, in deficit to meet needs. Thus, three sources (upper Fouara, lower Fouara and Ain Bendou), and thirty-four boreholes (including 23 operational) have been put into service by the Algerienne des Eaux (ADE) since 1984 (**Belmahi and Amiri, 2018)**
The current situation of water supply and irrigation in the wilaya of Tlemcen remains difficult: unequal distribution of resources and distribution, major risk of deficits important in the event of prolonged drought, limited irrigation ... .This situation should improve in the future **(Bouazzi, 2016)**

The constraints encountered are related to **(Alinehari, 2013):**

- Rainfall and its random nature;
- The existing imbalance between water resources at the wilaya level;
- The recurrence of the phenomenon of drought in time and space;
- Pollution and the quality of water resources;
- Overexploitation of groundwater.

Indeed, these constraints have led the public to be cautious with regard to all these uncertainties and led them to redefine a water strategy based on the need to use a water resource free from these constraints and in particular that of the climate (seawater desalination) **(Bouazzi, 2016).** The Urban Group of Tlemcen is supplied from the Desalination plant of Souk Tlata and Honaine. This production will be consumed at the level of the western corridor of the wilaya (Maghnia, Bab El Assa, Marssa Benmhidi, Ghazaouet and Nedrouma). The supply of these municipalities is reinforced by the Beni Bahdel dam **(Belmahi and Amiri, 2018)**

III.4.1. Drinking Water Supply of Boujlida

The drinking water supply to Boujlida is from the reservoir of Koudia (5000m^3). The reservoir is supplied by:

- The Honaïne desalination plant with a ductile iron pipe 200 mm in diameter in most of the time.
- The Sekak dam with a ductile iron pipe with a diameter of 400 mm when the Honaïne desalination plant is shut down.

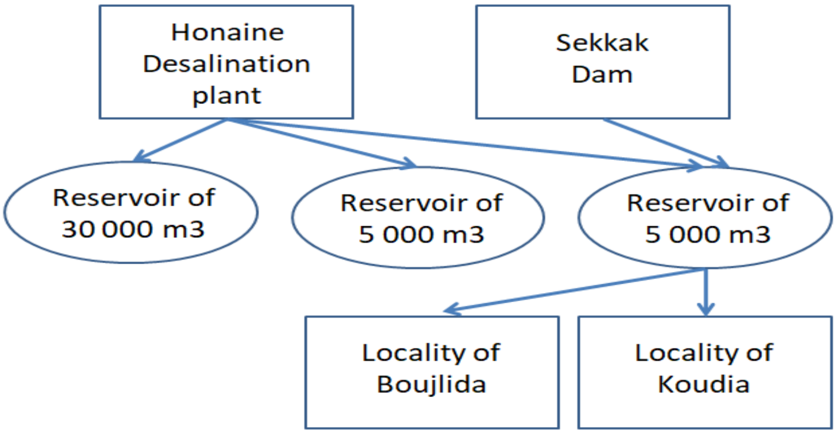

Figure 3.4: *Schema of the drinking water supply of Boujlida*

III.4.1.1.Sekkak Dam

This dam was originally intended for the agricultural development of the plains of Hennaya and El Fehoul. Upon completion of the work, the supply to ensure the transfer of water to the UGT was installed. The volumes of pumped water are not very important 7 HM^3/year. As the drinking water supply of the populations is a priority, the water has been partially or totally diverted for this purpose. The rainfall deficit and the increase in population are the main factors which have led to this reallocation. The concern of the local authorities to ensure an acceptable daily water supply to the inhabitants is a factor not to be overlooked. Indeed, there are many localities in the wilaya of Tlemcen where the daily allowance does not exceed 100 l/d/inhabitant **(Bensaoula and Adjim, 2008)**

III.4.1.2. Honaine Desalination Plant

The 'Honaïne' seawater desalination station, is the second desalination station started in 2006 by the Spanish group GEIDA (made up of the companies COBRA, SADYT, BEFESA and CODESA), was operational in July 2012, with a investment amount of $ 250 million. In North-West Algeria, the Wilaya of Tlemcen has been the subject of the installation of a seawater desalination station, in the region of 'Honaïne'. Its production capacity is 200,000 m^3/d, ensuring the supply of drinking water to 24 municipalities as well as the UGT, ie a population of approximately 555,000 inhabitants (**Benladghem, 2017)**

Table 3.1: *Coordinates of the reservoir supplying Boujlida*

Reservoir	Capacity (m^3)	Geographic Coordinate	X (m)	Y (m)	Z (m)
Koudia	5 000	34°54’09’’N 1°21’40’’W	649698.38	3863142.31	738

Figure 3.5: *The location of the reservoir supplying Boujlida*

The drinking water supply network in our study area is a mixed network, with the following particularities:

- Primary network already existing in High Density Poly Ethylene HDPE to which several networks are attached secondary in HDPE too (the area is expanding rapidly). Its total length is around 20 km (secondary networks included).
- All networks are built in HDPE with different standard diameters ranging from 40 mm up to 400 mm.

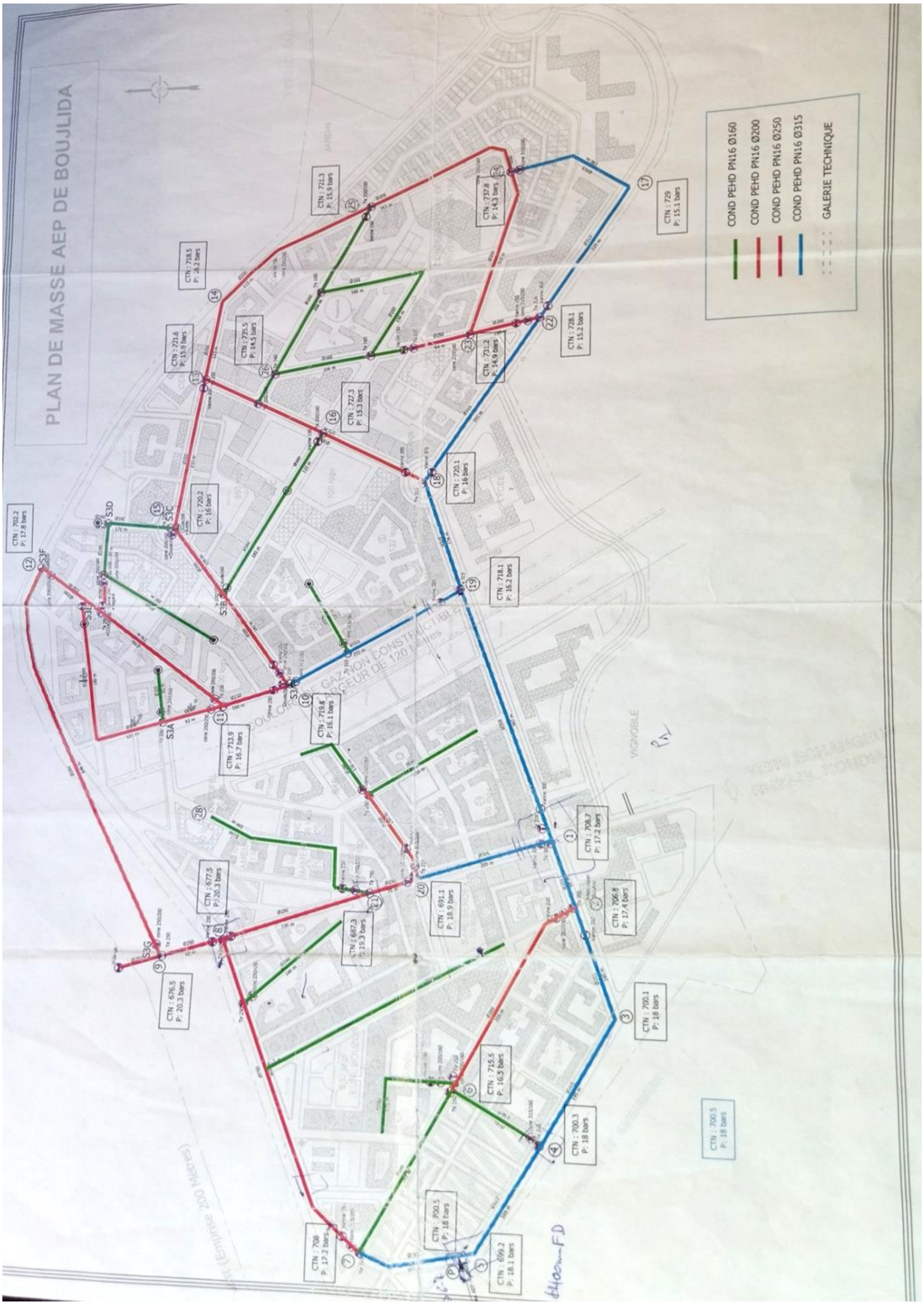

Figure 3.6: *The plan for the water supply network for Boujlida* (**ADE**)

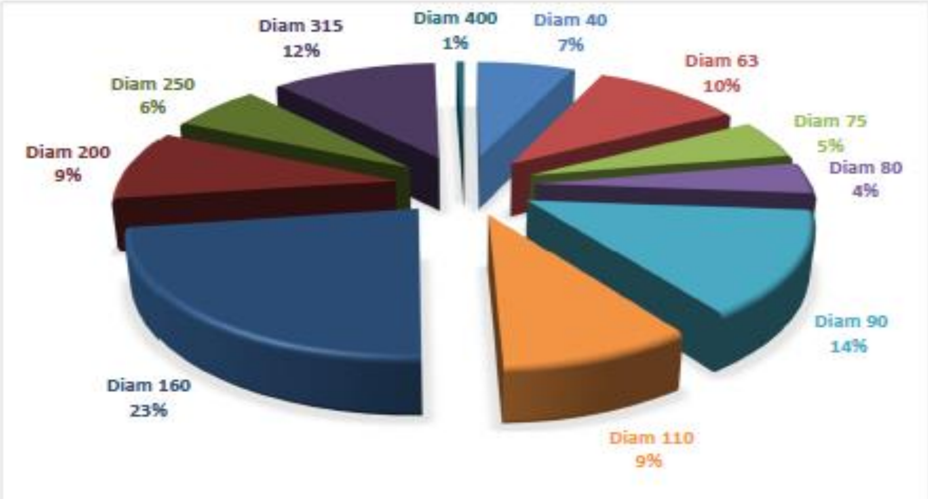

Figure 3.7: *Diameters of the drinking water supply network* (**Benzineb and Nana Wendpouire, 2018**)

III.5. Waste Water Treatment Plant

The wastewater treatment plant of the city of Tlemcen is located north of the capital of "Tlemcen Ville", west of Chetouane "Daïra" on the Route de Ain El Houtz designed for a population of 150,000 equivalent / inhabitant of a capacity of 30,000 m^3/d, it was carried out by the Algerian Hydrotreatment Company commissioned on November 5, 2005, currently managed and operated by the National Sanitation Office (ONA).

The Ain El Houtz wastewater treatment plant is located 6 km north of the city of Tlemcen, on the right bank of the Ain El Houtz wadi just at the foot of Jebel Touma. The station occupies an area of 13 hectares.

Figure 3.8: *The location of the WWTP of Tlemcen*

The treatment plant in the city of Tlemcen is a low load activated sludge type. In the biological treatment of effluents, aerobic processes are generally used in which bacteria cause direct oxidation of organic matter in wastewater from oxygen dissolved in water.

The WWTP is made up of the following chain of treatment operations:
• Pretreatment;
• Primary treatment by biological means by activated sludge;
• Secondary treatment by settling;
• Sludge treatment (for spreading)

The water after being purified will be stored in a retention basin located at the WWTP, then this water is reused for the irrigation of the Hennaya full for arboriculture. Farmers have the right once a year (to avoid any intensive cultivation that will make the soil sterile) to recover this dried sludge for reuse in the fertilization of their soil, provided that the standards for the reuse of this sludge conform to the type soil and crop that will be planted there. **(ONA)**

CHAPTER FOUR: Research Methodology

IV.1. Research Design

For this study, both qualitative and quantitative approaches in data collection and analysis have been used. For data collection, a qualitative approach was involved by interviewing the citizens of Boujlida-Tlemcen. Whilst the quantitative approach was involved by collecting numerical data from ADE about water production, water supply and water consumption.

To analyze the determinants of water demand in Boujlida, we used estimates on data collected at ADE Tlemcen. These data combine water consumption, water supply and water production. To complete this database, we carried out in September 2021 a survey of 160 households. This investigation relied primarily on three steals main. The first flight was interested in the characteristics of the household (level education of the head of the family, his age, position, number of children, household size ...). The second stole looked at the characteristics of the accommodation (type housing, housing status, type of equipment …). Finally, in the third end of our survey we were interested in the water resource. We questioned the type of water used for consumption (public network, wells, springs, public cisterns or others), its perception of the quality of the network water, the quality of the water service, its perception of the price of water.

IV.2. Survey

This was used to collect primary data from the citizens of Boujlida-Tlemcen, the survey involved use of a questionnaire, the method of survey using a semi-structured questionnaire was considered appropriate since part of the questionnaire offers the households a choice of picking their answers from a given set of alternatives while the other part of the questionnaire allows them to qualify their responses.

The questionnaire proposed was in French, however, while proceeding to the interviews some clarifications has been brought to the respondents by explaining the questions and also translating the questionnaire into dialectal Arabic.

The questionnaire prepared for the purpose of data collection contains four sections:

(a) General aspects: gender of the participants, age, profession, the total number of people living in the housing and housing type (individual or collective).

(b) The water consumption: drinking, cooking, housing equipments

(c) The water supply is divided two aspects:

(c.1) frequency of distribution and water pressure;

(c.2) satisfaction regarding the quantity of water they receive, the use of alternate sources, water conservation methods and its re-use.

IV.3. Data processing and analysis

Data were analyzed both quantitatively and qualitatively the data collected were carefully arranged and analyzed. The data were analyzed using Pivot Table from Excel. All the information was analyzed according to the research question and the information available.

IV.4. Ethical Considerations

The research process must ensure the participants' dignity, privacy and safety. In this study, the questionnaire filled was anonymous. To ensure confidentiality, the participants were guaranteed that the identifying information would not be made available to anyone who was not involved in the study and it would remain confidential for the purposes it was intended for.

Due to the Covid-19 pandemic, precautions have been implemented; during the interviews the wearing of the mask and the social distancing was mandatory, and each time before and after the questionnaire was given to the citizen we had to disinfect our hands.

CHAPTER 5: Results and Discussion

V.1 .Introduction

The study main objective was to assess the water management and sanitation in the city of Tlemcen, where Boujlida has been taken as a case of study, and analyze the socio-economic impact. This chapter is divided into two parts; the first part consisted on analyzing the data provided from ADE (water production, water distribution and water billed) and ONA (quality of treated wastewater), and a second part, consisting in analyzing the response from respondent living in Boujlida-Tlemcen. The chapter puts the data in perspective with the research questions asked and seeks to interpret it according to the topic, the chapter is arranged in thematic form starting with a presentation of results followed by interpretation of the finding. The data were analyzed using Pivot Table from Excel.

V.2. Efficiency and Performance of Boujlida Drinking Water Supply Network

In the field of drinking water supply, performance measurement by indicators relating to the qualitative results of the service appears to be a tool specific to improve management skills. The implementation of this methodology seeks to constitute a common panel of indicators covering all the missions of the services drinking water supply. These indicators, in a limited number and often quite simple to calculate, are ranked in order to guide the choice of the community, without withdraw the possibility of adapting the list to the particular context of its service. For better management and operation of Boujlida drinking water supply network, quality indicators have been judiciously chosen to assess the state of operation network and ensure the sustainability of the service provided. These indicators allow better identify the strengths and weaknesses in the conduct of the water service. These indicators were listed under technical and service indicators. They are calculated based on data on volumes produced, distributed consumed recorded at the level of Boujlida locality **(Abdelbaki, 2014)**

V.2.1. Network Performance of Boujlida

Regarding the production and distribution of drinking water, the first savings to be made is of course the efficiency of the network since each cubic meter of water produced has consumed kilowatt-hours lost as a result of leaks in the network. Network yields are seldom less than 70% in developed countries; however they can drop to less than 30% in certain urban farms in lack of support. The optimization of the water distribution service for a high efficiency implies the implementation of an adapted and efficient management, which combines the aspects of rapid maintenance of the network, renewal of the network and improvement of the commercial water supply management.

The efficiency of the water supply network represents the ratio between the volume of water consumed by users (individuals, industrialists) and the public service (for the management of the drinking water system) and the volume of water drinking water introduced into the distribution network, the higher the efficiency (at constant consumption), the lower the losses by leaks **(Abdelbaki, 2014)**

V.2.1.1. Production Efficiency

The production yield is an important indicator for the management technique of a drinking water supply network. It is defined as being the ratio between the stored volume and the volume produced (Formula V.1). It should be noted that the standard of production efficiency is 90% **(Gomella, 1985)**

$$\text{Production Yield (\%)} = \frac{Stored\ Volume}{Produced\ Volume} \times 100 \qquad \text{(V.1)}$$

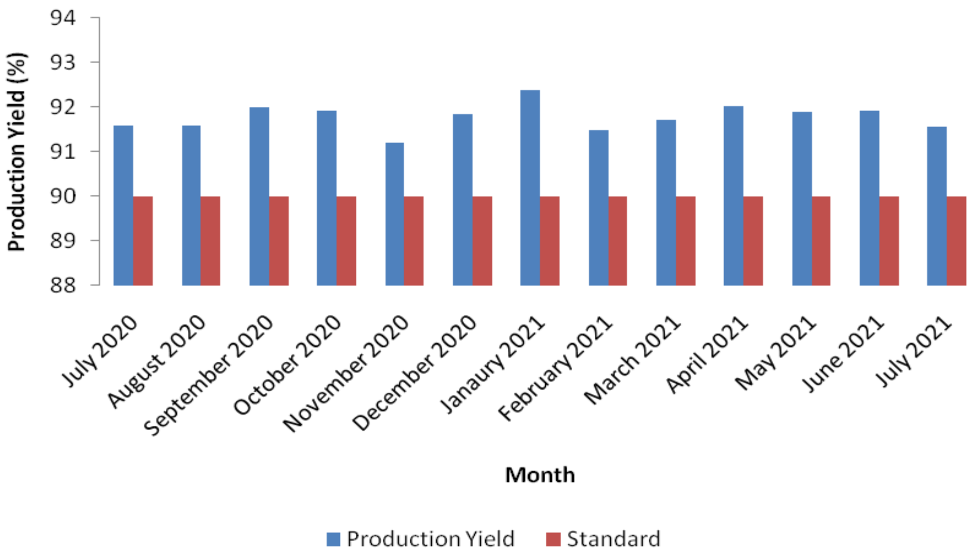

Figure 5.1: *Variation in Production Yield of Boujlida*

Figure 5.1 shows the production efficiency of Boujlida from July 2020 to July 2021, we can notice that the average yield is 92% which is higher than standard of 90%, which is acceptable.

According to table 5.1, we can see that the total volume lost in storage is about 103976 m^3, which corresponds to a loss in storage on average of 8%.

Table 5.1: *Variation in Water Losses and Production Yields*

Months	Volume Produced m^3	Volume Stored m^3	Volume Lost m^3	Loss Storage %	Production Yield %
July 2020	91371	83677.83	7693.17	8.42	91.58
August 2020	91314	83623.67	7690.33	8.42	91.58
September 2020	103512	95211.67	8300.33	8.02	91.98
October 2020	101460	93262.33	8197.67	8.08	91.92
November 2020	82023	74797.17	7225.83	8.81	91.19
December 2020	99009	90933.83	8075.17	8.16	91.84
January 2021	118788	109724	9064	7.63	92.37
February 2021	88350	80807.83	7542.17	8.54	91.46
March 2021	95076	87197.50	7878.50	8.29	91.71
April 2021	104424	96078.17	8345.83	7.99	92.01

May 2021	99978	91854.50	8123.50	8.13	91.87
June 2021	101346	93154	8192	8.08	91.92
July 2021	90459	82811.33	7647.67	8.45	91.55
AVERAGE	97470	89471,83	7998,17	8,23	91,77
TOTAL	1267110	1163133,83	103976,17	/	/

V.2.1.2. Primary Yield

This indicator represents the interannual evolution of the network's performance. It is essential to see the degradation or on the contrary the improvement in the state of the network over the years. Only the authorized consumed volumes are taken into account in the calculations of the primary yield **(Fecih *et al.*, 2018)**

It reflects the notion of network efficiency, since it compares the totality of the water used with that introduced into the network. It is an important element for the management of a drinking water supply network, and generally greater than 65% and may reach or even exceed 90% **(Gomella, 1985).** With the primary yield, the volumes used but not recorded are considered as losses. The primary yield "overestimates" the losses **(Belmahi and Amiri, 2018)**

$$\text{Primary Yield (\%)} = \frac{Volume\ Consumed\ Recorded}{Volume\ Supplied} \times 100 \qquad (V.2)$$

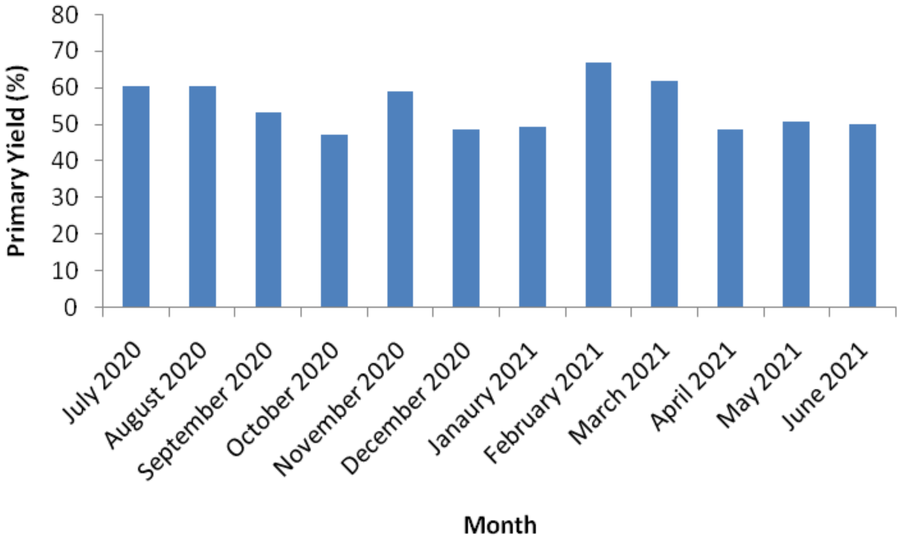

Figure 52: *Variation in Primary Yield of Boujlida*

Figure 52 represents the primary yields over the period of July 2020 to July 2010 for Boujlida. The average efficiency value of the Algerian national networks is 50% **(Benblidia, 2011),** in our case, the average primary yield of the Boujlida distribution network is 55%. This means that around 45% of the volume of drinking water introduced into the supply network is lost. For example, the month of April 2021 recorded an estimated water loss of 49,373 m^3, the equivalent of 14 to 15 Olympic swimming pools. However, it is however difficult to assess the performance of a water network only with this index**.** These losses represent water leaks, illicit pecking, water theft and unrecorded consumption.

According to ADE, there is the loss of volumes distributed in the new locality of Boujlida that is estimated at 5 l/s, which represents a monthly volume of 13,392 m^3 due to breakage in the HDPE pipes (ϕ315, ϕ250, ϕ200, ϕ160), this allows us to be sure that 7% of the water lost comes from pipe leaks, which means from 45% of water loss found above, we have 3% coming from breakage pipes, and for the remaining 42% the losses can come from other broken pipes that have not been resent, or from illegal pecking.

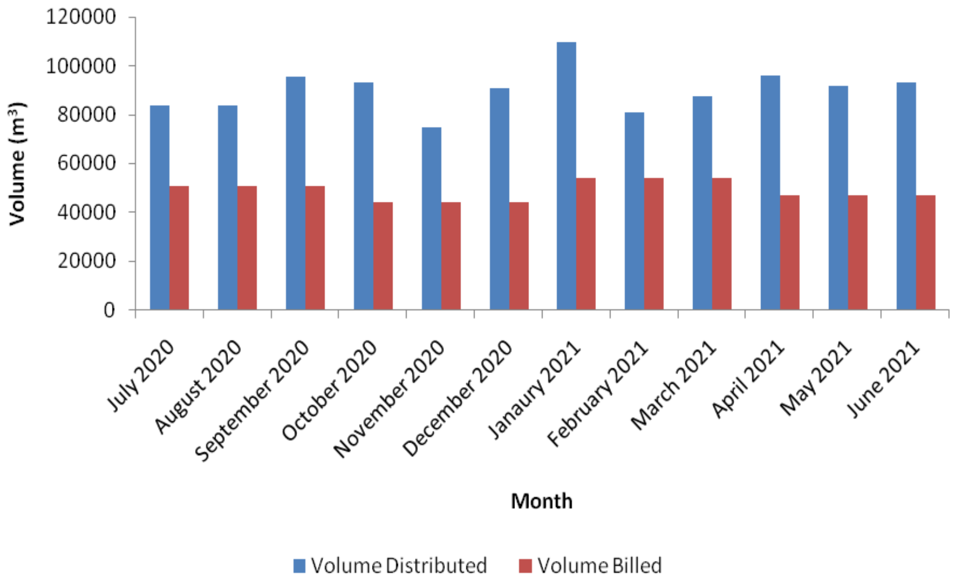

Figure 53: *Comparison between the Distributed Volume and the Billed Volume*

Figure 5.3 represents the comparison between the volume distributed and the volume billed; we can notice that there is a difference of almost the half, which confirms that the half of water that is distributed is lost while supplied.

Table 5.2: *Variation in Water Losses and Primary Yields*

Month	Volume Supplied m^3	Volume Consumed Recorded m^3	Volume Lost m^3	Volume Lost (%)	Primary Yield (%)
July 2020	83677.83	50602.67	33075.17	39.53	60.47
August 2020	83623.67	50602.67	33021	39.49	60.51
September 2020	95211,67	50602.67	44609	46.85	53.15
October 2020	93262.33	44029.33	49233	52.79	47.21
November 2020	74797.17	44029.33	30767.83	41.14	58.86
December 2020	90933.83	44029.33	46904.50	51.58	48.42
January 2021	109724	53913	55811	50.86	49.14
February 2021	80807.83	53913	26894.83	33.28	66.72
March 2021	87197.50	53913	33284.50	38.17	61.83
April 2021	96078.17	46704.67	49373.50	51.39	48.61
May 2021	91854.50	46704.67	45149.83	49.15	50.85
June 2021	93154	46704.67	46449.33	49.86	50.14

AVERAGE	90026,88	48812,42	41214,46	45,34	54,66
TOTAL	1080322,5	585749,01	494573,49	/	/

According to table 5.2, we can see that the total volume lost in distribution is about 494573m^3, which corresponds to a loss in distribution on average of 45%.

V.2.1.3. Linear Distribution Loss Index

The Linear Loss Index is the second most common indicator in developed countries. It measures the volumes of water lost per day for 1 km of network. This index has the big advantage of taking into account the effect of the population density of a municipality (rural, semi-rural, urban network) and of monitoring the evolution of networks. As the calculation formula for this indicator indicates, the length taken into account is that of the network without taking into account those of the connections. In fact, the length of the connections is often subject to great uncertainty and the most diffuse leaks are found mainly at the connections. As well as the yield, the authorized volumes consumed not counted are not taken into account and it is recommended to analyze in parallel the yield, the number of leaks, leak detection rate and the network renewal rate **(Fecih *et al.*, 2018)**

The linear loss index also translates the volume of water lost per unit length. This is the evolution over time of these two indicators (performance primary + linear index of loss) which will serve as the basis for any improvement plan network performance **(Abdelbaki, 2014).**

The linear index of distribution losses is defined as the ratio between the volume distribution losses and the length of the network. This ratio varies according to the type of network and can reach 10 to 15 m^3/km daily **(Valiron, 1994).**

$$\text{LDLI (m}^3\text{/km. d)} = \frac{Volume\ Supplied - Volume\ Billed}{Linear\ of\ the\ Network \times 365} \qquad \text{(V.3.)}$$

NB: Linear of the network of Boujlida = 20 Km

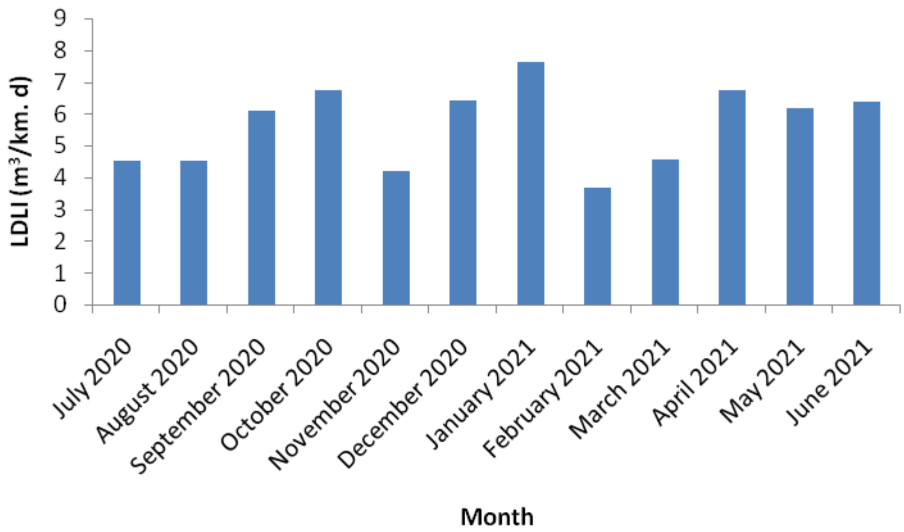

Figure 5.4: *Variation in Linear Distribution Loss Index*

Figure 5.4 shows the variation of this index of distribution water losses in Boujlida. This index varies between 3.68 and 7.65 m^3/km.d corresponding to 0.15 and 0.32 m^3/h/km respectively, resulting from an average water loss and that the loss can be limited by using appropriate technical means (Table 5.3) **(Abdelbaki, 2014)**

Table 5.3: *Comparison of the values of the linear indices of water losses* ***(National Institute development, 2001)***

LDLI (m^3/h/Km)	Level of Water Loss	Remarks
0.06 – 0.25	Low	New networks, very good maintenance
0.25 – 0.40	Average	Results that can be achieved using appropriate technical means
0.40 – 1.00	High	Low maintenance
1.0 – 2.00	Very High	Very limited maintenance
> 2	Extremely High	Non acceptable

Table 5.4: *Variation of the Linear Distribution Indices of Water Losses*

Months	Volume Supplied m^3	Volume Billed m^3	LDLI (m3/km.d)	LDLI (m3/h/km)	Level of Water Loss
July 2020	83677.83	50602.67	4.53	0.19	Average
August 2020	83623.67	50602.67	4.52	0.19	
September 2020	95211.67	50602.67	6.11	0.25	
October 2020	93262.33	44029.33	6.74	0.28	
November 2020	74797.17	44029.33	4.21	0.18	
December 2020	90933.83	44029.33	6.43	0.27	
January 2021	109724	53913	7.65	0.32	
February 2021	80807.83	53913	3.68	0.15	
March 2021	87197.50	53913	4.56	0.19	
April 2021	96078.17	46704.67	6.76	0.28	
May 2021	91854.50	46704.67	6.18	0.26	
June 2021	93154	46704.67	6.36	0.27	
AVERAGE	90026,86	48812,42	5,64	0,24	
TOTAL	1080322,5	585749,01	/	/	

V.2.1.3. Subscriber Density

It equals the number of subscribers per network kilometer. It is expressed in subscribers/Km

Subscriber density (Subscriber/km) $D = \frac{Number\ of\ Suscribers}{Linear\ of\ the\ Network\ (Km)}$ (V.4)

Several references exist to characterize a service from this parameter. According to **(Office de l'eau, 2011):**

D < 20: Rural type network

20 < D < 40: Intermediate type network

D > 40: Urban type network.

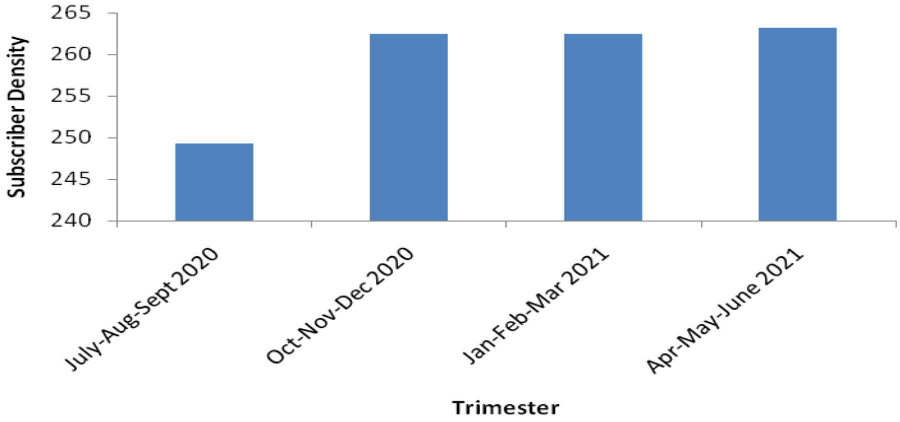

Figure 5.5: *Variation Subscriber Density*

The result from Figure 5.5 shows that from the trimester of July-August-September 2020 reached 250 subscribers/Km and increased to 263 subscribers/Km on the trimester of April-May-June 2021. The subscriber density was significantly higher than 40 subscribers/km (Average 259 Subscribers/km), so according to **(Office de l'eau, 2011)** the network is urban type (superior to 40 Subscribers/km).

Table 5.5: *Subscriber Density*

Trimester	Number of Subscribers	Subscriber Density (Subscriber/Km)	Classification of Network
July-Aug-Sept 2020	4986	249	Urban Type
Oct-Nov-Dec 2020	5250	262	
Jan-Feb-March 2021	5250	262	
April-May-June 2021	5264	263	

V.2.1.4. Loss Index per Subscriber

It makes it possible to carry out a first assessment of the level of loss independently of the other network characteristics **(Renaud, 2009)**; Table V.6 summarizes the different interval for comparison of loss index values per subscriber.

$$\text{LIPS } (m^3/\text{Sub/d}) = \frac{Volume\ of\ Lost\ Volume\ Distribued/day}{Number\ of\ Suscribers} \quad \text{(V.5)}$$

Table 5.6: *Comparison of Loss Index Values per Subscriber* (LIPS) **(Renaud, 2009)**

Level of the Loss	Loss Index per Suscriber (m^3/Sub/d)
Low Level of Losses	LIPS $\leq$ 0.08

Moderate Level of Losses	$0.08 < LIPS \leq 0.15$
High Level of Losses	$0.15 < LIPS \leq 0.29$
Very High Level of Losses	$0.29 < LIPS$

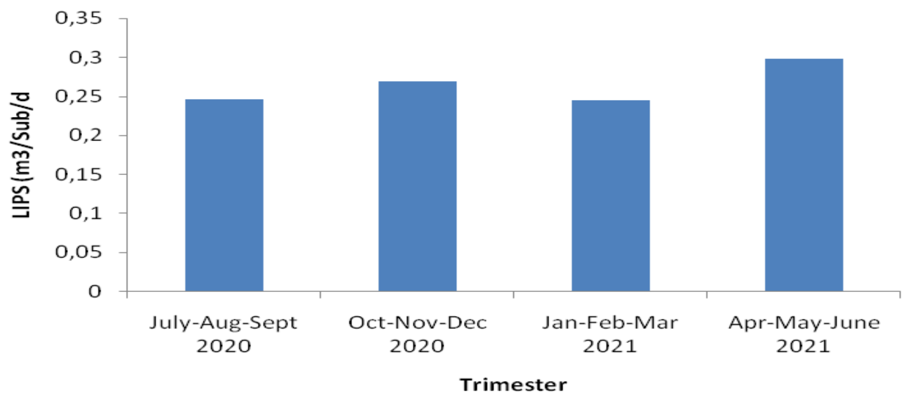

Figure 5.6: *Variation of the Loss Index per Subscriber*

The result shows that higher LIPS is for the trimester of April-May-June 2021 with a value of 0.30 m3/Sub/d, the loss indices per subscriber are greater than 0.29 m^3/sub/d corresponding to a very high level loss. According to table 5.6 and 5.7 the level of losses is from high to very high.

Table 5.7: *Variation of the Loss Index per Subscriber*

Trimester	Number of Subscriber	Lost Volume (m^3/d)	LIPS (m^3/sub/d)
July-Aug-Sept 2020	4986	1230.06	0.25
Oct-Nov-Dec 2020	5250	1410.06	0.27
Jan-Feb-Mar 2021	5250	1288.78	0.25
Apr-May-June 2021	5264	1566.36	0.30
	TOTAL	10990,52	/

V.2.1.5. Total Loss and Global Yield of the Network

Any water management body is called upon to calculate the overall yields, which constitute one of the performance indicators of the network for which it is responsible. The overall yield is expressed as the ratio of the volume consumed to the volume produced.

$$\text{Global Yield (\%)} = \frac{Volume\ Consumed}{Volume\ Produced} \times 100 \qquad (V.6)$$

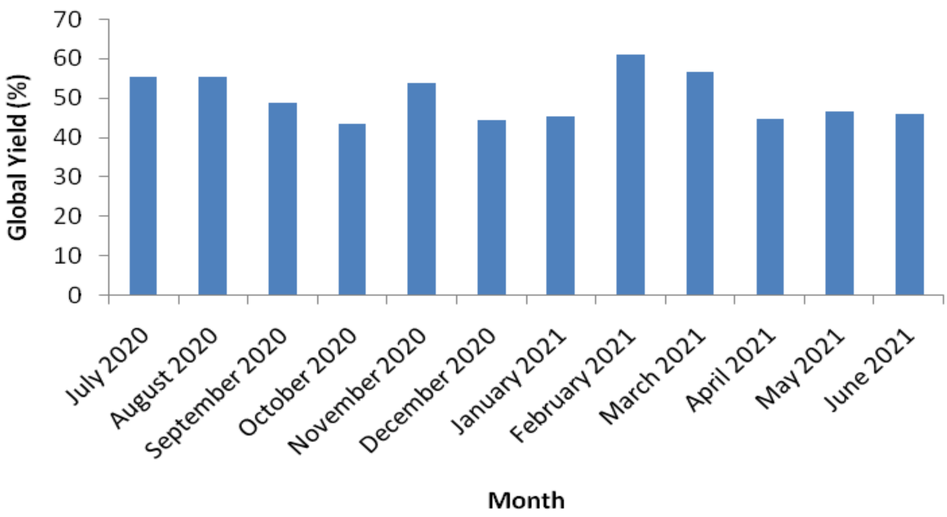

Figure 5.7: *Variation of the Global Yield*

According to Figure 5.7, the variation of the global yield is on average of 50%, where the highest global yield has been recorded for the month of February 2021 with 61%.

According to Figure 5.8, between July 2020 and January 2021 there was first a increase in the volume produced due to the increase in inhabitant leading to the increase on drinking water demand. Regarding volumes of water distributed and billed, they decreased due to the reduction of the volume produced.

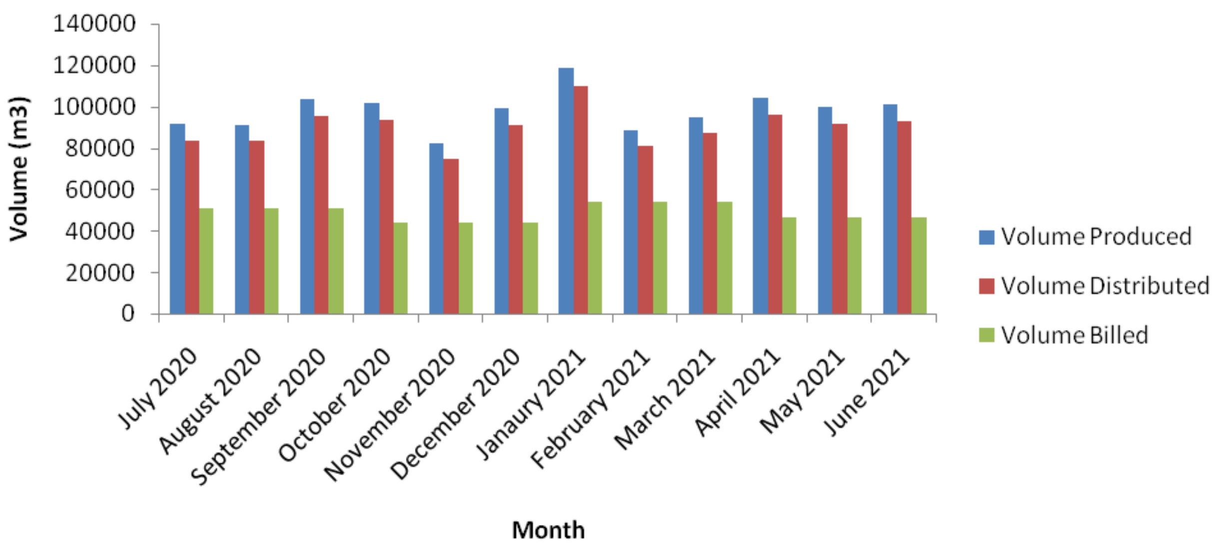

Figure 5.8: *Comparison between Produced, Distributed and Billed Volume*

Table 5.8: *Global Yield Variation*

Month	Volume consumed m^3	Volume Produced m^3	Global Yield (%)
July 2020	50602.67	91371	55.38
August 2020	50602.67	91314	55.42
September 2020	50602.67	103512	48.89

October 2020	44029.33	101460	43.40
November 2020	44029.33	82023	53.68
December 2020	44029.33	99009	44.47
January 2021	53913.00	118788	45.39
February 2021	53913.00	88350	61.02
March 2021	53913.00	95076	56.71
April 2021	46704.67	104424	44.73
May 2021	46704.67	99978	46.71
June 2021	46704.67	101346	46.08
AVERAGE	48812,42	98054,25	50,16
TOTAL	585749,01	1176651	/

The study of drinking water supply of Boujlida service required the use of several performance indicators because none of the performance parameters is sufficient on its own to characterize the performance of a network; it is the set of indicators that makes it possible to determine the state of a network because each brings different information. It is therefore proposed to combine several indicators to judge the performance of drinking water supply networks. In our case, we combined seven indicators:

- Production efficiency.
- Primary yield.
- Linear index of distribution losses.
- Loss index per subscriber.
- The density of subscribers.

The results obtained are as follows:

- The density of subscribers has shown that the network is urban.
- Production efficiency is acceptable.
- The primary efficiency is down compared to the standard which is 65%.
- The LDLI is average.
- The loss indices per subscriber is between 0.25 and 0.30 m^3/sub/d, therefore, the level of losses is comprised between high and very high.

The results show that the network must undergo some interventions to reduce the losses which are quite important for a network which is new, especially at the level of the leaks of the HDPE pipes (ϕ315, ϕ250, ϕ200, ϕ160), it is necessary to rehabilitate the network and to seek what the other sources of water leakages/lost for better service.

V.3. Evaluation of the Cost of Water

The cost of water represents the cost price of a unit of distributed water (m^3), all charges included, of a hydraulic installation. Water management activities and water and sanitation services come at a cost. This cost is made up of different elements. Failure to take into account some of these elements ultimately results in unsustainable use of water resources and services, resulting in significant welfare losses for the community. And in this case we are closer to the concept of cost price which is the sum of all the costs which constitutes the consideration for a good or service. These are two types of costs; indirect costs which cover the costs related to the provision of water services to consumers, they consist on investment costs, which cover expenses related to the construction of works and infrastructure and the replacement of existing ones or creating new ones, but also the costs of operation, maintenance, distribution of water, such as the cost of the electricity required for pumping, or the cost of repairs, and costs related to water resources management activities which are administration and governance costs (management overheads) and labor required to maintain the services. The second type of costs consists on resource costs, which correspond to the depletion and impoverishment of resources leading to the disappearance of certain possibilities for other users. thereafter, the scarcity value of the resource corresponds to the cost of depriving a possible next user of water; when the value of water is higher for this user, this inadequate allocation of resources makes society bear a opportunity cost by adding the efficiency of the installations, which expresses the water production minus the water losses linked to leaks in the network and/or to non-counted consumption **(Benbraika and Ghedab, 2013)**

The tariff level should be determined using a cost-based approach, as well as requests consumers. In Algeria, there are few studies that specify the cost of water services. According to our bibliographic research, we have identified:

- The **SOGREAH /ICEA** study **(2002)** which reveals that the cost of water at the head of the network is 35 DA/m^3. Water distribution costs from 20 to 25 DA/m^3, which is in total between 55 and 60 DA/m^3. The real cost of water would vary between 73 and 82 DA/m^3 with a sanitation cost of 31.5 to 35 DA/m^3. The cost of water would then be in a range of 100.5 - 117 DA/m^3.
- A study by **Benachenhou (2005)** showed that the real cost of a cubic meter of water in Algeria is around 130 DA/m^3.
- The actual cost per cubic meter of water and sanitation for the city of Souk-Ahras is 125 DA/m^3 **(Boukhari *et al.*, 2011),** including the costs of investment and operation (drinking water and sanitation) for a sale price of 18 DA/m^3.
- In another study carried out at ENSH, the real cost of water is equal to 170 DA/m^3 for the city of Bordj Bou Arreridj **(Zeroual *et al.*, 2013).**
- According to **Benblidia (2011)**, the selling price of 1 m^3 of drinking water is 64 DA, while its production cost was estimated in 2005 at around 90 DA/m^3 and which is currently about 125 to 150 DA/m^3 taking into account seawater desalination.

Table 5.9: *Water Tariff for Households* **(Executive Decree n°05-13 of 9 January 2005)**

Households	**Quarterly Tranche Consumption**	**Water and Sanitation DA/m^3**
1st Tranche	< 25 m^3/trimester	8.65
2nd Tranche	From 26 to 55 m^3/trimester	28.12
3rd Tranche	From 56 to 82 m^3/trimester	47.58
4th Tranche	> 82 m^3/trimester	56.23

V.3.1. Calculation of the Cost of Water and Economic Loss

In order to estimate the economic loss of water production and distribution and sanitation, we have considered the following values according to literature:

- The production of desalinated water equals 120 DA/m^3
- The distribution of water equals 50 DA/m^3, including the sanitation

Table 5.10: Produced, Distributed and Billed Volume per Trimester

Trimester	Billed Volume m^3	Distributed Volume m^3	Produced Volume m^3
July-Aug-Sept 2020	151808	262513	286197
Oct-Nov-Dec 2020	132088	258993	282492
Jan-Feb-Mar 2021	161739	277729	302214
Apr-May-June 2021	140114	281087	305748
TOTAL	585749	1080323	1176651

To know which tranche to consider for calculation, we have divided the billed volume (BV) by the number of subscribers, according to table 5.11, the volume of water consumed per trimester is comprised between 25 and 31 m^3/trimester, which corresponds to the 2nd tranche (table 5.9), where the water tariff and sanitation equals to 28.12 DA/m^3.

Table 5.11: Identification of the Water Consumption Tranche

Trimester	Billed Volume m^3	Subscribers	BV/Subscribers m^3/trimester
July-Aug-Sept 2020	151808	4986	30
Oct-Nov-Dec 2020	132088	5250	25
Jan-Feb-Mar 2021	161739	5250	31
Apr-May-June 2021	140114	5264	27

To quantify the cost of water production and water distribution (including sanitation), we multiply by the volumes by the correspondent cost.

Water Production Cost (DA) = Volume Produced (m^3) × 120 DA/m^3 (V.7)

Water Distribution Cost (DA) = Volume Distributed (m^3) × 50 DA/m^3 (V.8)

Total Cost (DA) = Water Production Cost (DA) + Water Distribution Cost (DA) (V.9)

Table 5.12: Water Distribution and Production Cost and Total Cost

Trimester	Water Distribution Cost (DA)	Water Production Cost (DA)	Total Cost (DA)
July-Aug-Sept 2020	13125658	34343640	47469298
Oct-Nov-Dec 2020	12949667	33899040	46848707
Jan-Feb-Mar 2021	13886467	36265680	50152147
Apr-May-June 2021	14054333	36689760	50744093
TOTAL	54016125	141198120	195214245

According to table 5.12, the total cost of the water production and distribution from July 2020 to June 2021 is estimated to 195214245 DA for a total volume produced and distributed of 1176651 m^3 and 1080323 m^3 respectively.

To quantify the economic loss for water production, and water distribution (including sanitation), we deduct the billed volume from the total cost to know the amount lost.
We have also calculated the cover rate of the billed volume by dividing the economic lost by the total cost.

Economic Lost (DA) = Total Cost (DA) – Billed Volume (DA) (V.10)
Cover Rate (%) = (Economic Loss (DA) / Total Cost (DA)) × 100 (V.11)

Table 5.13: *Economic Loss and Cover Rate*

Trimester	Economic Loss (DA)	Cover Rate (%)
July-Aug-Sept 2020	43200457	91
Oct-Nov-Dec 2020	43134392	92
Jan-Feb-Mar 2021	45604046	91
Apr-May-June 2021	46804088	92
TOTAL	178742983	/

According to table 5.13, the water loss is estimated at 178742983 DA from July 2020 to June 2021, this amount covers about 92% of the total cost, which means that the bill paid by the subscribers represents 92% of the total cost of water production and distribution.
According to **Boukhari (2019),** in some cases the consumers bills only covers 80% of the total cost, or does not barely covers the only salary charge (the first post of ADE charge is represented by salaries, which amount to 26 billion Algerian dinars (DA), almost as much as the figure business, which was 28 billion dinars in 2016).
In addition to economic losses, the lost volumes constitute an ecological waste of our natural water resources. These losses are all the more damaging and can lead to a risk of water shortage. These losses reduce an already very low water volume. Leaks also represent a health hazard. Bacteriological contaminations, even physicochemical, which will deteriorate the quality of the water, are then possible. Finally, leaks reduce the reliability of service in terms of continuity: pipe breaks drop the pressure and even cause service to be interrupted. Repairs often require shutting off power to a neighborhood and stopping traffic when the pipes are under the roadway (***Fecih et al., 2018)***

The deficit is covered by the State in the form of balancing subsidies, planned to compensate for the difference between the actual charges operations and the proceeds of water sales. This results in a low turnover which, combined with the limitation of the tariff, results in difficult financial situation for managers of water and sanitation, which prevent them from ensuring proper functioning the offer of their services to users.
The State, through its administration (MRE) or by the intermediary of public enterprises (ADE and ONA), provides to users drinking water priced at a lower amount at its cost of production. Consumer bills only covering part of the expenses, other sources funding, in

particular grants, should be put in place. The general subsidy mechanism is that aid to the water sector can lower costs production (subsidy of energy costs) but above all will substantially increase the resources of water services drinking (direct subsidy in the operating accounts of ADE and ONA). Receipts invoiced being lower than operating expenses, an annual grant from the General Directorate is paid into the unit's account ADE of Tlemcen.
Water Tariffs are economic instruments that help conserve water resources and tackle the challenges of providing water-related services to all citizens at an affordable price.
In practice, consumers pay too little for the water and sanitation services they receive. People are not aware of the real costs of providing water and sanitation services, as these have historically been heavily subsidized by public authorities. This is because water as a social good has been considered an abundant resource. However, with population growth and the needs of much larger communities requiring access to water, the availability of this resource is drastically decreasing in many parts of the world. **(Ferah and Farhi)**

In conclusion, it appears that the water and sanitation services management system requires significant support public budget to ensure not only the big investments in the water sector, but identically large direct subsidies condition the balancing of the operating account of each ADE and ONA unit.

V.4. Water Consumption in Boujlida

Figure 5.14 represents the variation in water consumption in Boujlida from July 2020 to June 2021. We can notice that the highest water consumption (151808 m^3) is for the trimester July-August-September 2020 for 4986 subscribers, this is due to the fact that this trimester refers to the summer season where the water consumption is generally the highest.
We can also notice that there is an increase in water consumption for the trimester January-February-March 2021 (161739 m^3), but this is only due to the increase of subscribers from 4986 to 5250, because this trimester refers to the winter season and we know that the water consumption is the lowest.

Table 5.14: *Number of Subscribers and the Volume Billed by Trimester*

Trimester	Volume Billed (m^3)	Subscribers
July-Aug-Sept 2020	151808	4986
Oct-Nov-Dec 2020	132088	5250
Jan-Feb-Mar 2021	161739	5250
Apr-May-June 2021	140114	5264

For the trimester of October-November-December 2020, which refers to the autumn season, we have the lowest water consumption of 132088 m^3 for 5250 subscribers, and for the trimester April-May-June 2021 referring to the spring season, we notice a slight increase in both water consumption and subscribers.
We can conclude from those results, that the highest water consumption is for the season of summer, while the lowest is for the winter season, however, for the season of spring and autumn we have almost the same water consumption.

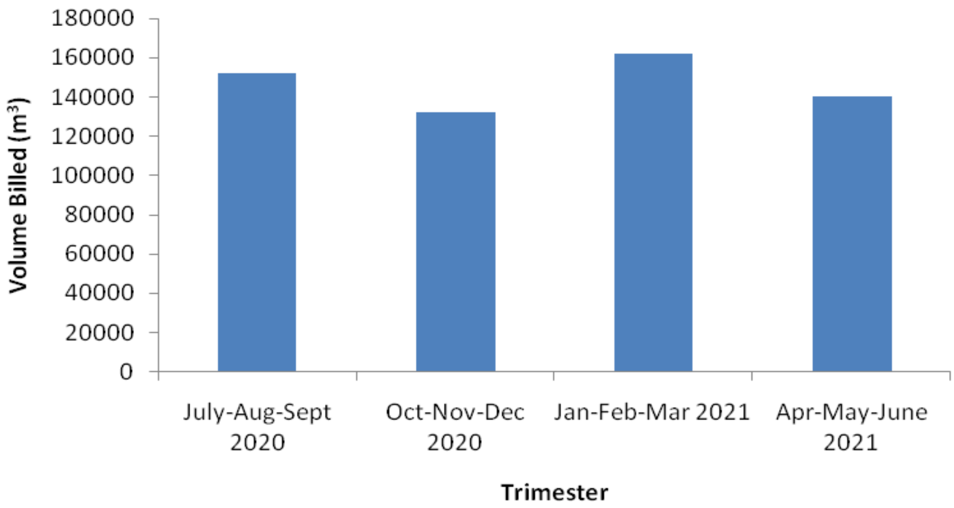

Figure 5.9: *Variation in Water Consumption in Boujlida*

V.4.1. Theoretical and Net Endowment of Drinking Water in Boujlida

Endowment is an estimate of unit consumption by user category. It is obtained by the ratio between the total consumption of a given category and the number of consumers of this category. The net allocation corresponds to the actual allocation invoiced, without taking into account water losses. The gross (theoretical) allocation corresponds to the volume of drinking water distributed divided by the number of inhabitants **(Belmahi and Amiri, 2018)**

$$\text{Theoretical Endowment L/d/inhab} = \frac{Volume\ Intended\ for\ Population\ (L)}{Number\ of\ Inhabitants \times 365\ days} \quad (V.12)$$

$$\text{Net Endowment L/d/inhab} = \frac{Volume\ Consumed}{Number\ of\ Inhabitants \times 365\ days} \quad (V.13)$$

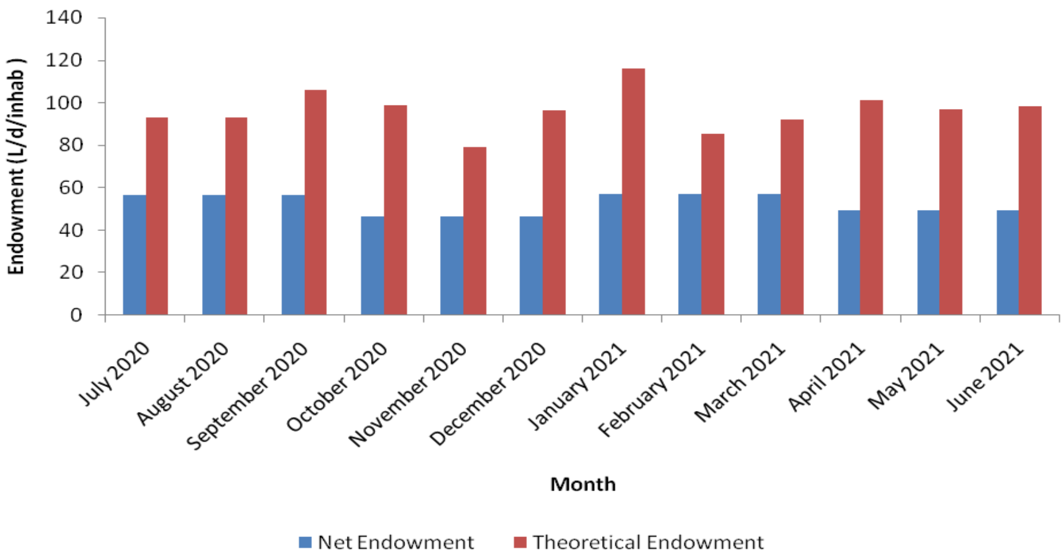

Figure 5.10: *Variation in Theoretical and Net Endowment in Boujlida*

From the results obtained in figure 5.10, we notice a big difference between the net endowment and the theoretical endowment, from July 2020 to June 2021, the theoretical endowment is 96 L/d/inhab, which is far from the net endowment of 52 L/d/inhab, and even further from Algerian endowment of 150 L/d/inhabitant.

Table 5.15: *Comparison between Net and Theoretical Endowment*

Month	Net Endowment (L/d/inhab)	Theoretical Endowment (L/d/inhab)
July 2020	56	93
August 2020	56	93
September 2020	56	106
October 2020	47	99
November 2020	47	79
December 2020	47	96
January 2021	57	116
February 2021	57	86
March 2021	57	92
April 2021	49	101
May 2021	49	97
June 2021	49	98
Average	52	96

V.4.2. Future Population Growth and Water Demand

Demographics and growing consumption driven by increased per capita income are the drivers, or pressures, having the greatest impact on water. The demand for water has never been greater. As demand increases, some countries are already reaching the limits of their water resources **(Belmahi and Amiri, 2018)**

According to data from ADE Tlemcen, the total number of dwellings in Boujlida is 8,064 for a population of 40,320 inhabitants (2019).

For the approximate evaluation of a population with a future horizon of one year "n", the following equation can be used:

$$P_n = P_0 \left(1+\frac{T}{100}\right)^n \qquad \text{(V.14)}$$

P_n: The population at the horizon of year n.

P_0: The population of the reference year,

T: The population growth rate = 3.1% for Chetouane (ONS, 2018)

n: The difference between the actual and the projected year

In order to estimate the water demand for the projected population, we use the equation below:

$$\text{Water Needs (L/d)} = \text{Endowment (L/d/Inhab)} \times \text{Population (Inhab)} \qquad \text{(V.15)}$$

With: Endowment = 150 L/d/inhab

Table 5.16: *Projected Population and Water Needs in Boujlida for 2050*

Horizon	Population	Water Needs (L/day)	Water Needs (m^3/day)	Water Needs (m^3/Year)
2019	40320	6048000	6048	2207520
2020	41570	6235488	6235	2275953
2021	42859	6428788	6429	2346508
2022	44187	6628081	6628	2419249
2023	45557	6833551	6834	2494246
2024	46969	7045391	7045	2571568
2025	48425	7263798	7264	2651286
2030	56411	8461690	8462	3088517
2035	65714	9857129	9857	3597852
2040	76551	11482693	11483	4191183
2045	89176	13376333	13376	4882362
2050	103882	15582259	15582	5687524

According to table 5.16, the projected population in Boujlida at horizon 2050 is 103882 inhabitants, which is equivalent to a water need of 15582 m^3/day (5687524 m^3/year) for an endowment of 150 L/d/inhab. The water service ADE has to mobilize additional resource or to raise the produced volume to satisfy the projected population for 2050.

V.5. Efficiency and Performance of WWTP of Ain El Houtz-Tlemcen

The only data of wastewater analysis that I had access to by ONA were from 1st July to 31st July 2021 (period of the internship). The physico-chemical analyzes were performed on the wastewater before and after the treatment in order to assess its quality and level of response to the requirements and standards established for irrigation. Results obtained from analyzes carried out on the wastewater are interpreted and compared to some existing recommendations and norms (Algerian, FAO and WHO).

The results include the following parameters: Temperature, pH, Turbidity, Electrical Conductivity (EC), Suspended Solids (SS), Dissolved oxygen (DO), Biological oxygen demand (BOD_5), Chemical oxygen demand (COD), Phosphates (PO_4^{3-}), Nitrate-nitrogen (NO_3-N) and Ammonium nitrogen (N-NH_4^+).

The number of samples analyzed were; 30 samples for Temperature, SS, DO, pH, Turbidity, and Conductivity (made every day), and 4 samples for COD, BOD, N-NO_2, N-NO_3, PO_4 (made once a week on Thursdays)

V.5.1. Temperature

Water temperature has impacts on water chemistry and biological life. Moreover, the level of chemical reactions increases at higher temperature. The change in temperature influences the amount of oxygen that can be dissolved in water as well as rate of photosynthesis by algae and other aquatic plants. As temperature decreases, the amount of oxygen that will dissolve in water increases. Water temperature plays an important role for example as regards the solubility of salts and gases of which, among others, the oxygen necessary for the balance of aquatic life. Otherwise, the temperature increases the rates of chemical and biochemical reactions by a factor of 2 to 3 for a temperature increase of 10 degrees Celsius (C °) **(Chikh *et al.*, 2018).** It conditions many parameters, such as electrical conductivity, dissolved oxygen and pH, as well as reactions of degradation and mineralization of organic matter. It also plays an important role in the nitrification and biological denitrification **(Boukherissi, 2015).** The activity of microorganisms varies with temperature, in particular the rate of development of the biomass. In addition, the degradation kinetics of the molecules are faster and the solubility of molecules in water, and therefore their bioavailability, is greater (**Mailler, 2015)**

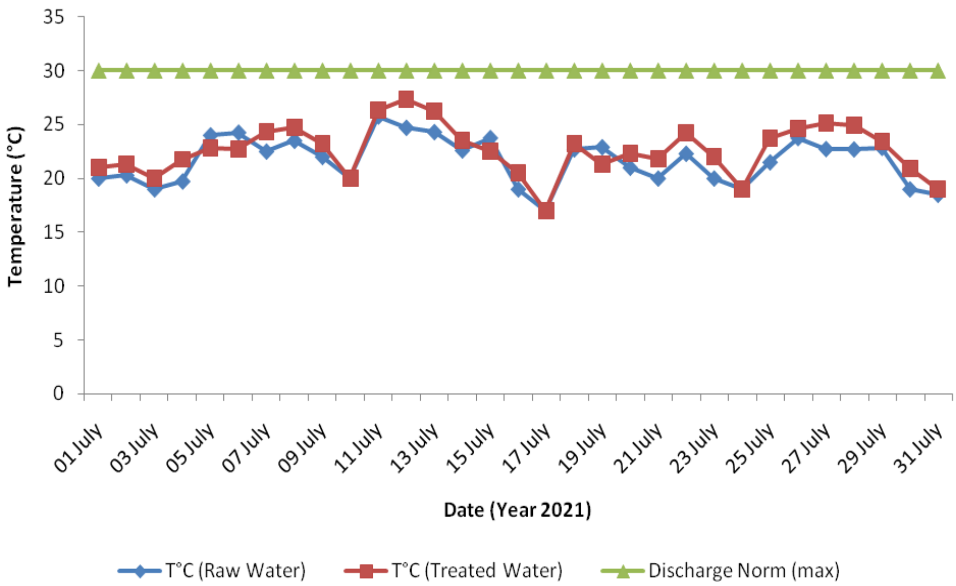

Figure 5.11: *Daily Variations of Temperature Before and After Treatments*

The obtained results from Figure 5.11 showed that the absolute values of temperature for the water before treatment vary between 17°C to 26°C at the inlet of the WWTP and from 17 °C to 27°C after the treatment. These results are in accordance with the standards of reuse (less than 30°C).

V.5.2. pH

The pH indicates the acidic or basic character of a medium, (PH < 7: acid medium, pH > 7: basic medium, Ph = 7: neutral medium). The pH value of the wastewater is permanently between 6.5 and 9.0. In general, the influence of PH is indisputable on the efficiency elimination of organic pollution, and all the work carried out to show that the optimal activity of nitrobacter and nitrosomonas takes place for a range of pH 7.8 to 8.5 **(Chikh *et al.*, 2018)**

The pH is a reflection of many biological and chemical processes occurring in the aquatic environment. Major among these are photosynthetic activities of aquatic plants, respiration of aquatic organisms, decomposition of organic matter, precipitation, dissolution and oxidation-reduction reactions taking place in the aquatic environment. The pH plays an important role in many aquatic life processes. Living organisms are dependent on and sensitive to pH. It is not only a measure of the potential pollutant but is also related initially to concentration of many other substances, particularly the weakly dissociated acids and bases **(Rahmoun, 2018)**

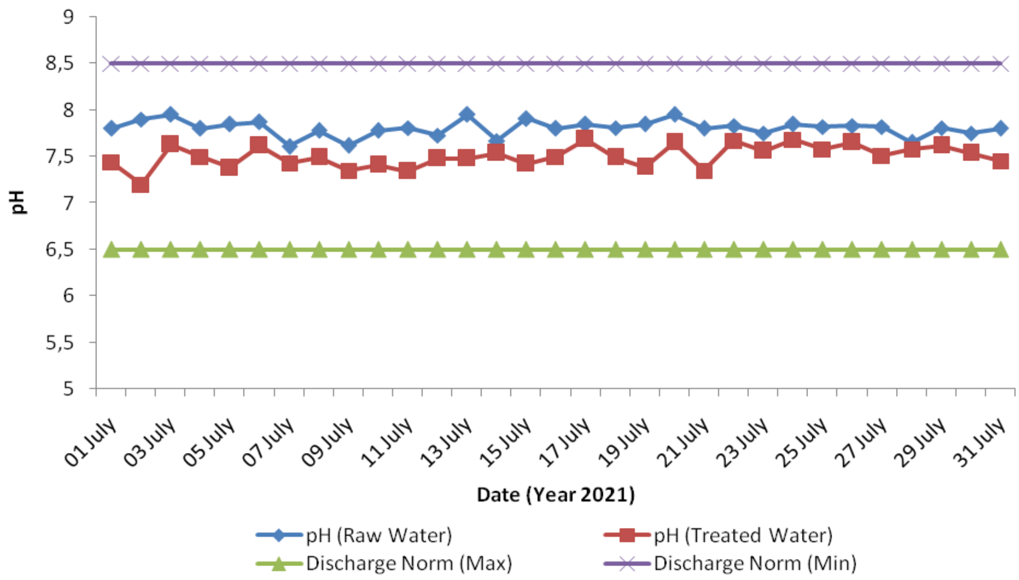

Figure 5.12: *Daily Variations of pH Before and After Treatments*

From the observations of figure 5.12, the pH at the inlet vary between 7.6 and 7.9, and from 7.34 to 7.69 after treatment, we note that the PH values are in accordance with the Algerian standards recommended for irrigation ($6.5 \leq pH \leq 8.5$).

V.5.3. Electrical Conductivity (EC)

Conductivity is a parameter is a general indicator of water quality, especially a function of the amount of dissolved salt, and can be used to monitor processes in the wastewater treatment that causes changes in total salt concentration and thus changes the conductivity. In wastewater treatment the main processes that reduce conductivity are biological nutrient removal. Sources of salinity include urban and rural run-off containing salt, fertilizers and organic matter. The composition of salt in water varies according to the source and properties of the constituent's chemical compounds **(Rahmoun, 2018)**

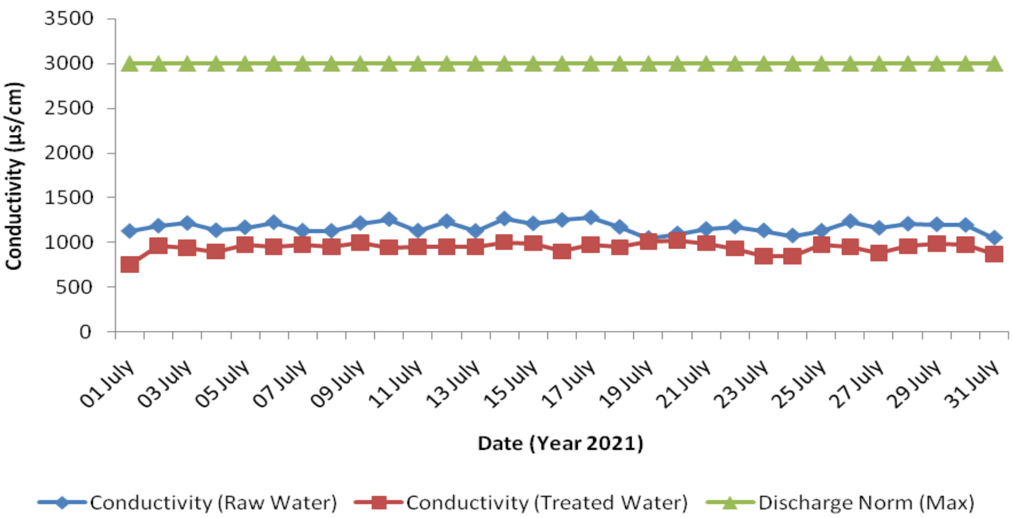

Figure 5.13: *Daily Variations of Conductivity before and after Treatments*

The obtained results from figure 5.13 shows that the electrical conductivity at the inlet vary between 1047 µS/cm and 1281 µS/cm and between 746 µS/cm and 1006 µS/cm at the outlet. Those values conform to the discharge norms (< 3000 µS/cm)

V.5.4. Suspended Solids (SS)

The suspended solids (SS) are, for the most part, biodegradable in nature. Most a large proportion of pathogenic microorganisms contained in wastewater are associated with SS. Suspended particles can, by definition, be removed by settling. It is a simple and effective step to reduce the organic load and the content of pathogenic germs in sewage. However, much more treatment is generally required to deal with health risks **(Belaid, 2010).** Suspended solids are the undissolved materials with a diameter greater than one µm contained in the water. They include both Mineral and organic and decanted spontaneously. This material is obtained by the differences between the weight of total materials and settling materials (material that settles after a rest period of two hours) **(Chikh *et al.*, 2018)**

The presence of organic matter in wastewater does not constitute, except in very in particular, an obstacle to the reuse of these waters. On the contrary, it contributes to the soil fertility. However, experience shows that maintaining a concentration high organic matter content in wastewater considerably hinders the effectiveness of treatments intended to eliminate pathogenic germs. Moreover, the significant concentrations of organic matter can also cause odors unpleasant, especially if the water happens to stagnate on the surface. Finally, an excessive presence of suspended solids can lead to difficulties in supplying effluents as well as closure of irrigation systems **(Belaid, 2010)**

The values of total suspended matters (figure 5.14) from the WWTP of Ain El Houtz at the inlet vary between 159 mg/l and 248 mg/l. For treated wastewater, SS values recorded were below the limit value set by the Algerian government for treated wastewater for irrigation (30 mg/l). The maximum value of SS is 27 mg/l which conforms to the Algerian norm.

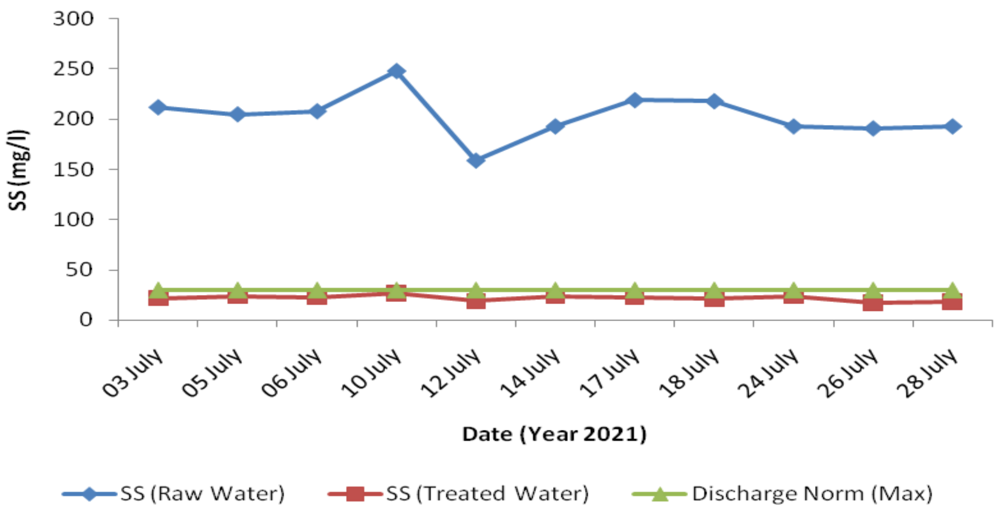

Figure 5.14: *Daily Variations of Suspended Solids before and after Treatments*

V.5.5. Turbidity

The estimation of the level of suspended solids optically is made by measuring direct turbidity. This global parameter corresponds to the reduction in the transparency of a liquid due to the presence of suspended particles. As examples of such particles, we can cite silt, clay, algae, organic matter, microorganisms, colloidal material and even macromolecules that are dissolved in the sample (tannins and lignin). The light beams, passing through a sample of water, can be subjected to following phenomena: part of the light is absorbed by the particles; another is transmitted in the environment; a last diffuses the light in all directions. So the turbidity can be determined either by measuring the transmission or by measuring the intensity scattered light (**Do Carmo Lourenço da Silva, 2008)**

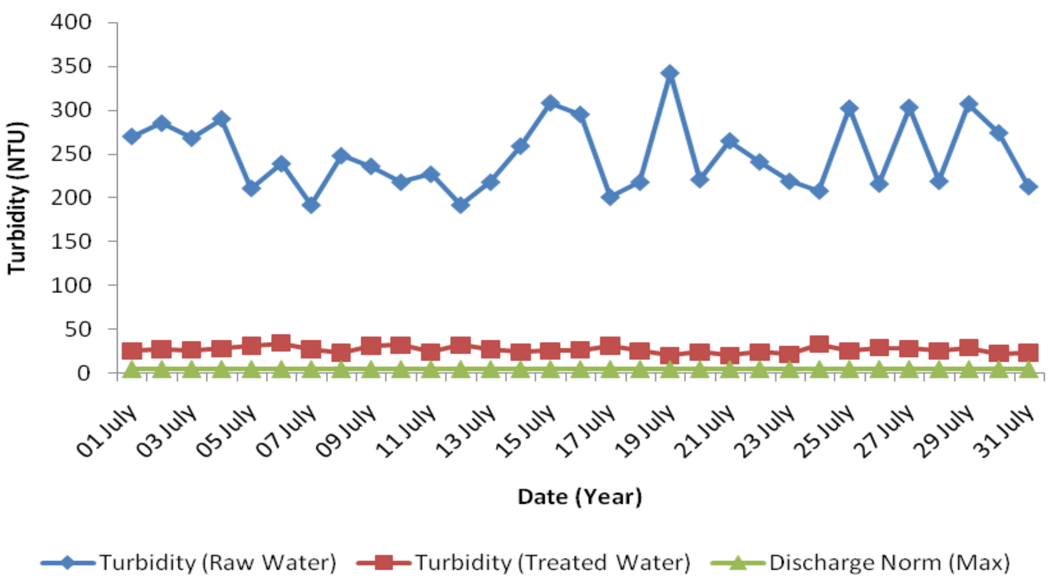

Figure 5.15: *Daily Variations of Turbidity before and after Treatments*

The obtained results from figure 5.15 shows that the turbidity at the inlet varies between 192 and 342 NTU, and at the outlet between 20 and 34 NTU. Those values are not conform to the discharge norms (< 5 NTU). Even if the turbidity is higher than the norms, this will have no negative impact in reuse in irrigation.

V.5.6. Dissolved Oxygen (DO)

Dissolved oxygen is necessary in aquatic systems for the survival and growth of many aquatic organisms and is used as an indicator of the health of surface-water bodies. Most of the chemical and biological reactions in groundwater and surface water depend directly or indirectly on the amount of available oxygen. The oxygen content of water depends on a number of physical, chemical, biological and microbiological processes. Moreover, The oxygen concentration is an important indicator of pollution of a water body, indicating its biological state, the predominant processes occurring in it, the destruction of organic substances and the intensity of self-purification **(Rahmoun, 2018)**

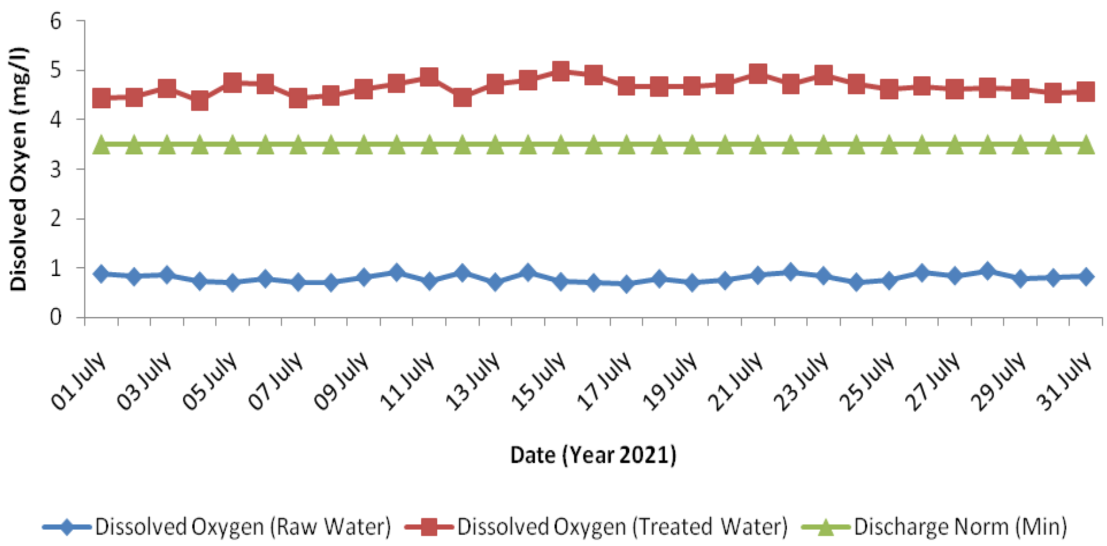

Figure 5.16: *Daily Variations of Dissolved Oxygen before and after Treatments*

The values of dissolved oxygen (figure 5.16) before treatment vary between 0.68 mg/l and 0.95 mg/l. After treatment, it varies between 4.38 mg/l and 4.98 mg/l. Those values conforms to the norms because it is higher than 3.5 mg/l

V.5.7. Biological Oxygen Demand (BOD_5)

BOD5 is the amount of oxygen consumed by the bacteria at 20 ° C In the dark and for 5 days. Incubation of a sample previously inoculated, which ensures the biological oxidation of a fraction of carbonaceous organic matter. This parameter measures the quantity of aerobic oxidation **(Metahri, 2012).** The method is based on measuring the oxygen consumed in a water sample more or less diluted to degrade the initial pollution by biochemical means, by determination of the dissolved oxygen concentration before and after incubation. This analysis was developed at the beginning of the twentieth century in the United Kingdom. Incubation of the sample or its dilutions is carried out under conditions defined: at 20 ° C in a thermostatically controlled chamber so that the biological activity is the same for all tests; in the dark to avoid photosynthesis due to algae that can be present in the water, which would release oxygen; for a fixed period of 5 (BOD_5), 7 (BOD_7) or 21 (BOD_{21}) days or more as for the ultimate BOD (BOD_∞). The BOD_5 value measured in a wastewater sample corresponds to approximately 60 at 70% of the ultimate BOD value. BOD_5 therefore only represents a fraction of the BOD ultimate ($BOD\infty$), because the complete mineralization of organic matter can take up to 20 days or more (**Do Carmo Lourenço da Silva, 2008).**

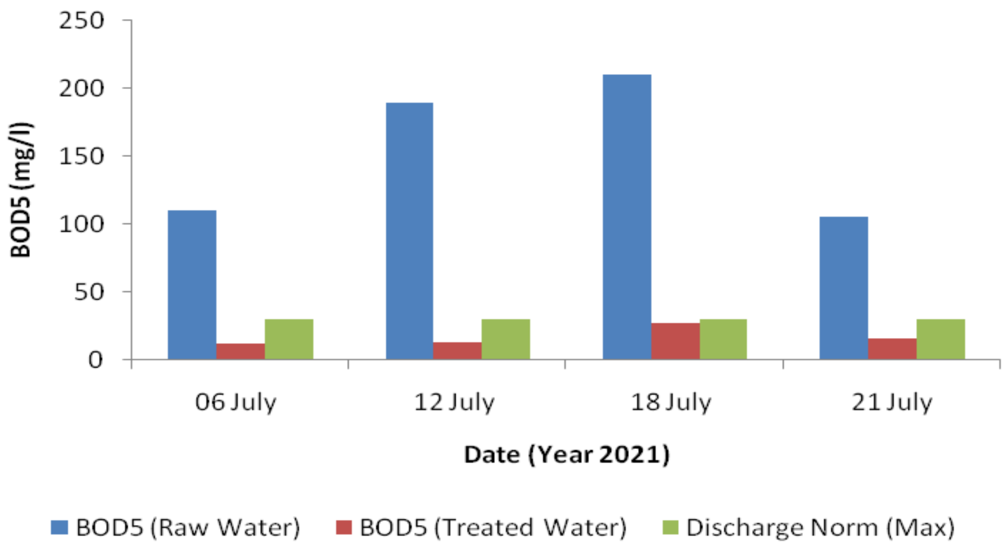

Figure 5.17: *Daily variations of* BOD_5 *before and after treatments*

The values of biological oxygen demand (BOD_5) for the wastewater before treatment in WWTP of Ain El Houtz (figure 5.17) varied between 106 mg/l and 220 mg/l. After treatment it varies between 12 mg/l and 27 mg/l. The variations of BOD_5 after the treatment is below the norm value set by the Algerian government for irrigation water (30 mg/l). In terms of biodegradable organic pollution, the treated wastewater does not present any risk and can be used for irrigation.

V.5.8. Chemical Oxygen Demand (COD)

Chemical oxygen demand is the measurement of the amount of oxygen required for oxidizing the organic matter and inorganic oxidizable contained in a sample. This parameter gives an estimate of the amount of pollutants present in an industrial effluent or a wastewater. The COD value indicates the mass of oxygen consumed per liter of solution and expressed in milligrams per liter (mg/L). The higher COD values, the higher the amount of pollution in the water sample. Generally, COD is considered one of the important quality control parameter of an effluent in wastewater treatment facility **(Chikh *et al.*, 2018) (Rahmoun, 2018)**

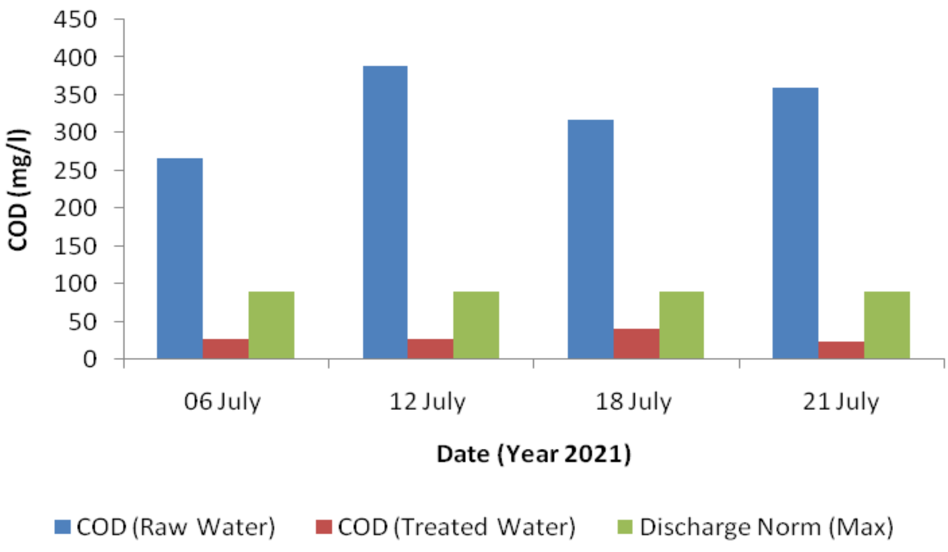

Figure 5.18: *Daily variations of COD before and after treatments*

The values of chemical oxygen demand (COD) for the wastewater before the treatment (figure 5.18) varies between 267 mg/l and 389 mg/l and after the treatment it varies between 24 mg/l and 41 mg/l. The COD variation of the treated waste water is below the limited value set by the Algerian government for water intended for irrigation (90 mg/l).

V.5.9. Phosphates (PO_4^{3-})

Phosphorus is a naturally occurring nutrient found in soil and rocks that is required by all living organisms. It is one of the most important nutrient elements in aquatic environment and usually used as an index of eutrophication phenomena. High levels of phosphates in aquatic environments can fuel algal growth, resulting in algal blooms that can potentially lead to eutrophication as the thick algal mats block out sunlight causing the algal cells to die off. It has a double existence as nutrient element and sometimes as a pollutant. **(Rahmoun, 2018)**

The origin of phosphorus in wastewater is inferred from knowledge of the sources of natural phosphorus and its use. It can come from human metabolism, washing and cleaning products, industrial waste (agro-food industries, slaughterhouses, specialized industrial and chemical laundries) and agricultural waste. This phosphorus, particulate or soluble, consists essentially of inorganic phosphorus (largely in the form of polyphosphates), orthophosphates (part of which comes from the hydrolysis of inorganic phosphate) and organic phosphorus. The removal of phosphorus consists on putting the bacterial mass is under continuous stress by the alternation of aerobic and anaerobic phases. During the anaerobic phase, phosphorus is released. However, during the aerobic phase, the phosphorus released previously is assimilated in a greater quantity, thus allowing a biological overconsumption of phosphorus, which is extracted with the excess sludge. Biological dephosphatation can achieve yields of 60 to 70%. It requires delicate adjustments and rigorous monitoring of biological functioning (**Do Carmo Lourenço da Silva, 2008)**

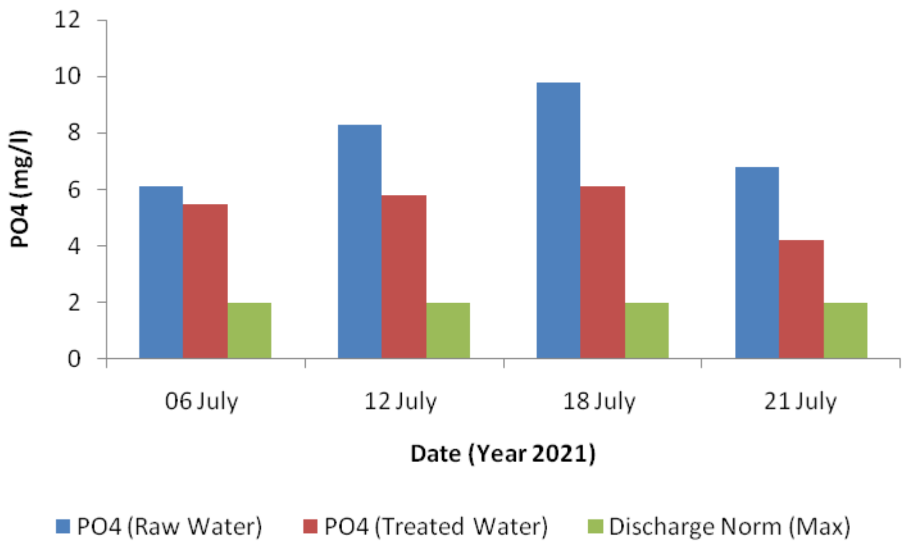

Figure 5.19: *Daily variations of phosphorous before and after treatments*

Before the treatment, the values of PO_4^{3-} for the waste water from the WWTP of Ain El Houtz vary between 6 mg/l and 10 mg/l, while after treatment between 4 mg/l and 6 mg/l. The maximum value after treatment was recorded at 6 mg/l, which is too high than the limited phosphate standard set by FAO and the limited value set by the Algerian government for irrigation water (2 mg/l). This is probably resulted from the extensive discharge from sewage, the surrounding agricultural areas during this season and also specially a malfunction of WWTP.

V.5.10. Nitrite- Nitrogen (N-NO_2)

The nitrogen present in urban wastewater comes mainly from human excreta. Urine contributes significantly to this intake, especially in the form of urea, uric acid and ammonia. In addition, cooking water carries proteins comprising amino acids, and certain surfactants (detergents, softeners) which include nitrogen radicals in their molecules. Nitrogen in wastewater consists mainly of ammonifiable or refractory organic nitrogen (in soluble and particulate form) and ammoniacal nitrogen. Organic nitrogen is said to be ammonifiable when it can be transformed by enzymatic hydrolysis into ammoniacal nitrogen. Nitrogen is present in wastewater in both organic and inorganic form. In a sample of urban wastewater, the most common inorganic substance is ammoniacal nitrogen (about 50% of the total nitrogen concentration). Organic nitrogen is quantified by the difference between determination of Kjeldahl nitrogen and ammoniacal nitrogen. Nitrogen in the form of nitrite and nitrate is also determined separately and its concentrations close the mass balance of nitrogen in wastewater (**Do Carmo Lourenço da Silva, 2008)**

Nitrification is a microbial process by which reduced nitrogen compounds (primarily ammonia) are sequentially oxidized to nitrite and nitrate. The nitrification process is primarily accomplished by two groups of autotrophic nitrifying bacteria that can build organic molecules using energy obtained from inorganic sources, in this case ammonia or nitrite. **(Rahmoun, 2018)**

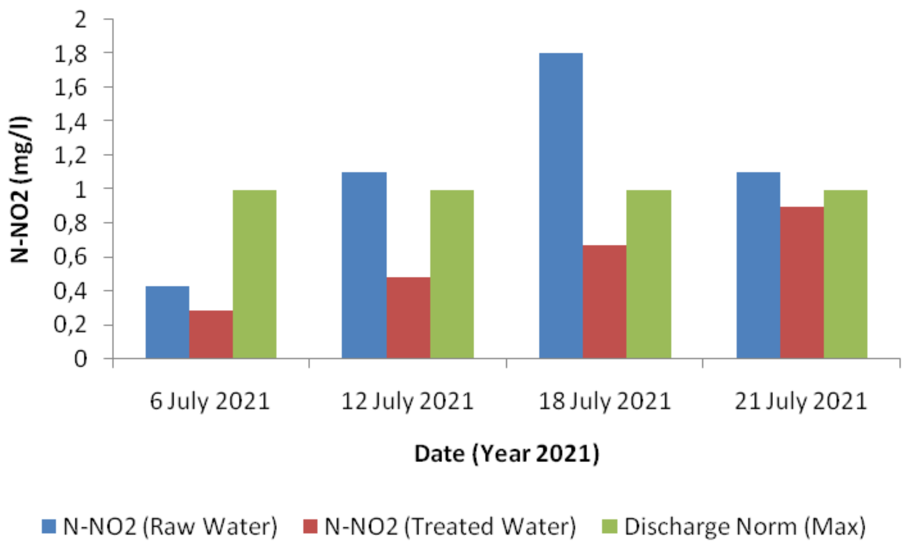

Figure 5.20: *Daily variations of nitrite before and after treatments*

The values of Nitrite for the treated wastewater from the WWTP of Ain El Houtz varies between 0.43 mg/l and 1.8 mg/l before the treatment, and between 0.29 mg/l and 0.9 mg/l. The nitrite variation of the treated water is below the limited value set by the Algerian government for irrigation water (1 mg/l).

V.5.11. Nitrate Nitrogen (N NO_3^-)

Nitrification occurs the when organic nitrogen and ammonium NH_4^+ are oxidized to NO_3^- nitrates by the autotrophic bacteria Nitrosomonas and Nitrobacter which successively convert ammonia to NO_2^- nitrites, then those of nitrites to nitrates. Nitrification is carried out in the same reactor as the treatment of carbonaceous pollution. However, taking into account the slower kinetics of nitrification, this can only take place in structures with a very low load. The second phase, denitrification, takes place under anoxic conditions. Nitrates are used as an oxidant by replacing oxygen by heterotrophic bacteria which reduce them to nitrogen N_2. In addition to anoxic conditions, denitrification requires a sufficient carbon source. This is why in activated sludge systems, denitrification can take place in a separate basin which is then upstream of the aerated biological basin. It can also take place in the same pool by alternating aeration/anoxia phases, by programming the on and off times of the aeration system **(Renou, 2006)**

The values of nitrate-nitrogen (figure 5.21) for the wastewater before treatment varies between 2.4 mg/l and 3.6 mg/l, while after the treatment the values varied between 1.2 mg/l and 1.8 mg/l. The nitrate variation of the treated wastewater is below the limited value set by the Algerian government for irrigation water (30 mg/l). This result can be attributed to the performance of nitrification-denitrification bacteria during biological treatment.

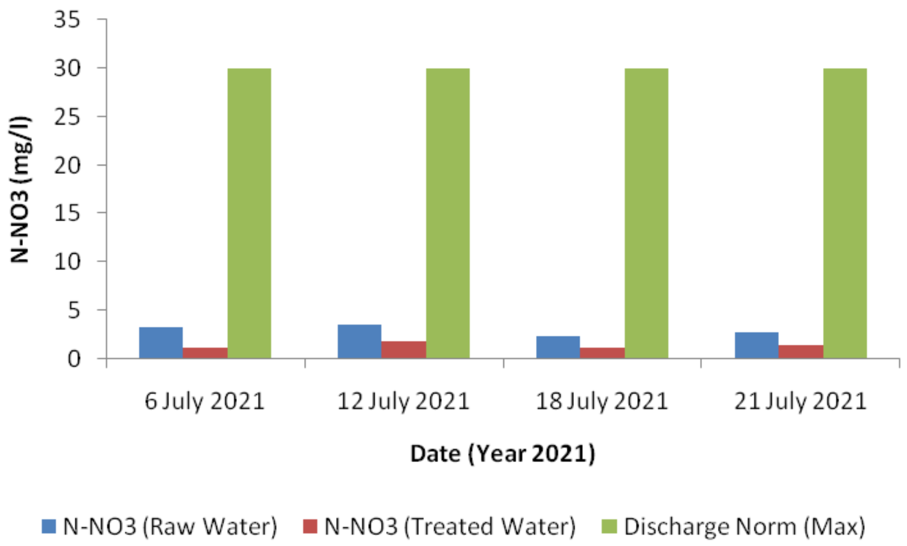

Figure 5.21: *Daily variations of nitrate before and after treatments*

V.5.12. Ammonium Nitrogen (N NH_4^+)

Ammonium nitrogen is a form of mineral nitrogen essential in the biological development of aquatic ecosystems. Ammonia is the first inorganic product in the regeneration of organic nitrogenous materials. It is also considered as a chief nitrogenous excretory product of many aquatic organisms, especially zooplankton. It may be used as a good indicator for the degree of pollution. Ammonia exists in solution in the form of the ion (NH_4^+) and in a free form, not ionized (NH_3). Ammonium ion NH_4^+ is frequently found at low levels in water compared to nitrate and organic nitrogen. It is the predominant form in the pH range of most natural waters and less toxic to fish and aquatic life as compared to NH_3. As the pH increases above 8, the ammonia fraction begins to increase rapidly. In the rare situation that a natural water pH exceeds reaches 9, ammonia and ammonium ion would be nearly equal. Ammonium ion has been recognized as an important alternative nitrogen source for various aquatic plants and in most environments may be assimilated in preference to nitrate **(Rahmoun, 2018)**

The values of ammonium (figure 5.22) for the wastewater from the WWTP of Ain El Houtz varies between 31.6 mg/l and 42.4 mg/l before the treatment and between 5.8 mg/l and 19.8 mg/l after treatment. The ammonium variation of the treated wastewater recorded is higher to the limited value set by the FAO for irrigation water (5 mg/l).

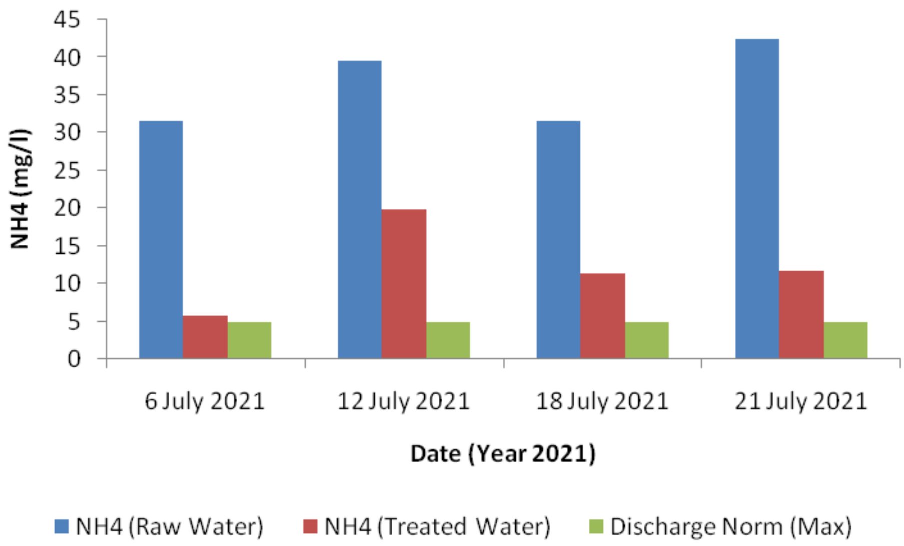

Figure 5.22: *Daily variations of ammonium before and after treatments*

According to the results of the physic-chemical analysis of Temperature, pH, Turbidity, Electrical Conductivity, Suspended Solids, Dissolved oxygen, Biological oxygen demand, Chemical oxygen demand, Phosphates, Nitrate-nitrogen, and Ammonium nitrogen of the wastewater before and after treatment, we can state that all the parameters conform to the norms of reuse in irrigation, except phosphates, ammonium and turbidity, that exceeds the norms. The excess of phosphates may be due to the intensive use of fertilizers that is then discharged in the sewage network. Ammonium excess is due to the ammonification of nitrates due to excess of oxygen. The turbidity will not have negative impact on reuse in irrigation, since the suspended solids conform to the norm of reuse to not clog the irrigation system.

In order to reuse treated wastewater without any health and environmental risk, the WWTP should include a tertiary treatment since the chlorination basin is not functional.

V.6. Results of the Survey

Through questionnaires, interviews and field observations, the assessment of socio-economic impact of water management has been highlighted. Our study carried out in Boujlida-Tlemcen, where 160 households have been interviewed which corresponds to 728 inhabitants.

The inhabitants were questioned at their homes but also in the street (shops, bus station…). The results are presented below.

V.6.1. Gender

In the questionnaire, the respondent had to tick either men or women.

The figure V.23 represents the percentage of men and women responding to the questionnaire, we can notice that 54% of the respondents are women and 46% are men, this is due to the fact that the interviews have been made outside and inside the housing, so for the ones made inside, the majority of the respondents were women, and for the ones at the outside were men.

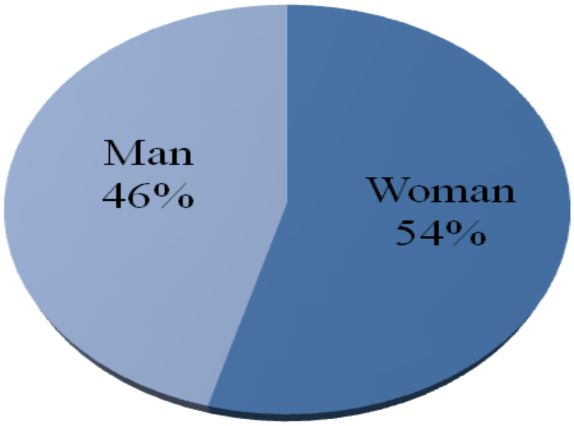

Figure 5.23: *Percentage of gender*

V.6.2. Age Group

In the questionnaire we let each respondent give their age, and after analyzing the responses, we have set 6 age ranges to facilitate the graphic representation; 18-28, 29-39, 40-50, 51-61, 62-72, and 73-83 years.

The figure 5.24 represents the percentage of age group responding to the questionnaire and figure 5.25 represents the percentage of age group which corresponds to each gender, we can notice that the highest age group is 40-50 years with a percentage of 33% which 15% corresponds to men and 18% to women. The second highest range is 29-39 years with 29%, corresponding to 9% of men and 20% of women.

For the range of 18-28 years with a percentage of 15%, we have 6% for men and 9% for women, and the range of 51-61 years with 10%, it corresponds to 8% for men and 3% to women. Finally for the range of 62-72 with a percentage of 9%, 6% are for men and 3% for women, and for the range of 73-83 with a percentage of 4%, 3% are for men and 2% for women.

According to the questionnaire, the mean age value of the respondents is 43 years. We can conclude that the age group of the respondents is 29-50 years.

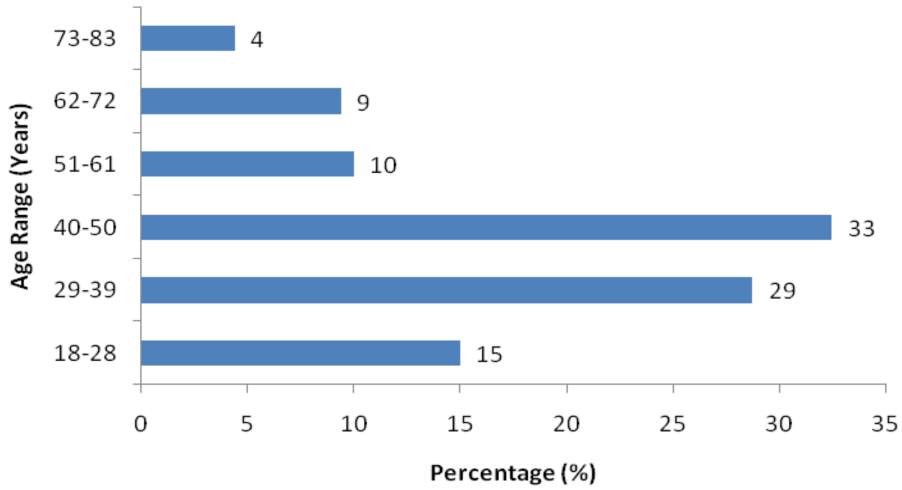

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Figure 5.24: *Percentage of Age Group*

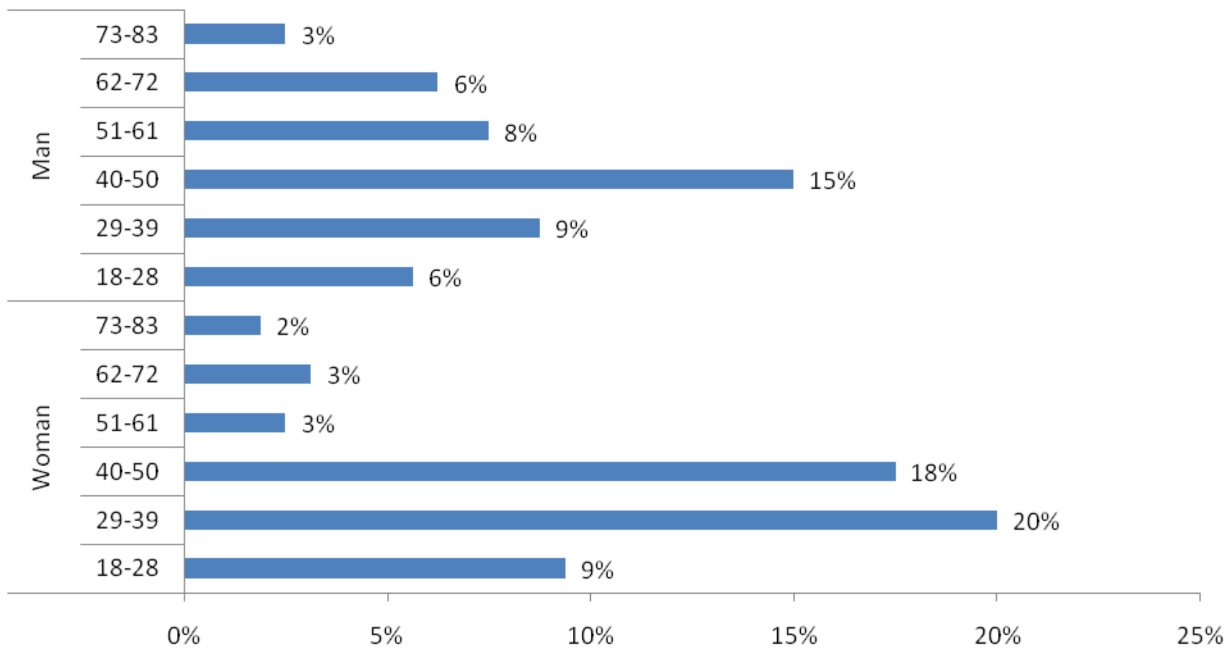


Figure 5.25: *Percentage of Age Group according to Gender*

V.6.3. Profession

In the questionnaire, the respondent had to choose between 7 different professions; Artisan/Retailer/Business Executive, Teacher/Liberal/Professor, Farmer, Retired, Student, Housewife, and Other.

Figure 5.26 represents the percentage of respondents' profession and figure 5.27 represents the percentage of respondents' profession according to gender. We can observe through the figures that the highest percentage is 29% who responds other (9% for men and 20% for women), then 23% responds Teacher/Liberal/Professor (11% to men and 12% to women). 15% from the respondent are retired (10% for men and 5% for women) and 12% are housewives. Among the respondents 9% are students (5% men and 4% women), 11% are Artisan/Retailer/Business Executive (9% for men, 2% for women), and 1% are farmers (corresponding to men).

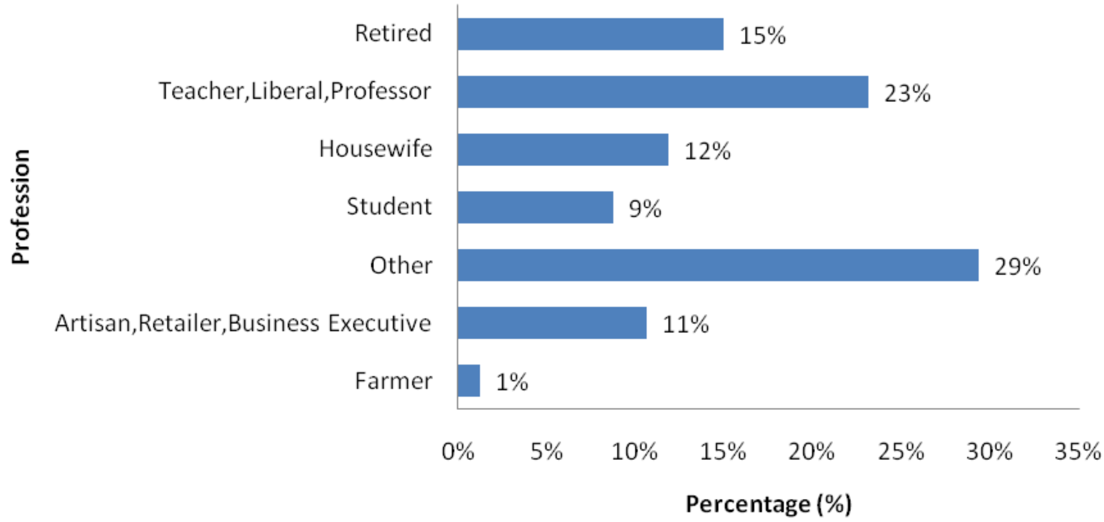


Figure 5.26: *Percentage of Respondents' Profession*

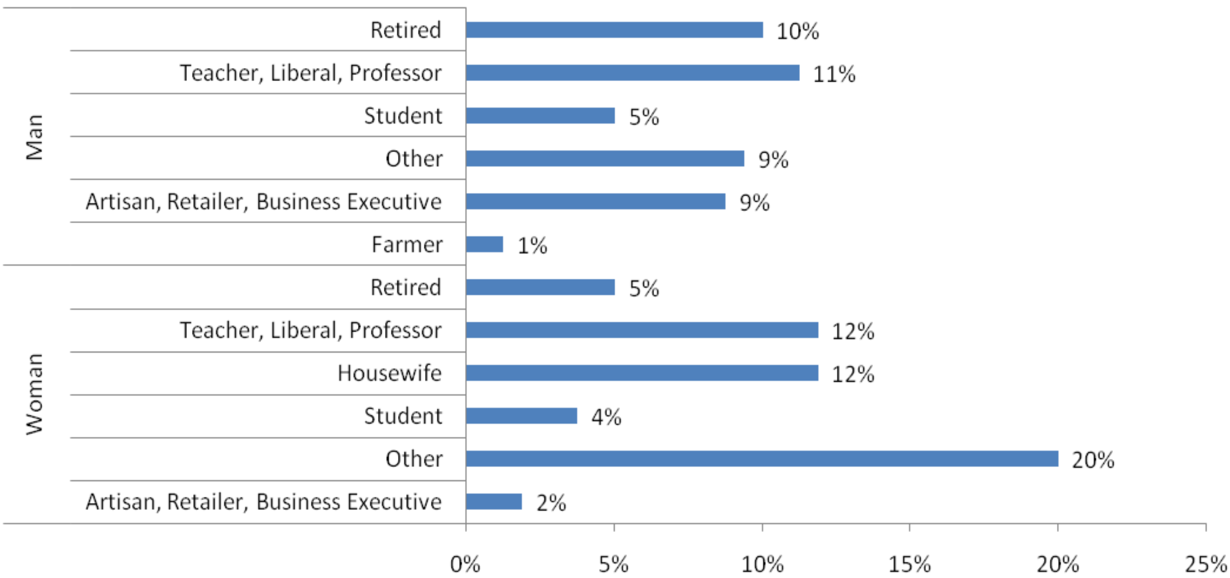


Figure 5.27: *Percentage of Respondents' Profession according to Gender*

V.6.4. Type of Housing

In the questionnaire the respondents had 4 housing categories proposed; Villa with garden, Villa without garden, Detached house, and Apartment.

The type of housing will allow us further to have an idea about the water consumption.

According to figure 5.28 which represents the percentage of housing type of the respondents, we can notice that the majority of the respondents live in apartment (81%), then 7% live in detached house and villa without garden, and only 5% live in villa with garden. Those results are due to the fact that the majority of Boujlida housings are buildings (Boujlida has 8064 dwellings). We have also notices that the type of housing has no significant relation with the profession of the inhabitants, and that for each housing category we may find the same profession. So we cannot conclude in our case that the type of housing is related to the income of the inhabitants.

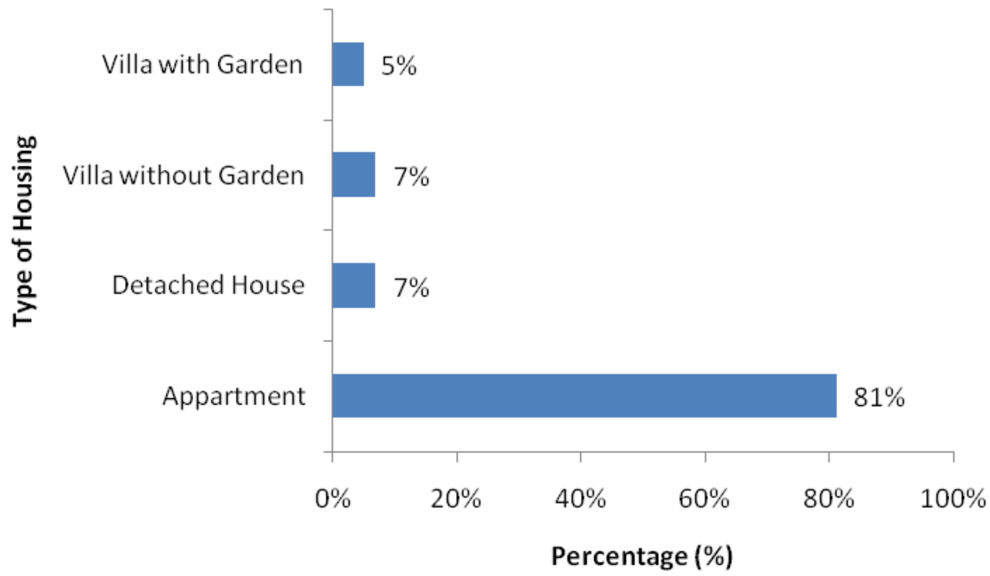


Figure 5.28: *Percentage of the Type of Housing of the Respondents*

V.6.5. Number of Inhabitants per Housing

In the questionnaire, the respondents had to write directly the number of inhabitants per housing. However, to facilitate the presentation of the results we set three ranges of inhabitants; 1 to 4, 5 to 8, and 9 to 12 inhabitants.

The number of inhabitants per housing allows to us to know the total number of inhabitants interviewed, because we suppose that the answers given represents the households.

The figure 5.29 represents the percentage of inhabitants per housing according to the three ranges cited above, we can notice that 49% of housings are composed of 5 to 8 inhabitants, then 47% of 1 to 4 inhabitants, and 4% are composed of 9 to 12 inhabitants. We have also noticed that the housings composed of the highest inhabitants are not specifically for the villas or detached house, we have noticed that even for some apartments, they are more than 6 inhabitants.

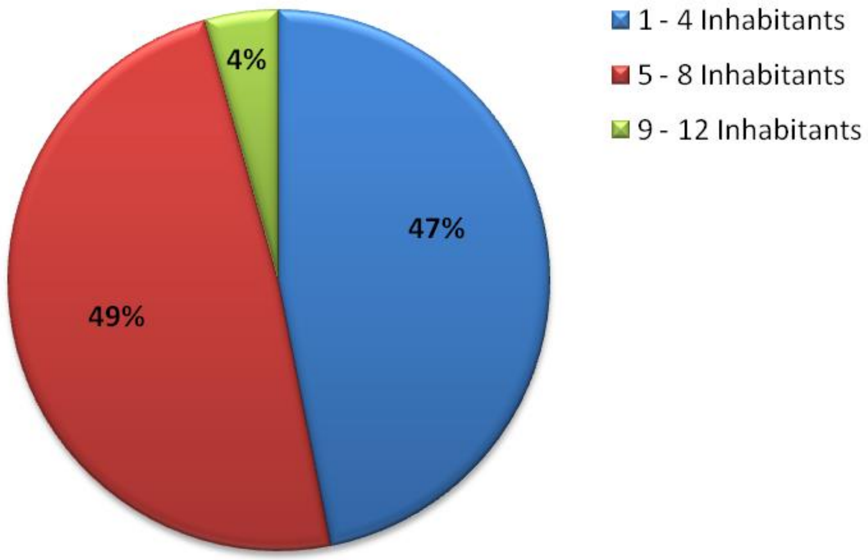


Figure 5.29: *Percentage for Number of Inhabitant per Housing*

V.6.6. Floor that the Respondents Living in Apartment Occupy

In the questionnaire, the respondent who lives in apartment had 6 possibilities for which floor they occupy; from Ground Floor to 5th Floor.

The information about the floor that the respondent occupies will be useful to see if the tap water pressure varies according to the floor.

The figure 5.30 corresponds to the percentage of the floors that the respondents occupy, we can notice that 27% occupy the 3rd floor, 19% the 5th floor, 18% the 4th floor, 15% the 2nd floor, 12% the 1st floor and 8% the ground floor.

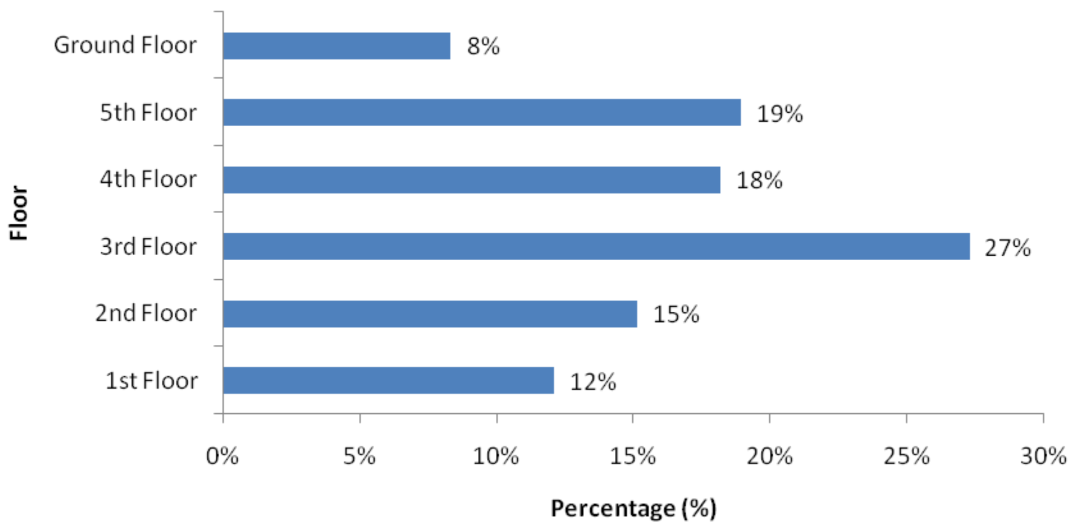


Figure 5.30: *Percentage of the Floor that Respondents Occupy*

V.6.7. Type of House Equipment

In the questionnaire, the respondent had 4 house equipments proposition; Shower, Bathtub, Washer, and Dishwasher. This information allows establishing the water consumption.

Figure 5.31 represents the percentage of house equipment that the respondent have, we can notice that 46% have a shower and a washer, 18% have a shower, a washer and a dishwasher, 17% have only a shower, 8% have a shower, a bathtub and a washer, 7% have the 4 equipments, 3% have bathtub, washer and a dishwasher, and 1% have a bathtub and a washer. We can see that all respondent have a shower or a bathtub which represents the basic sanitation hygiene. All the respondents have a washer except 17%, and only 28% have a dishwasher.

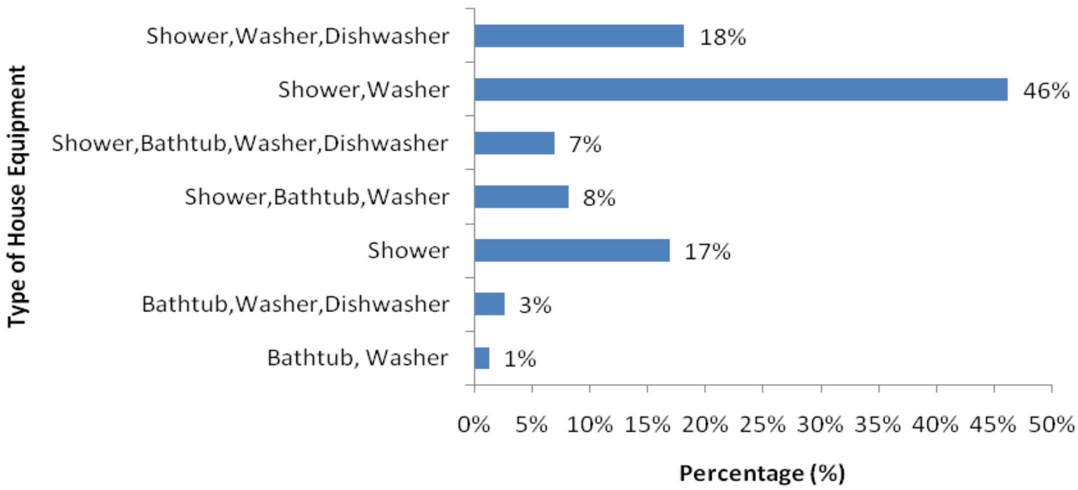


Figure 5.31: *Percentage of Type of House Equipment*

V.6.8. Frequency of Water Supply

In the questionnaire, the respondent had 7 possibilities for the frequency of water distribution; once, twice, 3 times, 4 times, 5 times, 6 times, and 7 times a week.

According to the figure 5.32 which represents the percentage of the frequency of water distribution, we can notice that the majority of the respondents (74%) receive water 3 to 5 times a week, 13% receive water 2 times a week, 3% receive water once a week, and only 10% of the respondents receive water 6 to 7 times a week.

Through our investigation, we have asked the respondents if they know why the frequency of distribution is not steady and why the water supply is not 24/24 7/7, the majority did not know the reason.

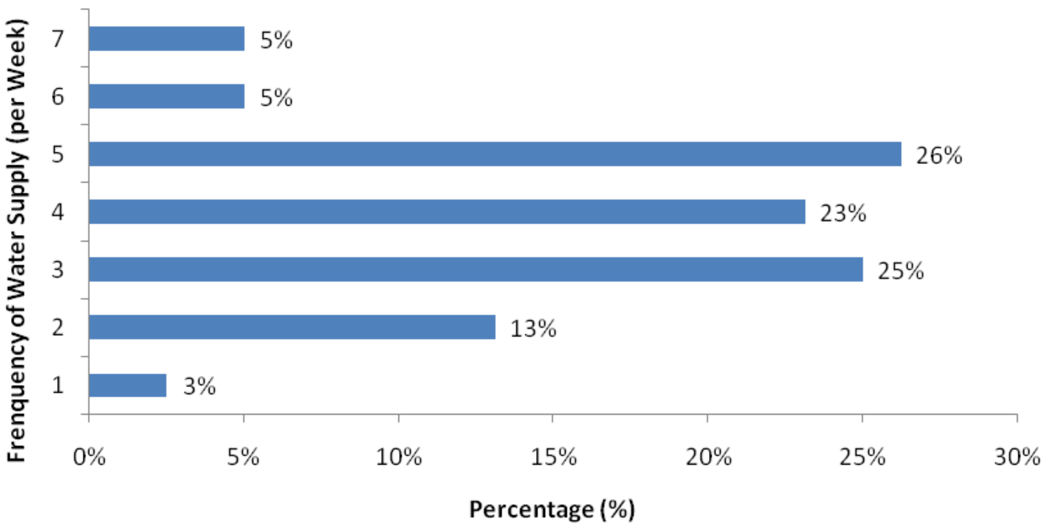


Figure 5.32: *Percentage of Frequency of Water Supply*

V.6.9. Drinking Tap Water or Other Resource

In the questionnaire, the respondents had to tick if they drink tap water or not. According to the figure 5.33 which represents the percentage of people drinking tap water, we can notice that the majority of the respondents (86%) do not drink from tap water and only 14% drink tap water.

In order to know which alternative resources the respondents use if not drinking tap water, an additional question has been added where the respondents had to tick if the alternative resource is buying bottled water or filling water from fountain. According to figure 5.34 which represents the water sources alternative for inhabitants who do not drink from Tap Water, we can notice that 40% of the respondents buy bottled water, and 40% buy bottled water and fill water from fountain, and 20% fill water from fountain.

We have also asked the respondents if they know the origin of the tap water, the majority did not know.

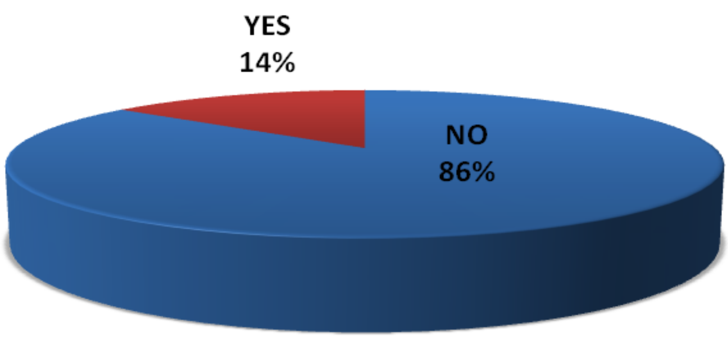


Figure 5.33: *Percentage of Inhabitant Drinking or not from Tap Water*

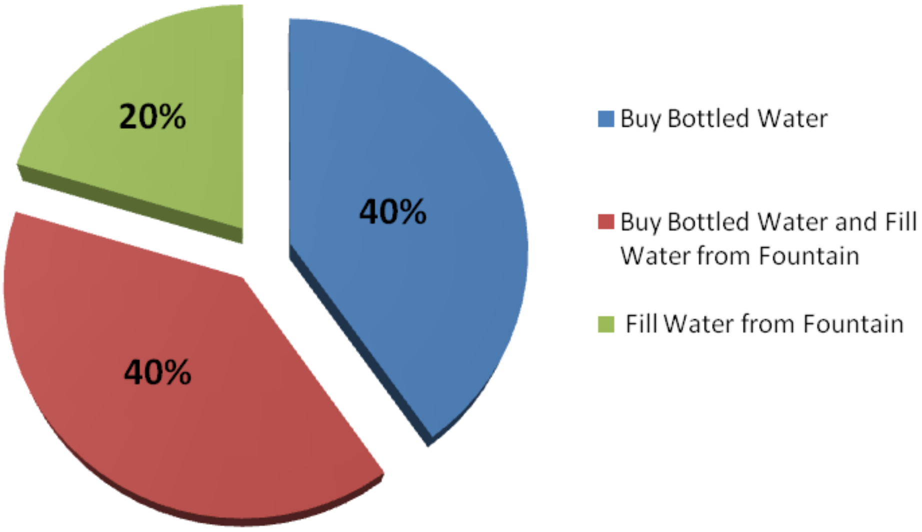


Figure 5.34: *Percentage of which Water Sources Alternative Inhabitant Use if not Drinking from Tap Water*

V.6.10. Tap Water for Cooking

In the questionnaire, the respondents had to tick if they use tap water for cooking or not.

According to the figure 5.35 which corresponds to the use or not for tap water for cooking, we notice that 93% of the respondents use tap water for cooking and only 9% do not.

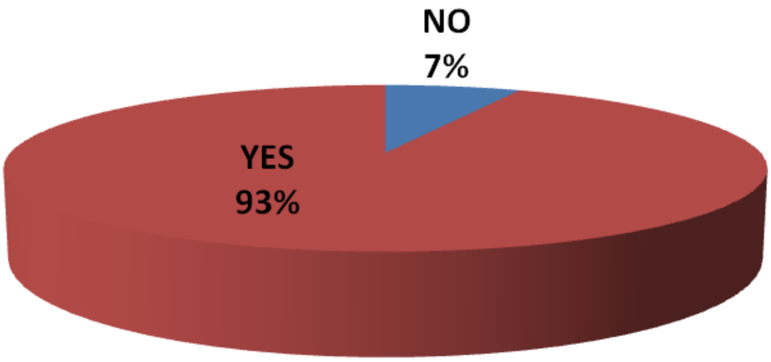


Figure 5.35: *Percentage of Inhabitant Responding if they Use Tap Water for Cooking*

V.6.11. Tap Water Taste and Color

In the questionnaire, in order to assess the organoleptic quality of tap water, we asked the respondent if the tap water has a taste or a color.

Figure 5.36 and 5.37 represent the respondents answer about taste and color respectively, we can notice that 55% respond that tap water has no taste and 45% respond that it has a taste. For the color, the majority (82%) respond that tap water has no color and only 18% respond that it has a color.

The taste and color of tap water could be due to the wear of pipes leading to polluted water intrusion, but also due to rusting of supply network.

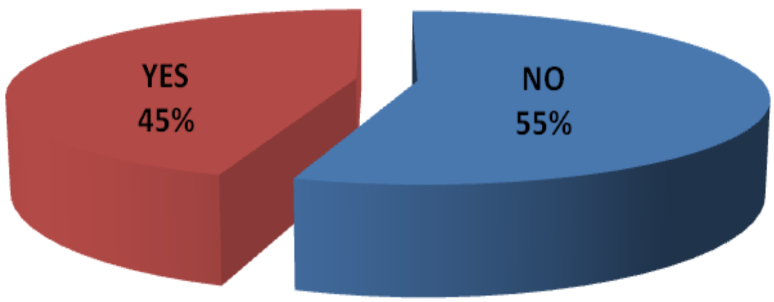


Figure 5.36: *Percentage of Inhabitant Responding if Tap Water has a Taste*

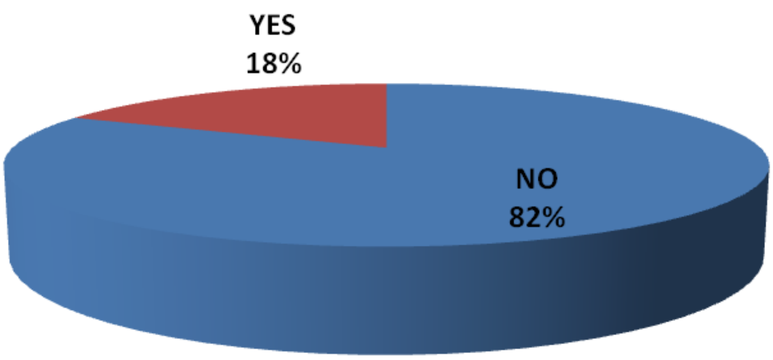


Figure 5.37: *Percentage of Inhabitant Responding if Tap Water has a color*

V.6.12. Tap Water Pressure

In the questionnaire, the respondents had to estimate the tap water pressure; too low, adequate, too high. According to figure 5.38 which represents the responses about tap water pressure, we can notice that 62% of the respondents receive water at an adequate pressure, 33% at a too high pressure, and only 5% at a too low pressure. The high pressures are due to the fact that Boujlida network suffers from several pressure problems due to the fact that the area is formed by several very steep slopes and therefore there is a big difference altitude between the nodes of the network.

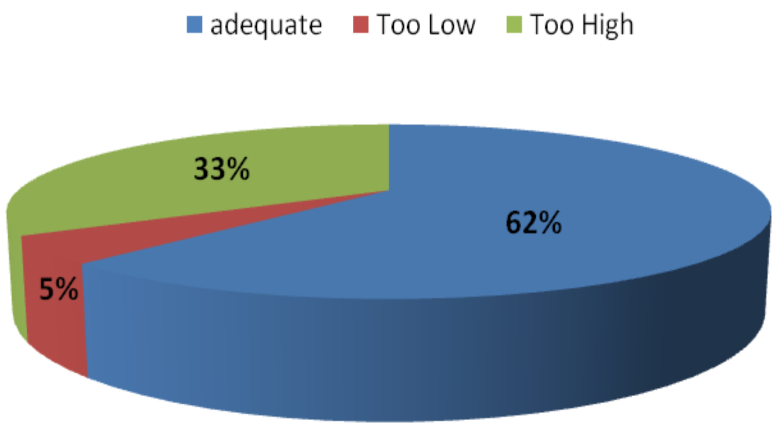


Figure 5.38: *Percentage of Inhabitant Responding about Tap Water Pressure*

V.6.13. Time Slot Corresponding to the Highest Water Consumption

In the questionnaire, the respondents had to choose between 5 ranges that correspond to their highest water consumption; 6am-11am, 12am-2pm, 3pm-7pm, 8pm-midnight, midnight-5am. However, to facilitate the presentation of the results we set 4 ranges of time slot according to the responses; 4pm-11pm, 6am-3pm, 6am-11pm, 6am-5am.

The figure 5.39 represents the time slot for the highest water consumption, we can notice that 39% respond that the highest water consumption is between 4pm to 11pm, 27% respond that it is between 6am to 3 pm, 29% respond that it is between 6am and 11pm and 4% respond between 6am and 5am. The results show that the trend of the highest water consumption is on the afternoons when everyone come back home.

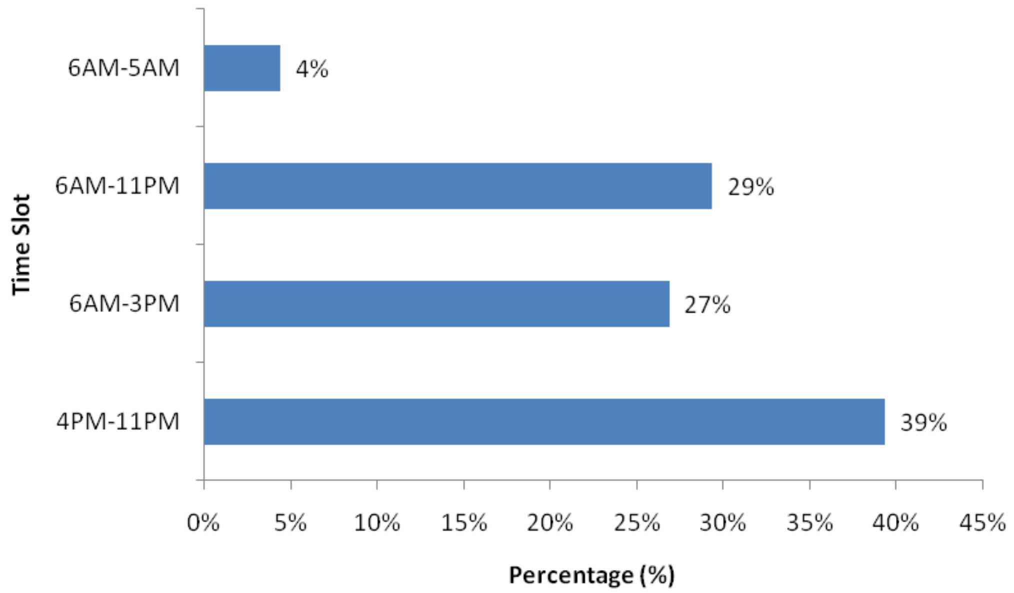


Figure 5.39: *Percentage of Time Slot Corresponding to the Highest Water Consumption*

V.6.14. Water Consumption and Water Needs

In the questionnaire, the respondents had to choose between 3 propositions about their water consumption; low, average or high water consumption.

Figure 5.40 represents the responses about the water consumption trend, we can notice that the majority (70%) of the respondent said that they have an averaged water consumption, 29% said that they have a high water consumption and 1% that they have low water consumption.

An additional question about the coverage of water needs has been added; the respondents had to say if yes or no their water needs have been covered.

The figure 5.41 shows the responses about water needs coverage, we can notice that 19% respond that it was not covered.

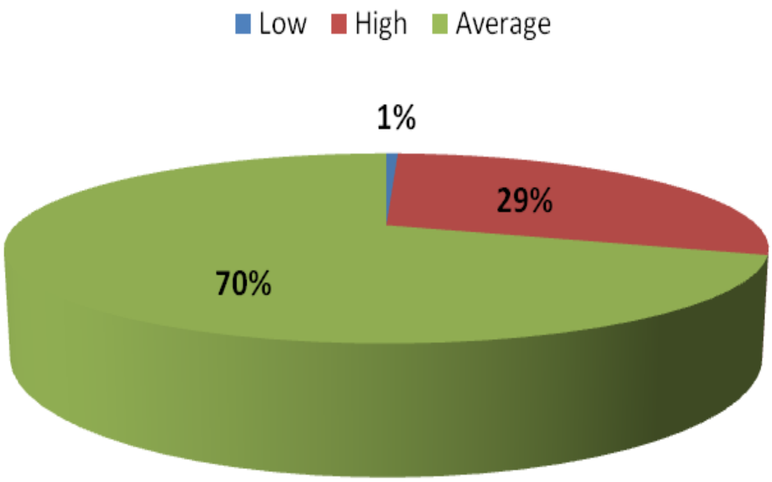


Figure 5.40: *Percentage for Inhabitant Responding about the trend of their Water Consumption*

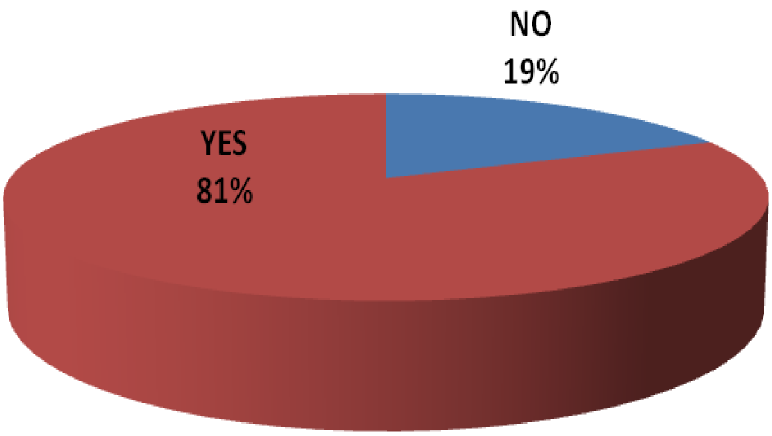


Figure 5.41: *Percentage for Inhabitant Responding if the Water Supplied is Enough to Cover their Water Needs*

V.6.15. Water Bill

In the questionnaire, the respondents had to evaluate their water bill, for that, we have proposed 4 possibilities; not expensive, reasonable, expensive and very expensive.

According to figure 5.42 which represents the responses about the water bill, we can notice that 72% respond that the water bill is reasonable, 20% respond that it is expensive, 6% respond that it is very expensive, and 2% that it is not expensive.

We have also asked the respondent if they are aware about the price of 1 cubic meter of water they are paying, and how the bill is structured (tranche, semester, sanitation, drinking water…), the majority of the respondent did not know.

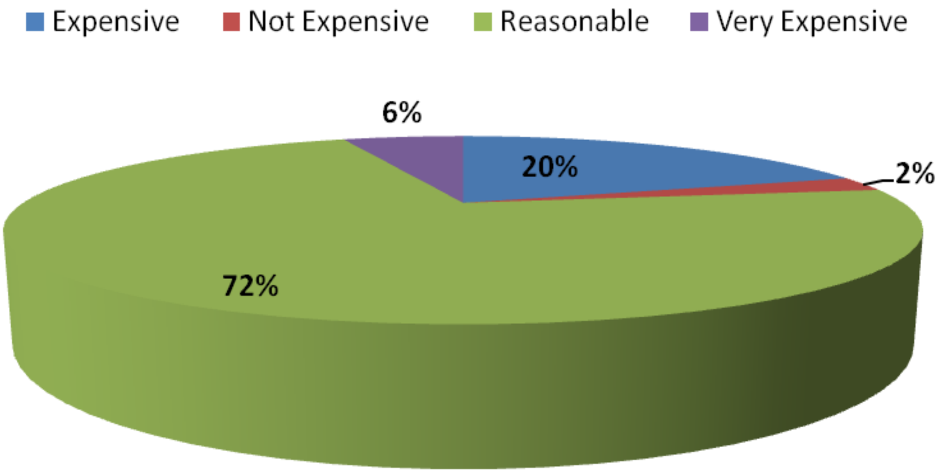


Figure 5.42: *Percentage for Inhabitant Responding about the Water Bill*

V.6.16. Water Tank

In the questionnaire, the respondents had to say if they had or not a tank and if yes its capacity.

The figure 5.43 represents the percentage of respondents that have or not a tank, we can notice that 55% had a tank in their houses, and 45% did not have.

The figure 5.44 represents the percentage of tank capacities, we can notice that 56% of the respondents that have a tank its capacity is between 700 and 1100 liters, 19% have a tank capacity of 200-400 liters, 16% have a tank capacity of 1700-2100 liters, 6% with a tank capacity of 1200-1600 liters, 1% for a tank capacity of 2200-2600 liters, and 1% for a tank capacity of 10000 liters.

We have also noticed that the respondents having water tank are not especially the ones with high incomes, which reflects the impact of water shortages and irregularity in water supply to push inhabitant to store water.

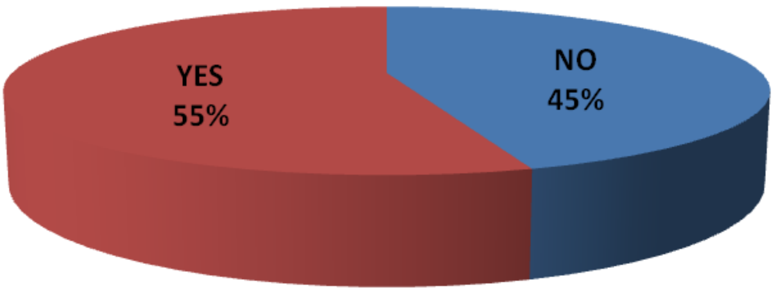


Figure 5.43: *Percentage for Inhabitant Responding if they had a Tank*

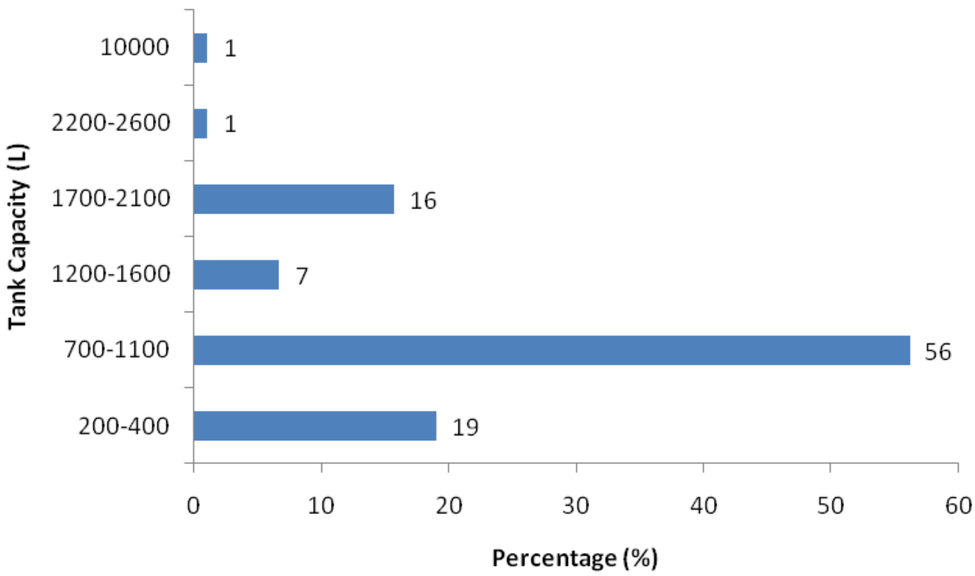


Figure 5.44: *Percentage for Tank Capacity*

V.6.17. Connection to the Sewage Network

In the questionnaire, the respondents had to say whether they are or not connected to the sewage network. According to figure 5.45 which represents the percentage of housing connected or not to the sewage network and figure 5.46, we can notice that 58% are connected to the sewage network, where 48% are apartment, 6% detached house, 3% villa without garden, and 1% villa with garden.

There 42% of housing that are not connected to the sewage network, where 34% are apartment, 4% villa with garden, 4% villa without garden and 1% detached house.

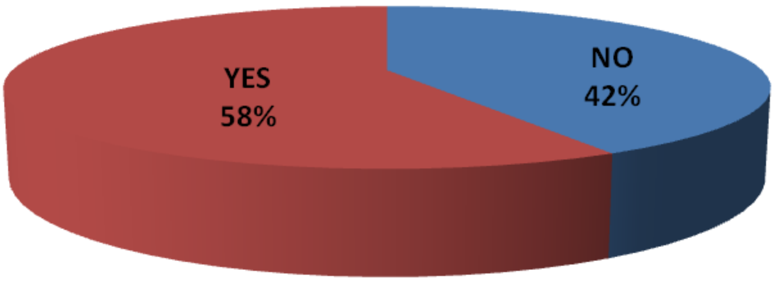


Figure 5.45: *Percentage for Housing Connected or not to the Sewage Network*

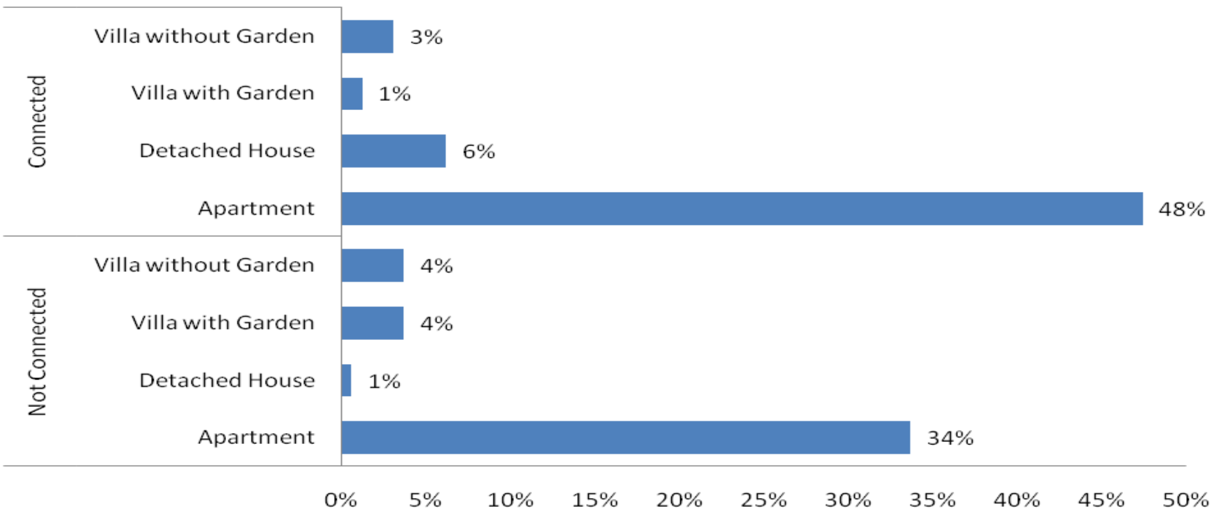


Figure 5.46: *Percentage for Type of Housing Connected or not to the Sewage Network*

V.6.18. Likert Scale for Water Management and Water Quality

In the questionnaire we have asked to the respondents to evaluate the water management and the water quality through a Likert scale.

The figure 5.47 represents the responses for the water management; we can notice that 52% of the respondents evaluate the water management between 4 and 8 on Likert scale, 24% between 7 and 8, 15% between 2 and 3, 8% between 9 and 10, and 2% between 0 and 1.

Figure 5.48 represents the responses for the water quality; we can notice that 53% evaluate the water quality between 5 and 7, 20% between 8 and 9, 27% between 2 and 4, and 1% between 0-1.

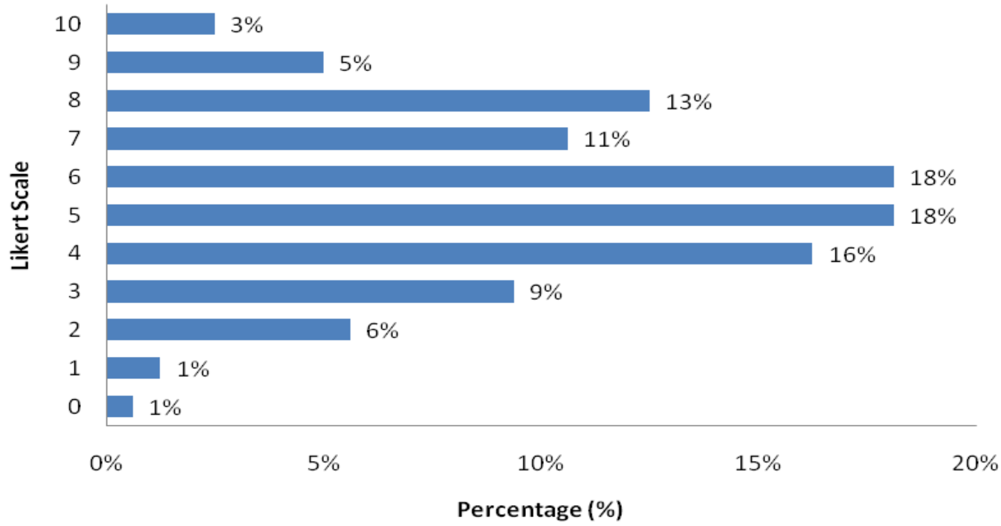


Figure 5.47: *Percentage for Inhabitant Giving a Mark for Water Management*

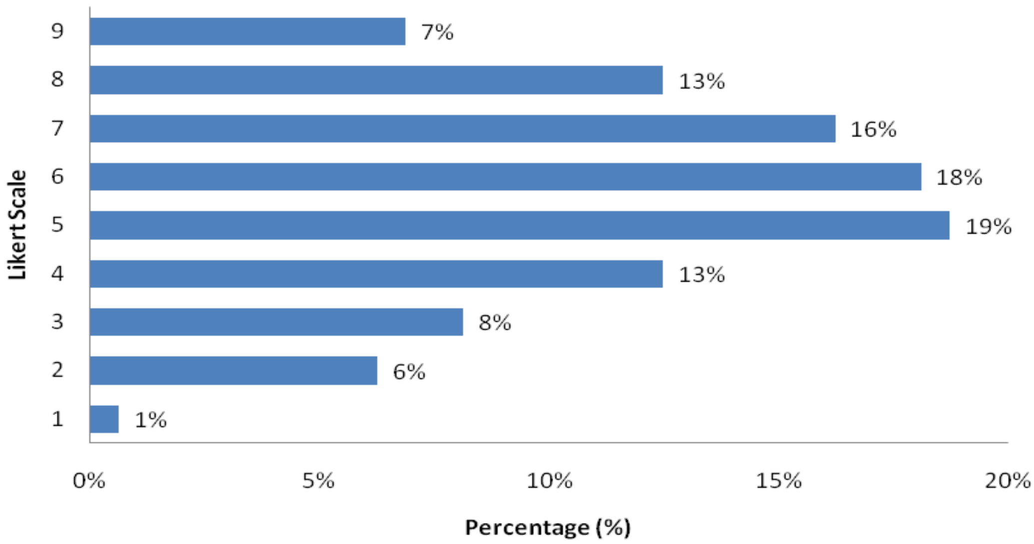


Figure 5.48: *Percentage for Inhabitant Giving a Mark for Water Quality*

Through the survey, we can conclude that there is a lack of communication between ADE and consumers, and there is an inexistent awareness program, neither on the origin of the water consumed nor about the reason for irregularity of water distribution. Moreover, consumers are unaware of the price they are paying for 1 cubic meter of water.

The respondents (33%) complained about the high pressure that the water is supplied which damage their taps and pipes leading to leakages, this is situation is due to the steep slopes which leads to high pressure, and even if there is pressure reducer in the network, some areas still receive water with high pressure.

The majority of the consumers (86%) do not drink tap water even if it has no taste and no color; where 55% stated that it has no taste and 82% stated it has no color, however 93% use it for cooking. The majority of respondents buys bottled water or fills water from fountain and even both.

To remedy the shortage of water, storage becomes widespread; 55% of the respondents had a water tank, 56% had a water tank with a capacity between 700 and 1100 liters. Confronted with the irregularities of supply and the repetitive cuts of water, the households tend to store much more water than what they really need. The storage of water thus led to the development of wasting behavior, a paradoxical practice in the context of shortage. It would be wiser to establish a clear program of rationing with time slots well defined by sectors, to decrease the overconsumption. The water is stored all week in reservoirs often in the terrace roof, exposed to the sun and impurities, which could create an underestimated health risk. The public awareness toward the risks of degradation of the water in reservoirs is practically non-existent.

24% of the respondents consider the water management as very satisfactory (7-8), and 52% as satisfactory (4-8). For the water quality, 20% consider as very satisfactory (8-9), and 53% as quite satisfactory (5-7).

CHAPTER 6: Conclusion and Recommendations

VI.1. Introduction

The study was conducted to assess the Socio-economic impact of water management. Our case of study is a locality named Boujlida, commune of Chetouane located at the city of Tlemcen. A total of 160 questionnaires (corresponding to 728 inhabitants) were administered in the locality of Boujlida in order to determine basic evidence regarding the quality of water supplied, the rate of satisfaction of water needs, the effectiveness of water and sanitation services.

Another aspect of the study has been studied regarding the efficiency of the drinking water supply network, and the evaluation of water needs coverage by water services, we have also studied the efficiency of WWTP of the city of Tlemcen which receives wastewater from the locality of Boujlida.

To summarize; our study is divided on three axes:

- The efficiency and performance of water supply network and the management of water by ADE.
- The efficiency and performance of the WWTP and the management of sanitation by ONA.
- The satisfaction of households about drinking water supply and water management.

This chapter presents the conclusion, and recommendations on the topic relate to this. The recommendations are addressed to water and sanitation services (ADE and ONA), policy makers, household members and leaders to improve or accelerate the water and sanitation improvement.

VI.2. Conclusion

In the field of drinking water supply, performance measurement by indicators relating to the qualitative results of the service appears to be a tool suitable for improving management control. The implementation of this methodology seeks to constitute a common panel of indicators covering all the missions of the drinking water supply services. These indicators, in a limited number and often quite simple to calculate, are ranked in order to guide the choice of the local authority, without however depriving it of the possibility of adapting the list to the specific context of its service.

The primary yield of the water supply network over the studied period (July 2020-2010) for Boujlida was 55% which means that about half of the volume of drinking water introduced into the network is lost. According to ADE, there is the loss of volumes distributed in the new locality of Boujlida that is estimated at 13,392 m^3 per month due to breakage in the HDPE pipes (ϕ315, ϕ250, ϕ200, ϕ160), so the losses can come from other broken pipes that have not been resent, or from illegal pecking. Additional indicators have been studied, where we found that the density of subscribers has shown that the network is urban, that production efficiency is acceptable, and that the loss indices per subscriber are high.

These indicators indicate on the one hand the degree of management of the drinking water supply networks and on the other hand they are considered as criteria influencing the

decision-making in the programming of renovation and rehabilitation works for improving the quality of service provided.
The optimization of the water distribution service for a high efficiency implies the implementation of an adapted and efficient management, which combines both the aspects of rapid maintenance of the network (at the level of the leaks of the HDPE pipes of ϕ315, ϕ250, ϕ200, ϕ160), renovation of the network and improvement of the water supply management.

The water bill covers about 92% of the total cost of water production and distribution (and also salary charge). This deficit is covered by the State in the form of balancing subsidies, planned to compensate for the difference between the actual charges operations and the proceeds of water sales. This results in a low turnover which, combined with the limitation of the tariff, results in difficult financial situation for managers of water and sanitation, which prevent them from ensuring proper functioning the offer of their services to users.
Subsidized water pricing has a negative effect on efficient water use because it encourages wastefulness but the dilemma is that if the Government withdraws its subsidy, the price of water will soar and low-income citizens will no longer afford adequate consumption.
Water Tariffs are economic instruments that help conserve water resources and tackle the challenges of providing water-related services to all citizens at an affordable price.
In practice, consumers pay too little for the water and sanitation services they receive. People are not aware of the real costs of providing water and sanitation services, as these have historically been heavily subsidized by public authorities. This is because water as a social good has been considered an abundant resource. However, with population growth and the needs of much larger communities requiring access to water, the availability of this resource is drastically decreasing in many parts of the world.
The solution may be the multiplication of water price by a factor in a range of 4 to 100 depending on the context to balance water supply and demand; however, it is not the most appropriate solution. The "Real Price" is difficult to implement; because, tariffed water would become inaccessible for the poorest who are generally the most needy; the price of water would be difficult to reflect the environmental costs and the existence value of the resource; the multiplicity of uses of water makes it difficult for a price to correctly reflect the costs of these uses.

The projected population in Boujlida at horizon 2050 is 103882 inhabitants, which is equivalent to a water need of 15582 m^3/day (5687524 m^3/year) for an endowment of 150 L/d/inhab. The population growth combined with the threat of global warming have to lead water managers and planners to think critically about current and future household water needs and how best to meet them. It is therefore necessary to analyze thoroughly patterns of domestic consumption with a view to an overall reduction of demand through optimal use of water.

In the field of sanitation, the performance of the WWTP of Ain El Houtz-Tlemcen has been studied. The study focused on the interpretation of the physico-chemical parameters from 1st - 31th July 2021. Following the obtained results, we can conclude that the quality of the treated wastewater is satisfactory for the reuse in irrigation. The wastewater treatment process of the plant is effective to produce water that meets the reuse standards; however, a tertiary treatment has to be added to eliminate the bacteriological contamination risk since the chlorination is not carried out.

For the quality of service, a survey was conducted among subscribers of Boujlida locality. The themes addressed in this survey relate mainly to general information (gender, type of housing, house equipment), water consumption trend, water supply pattern (frequency, pressure) and consumers satisfaction (quality, management).
The respondents has been divided onto 54% women and 46% men, the majority of the respondents live in apartment (81%), 49% of housings are composed from 5 to 8 inhabitants, and all respondents had a shower or a bathtub and a washer.
The majority of the respondents receive water 3 to 5 times a week, with an adequate pressure, that they use for cooking, however, only 14% drink tap water, and the others buy bottled water and/or fill water from fountains, 55% had a water tank due to the irregularity of distribution. Almost more than half of the respondents stated that tap water has a taste; however, the majority said that it has no color. The majority of the respondents stated that the water bill is reasonable. Only 42% of the housings are connected to the sewage network.

The irregularity of water supply leads to different behaviors among the consumers. Facing the constraints of water rationing, the households adapt themselves using internal storage systems. The use of water depends on the storage capacity and the improvement of the hydraulic equipment installed to ensure adequate internal distribution within the house. The households are ready to invest more to improve their storage systems and internal distribution, to ensure a minimum of comfort. Consumers even call upon the informal water suppliers to satisfy their requirements in spite of the exorbitant costs.

The management of water demand as much as on supply is of critical importance in a country with limited fresh water resources. Reducing water demand must be a major long-term challenge for the management of water resources that integrates sustainability issues in terms of environmental and economic dimensions. The ultimate aim is to consume less by consuming better.

VI.3. Recommendations

Increasing the supply of drinking water means; acting on the demand for this particular product. The management or control of demand (approach in terms of demand) is essential. In addition to the introduction of appropriate technologies, this action takes place by combining the following points:

- Reduction of losses in hydraulic networks and contingency, improvement of pipeline systems, supply and distribution.

- Water saving: water education and massive awareness raising, introduction of educational programs encouraging the preservation of this resource.

- The adoption of a policy of incentives to fight against water wastage (the price of water).

- Preventive maintenance: It is obvious that by carrying out regular and preventive maintenance of piping and equipment inside and outside buildings, the loss of water due to leaks decreases.

- The use of water saving equipment.

In addition, a number of technical measures can be considered in order to improve the results obtained after diagnosis and to optimize the management of the distribution network:

- Analysis of the characteristics of the pipes (age, diameter and material). This analysis is crossed with the sections having experienced leakage problems in order to determine a renewal strategy;

- Analysis of the volumes recorded and billed to the role of water during the last years in order to extrapolate the future evolution of the volumes consumed and the number of subscribers.

- Analysis of production volumes of resources to determine minimum and maximum production capacity. This cross-analysis with the extrapolation of the future population will make it possible to determine the resource-consumption adequacy but also, if applicable, the number of future subscribers who can be connected to the distribution network;

- Improved operating pressure, this effectively reduces the risk of leaks on the network. On the other hand, depending on the pressure conditions on the network, the installation of new devices may be essential;

- Regular monitoring of the volumes distributed in order to avoid drifts and an increase in the volume of leaks.

BIBLIOGRAPHY

A.N.A.T. (2016). Etude de révision de PDAU du groupement des communes de tlemcen – Chetouane – mansourah – Béni Mester. "PDAU revision study of the grouping of communes of tlemcen - Chetouane - mansourah - Béni Mester".

Abdelbaki C. (2014). Modélisation d'un réseau d'AEP et contribution à sa gestion à l'aide d'un SIG -Cas du Groupement Urbain de Tlemcen-. "Modeling of a DWS network and contribution to its management using a GIS - Case of the Urban Group of Tlemcen". Doctorate Thesis. Tlemcen-Algeria.

Abdelbaki C. and Boukli Hacène F. (2007). Etude du phénomène de dégradation des eaux souterraines du groupement urbain de Tlemcen. « Study of the phenomenon of groundwater degradation in the Tlemcen urban group ». Revue des Energies Renouvelables, 10, 257 – 263

Abdelbaki C., Allal M.A., Smir D.S.M. (2012). The supply network of drinking water for urban groupings in Tlemcen - Algeria: efficiency and performance. 6éme Conférence Internationale Ressources en eau dans le bassin mediterraneen, WATMED 6, Sousse, Tunisia.

Abdelbaki C., Touaibia B., Allal M.A. and Kara Slimane F.(2012). Applied systematic approach to water supply network the case of an urban cluster of Tlemcen-Algeria. Procedia Engineering, 33, 30-37.

Abdelbaki C., Touaibia B., Mahmoudi H., Djelloul S.M., Allal M.A., Goosen M.. Efficiency and performance of a drinking water supply network for an urban cluster at Tlemcen Algeria. Desalination and Water Treatment 52 (2014) 2165–2173.

ADE. Algérienne Des Eaux Tlemcen. Internal Documents, not published.

Adjim H. (2004). Evaluation et affectation des ressources hydriques Superficielles du bassin versant de la Tafna. "Assessment and allocation of surface water resources of the Tafna watershed". Magister in Hydraulic Development, University of Tlemcen.

Alinehari A. (2013). Etude de la sécurisation de l'alimentation en eau potable du Groupement Urbain de Tlemcen. « Study of the security of the drinking water supply of the Tlemcen Urban Group ». Master Thesis, University of Tlemcen-Algeria.

Baechler L. (2012). Water Geopolitics and Water Management: Introduction: La bonne gestion de l'eau : un enjeu majeur du développement durable. « Introduction: Good water management: a major challenge for sustainable development ». Centre international de formation européenne, n° 365, 3 à 21

Baghli N., Bouanani A. and Megnounif A. (2012). Génèse de la gestion des bassins. « Genesis of basin management». Séminaire EURO-RIOB.

Belaid N. (2010). Evaluation des impacts de l'irrigation par les eaux usées traitées sur les plantes et les sols du périmètre irrigué d'El Hajeb-Sfax: salinisation, accumulation et phytoabsorption des éléments métalliques. « Assessment of the impacts of irrigation by treated wastewater on the plants and soils of the irrigated perimeter of El Hajeb-Sfax:

salinization, accumulation and phytoabsorption of metallic elements».Doctorate Thesis in Water Soil Environment. University of Limoges-France.

Belmahi A.R and Amiri D. (2018). Collaboration à l'établissement du schéma optimal d'utilisation de la ressource en eau du groupement urbain de Tlemcen, à l'horizon 2050. « Collaboration in the establishment of the optimal plan for the use of the water resource of the Tlemcen urban grouping, by 2050 ». Master Thesis, University of Tlemcen-Algeria.

Benachenhou A. (2005). Le prix de l'avenir. Le développement durable en Algérie. Fortem International, Paris, France, 175 p.

Benblidia M. (2011). L'efficience d'utilisation de l'eau et approche économique. Etude nationale, Algérie. Plan Bleu. Centre d'Activités Régionales PNUE/PAM. « Water use efficiency and economic approach. National study, Algeria. Blue Plan. UNEP Regional Activity Center».

Benbraika A., Ghedab R. (2013). La tarification des coûts relatifs à l'eau en Algérie. « The pricing of water costs in Algeria ». Revue des Sciences Humaines – University Mohamed Khider Biskra-Algeria No: 29.

Benladghem Z. (2017). L'urbanisation et les ressources en eau dans le groupement urbain de Tlemcen. « Urbanization and water resources in the Tlemcen urban grouping ». Master Thesis, University of Tlemcen-Algeria.

Bensaoula F., Bensalah M. and Adjim M.. (2008). L'importance des eaux karstiques dans l'approvisionnement en eau de la population de Tlemcen, "The importance of karst waters in the water supply of the people of Tlemcen". Larhyss journal, 6, 57-64.

Bensaoula F., Bensalah M., Adjim M., (2005). Les forages récents dans les aquifers karstiques des monts de Tlemcen. "Recent drilling in aquifers karsts of the Tlemcen mountains". Larhyss Journal, N°4, 7-15.

Bensaoula F., Bensalah M., Adjim M., (2006). Les forages récents dans les aquifèreskarstiques des monts de Tlemcen." Recent drilling in aquifers karsts of the Tlemcen mountains". Larhyss Journal, N°4, 7-15.

Bensaoula F., Derni I.and Adjim M.. (2012). Trente années de prospection et de mobilisation des ressources en eau souterraine, par forages dans la wilaya de Tlemcen. "Thirty years of prospecting and mobilizing groundwater resources, by drilling in the wilaya of Tlemcen", Larhyss Journal, 10, 91-99.

Bensaoula F.,Adjim M.,Bensalah M.,(2007).L'importance des eaux karstiques dans l'approvisionnement en eau de la population de Tlemcen. "The importance of karst waters in water supply for the population of Tlemcen". Larhyss journal,N°6,57-64.

Benzineb M.Y and Nana Wendpouire A.M. (2018). Contribution à l'optimisation du réseau d'AEP de BOUJLIDA à l'aide d'EPANET et PORTEAU. « Contribution to the optimization of the AEP network of BOUJLIDA with the help of EPANET and PORTEAU». Master Thesis, University of Tlemcen-Algeria.

Berrahma B. (2009), L'étude d'un Nouveau Schéma de répartition des ressources dans le groupement urbain de Tlemcen. "The study of a New Scheme for the distribution of resources in the urban grouping of Tlemcen". Engineer thesis, university of Tlemcen.

Bessedik M. (2019). Pratiques de l'eau en situation de pénurie dans la ville de Tlemcen: Comportement des citadins face au rationnement de l'eau. « Water practices in a scarcity situation in the city of Tlemcen: Behavior of city dwellers in the face of water rationing ». Edition Universitaire Européenne. 245p.

Bouanani A. : (2004) Hydrologie, transport solide et modélisation. Etude de quelques sous bassin de la Tafna (NW-Algérie). « Hydrology, solid transport and modeling. Study of some sub-basin of the Tafna (NW-Algeria) ». Doctorate thesis in Hydrogeology, University of Tlemcen-Algeria.

Bouazzi K. (2016). Etude de la consommation eau des ménage à Tlemcen. « Study of household water consumption in Tlemcen». Master Thesis, University of Tlemcen-Algeria.

Bouchekima B., Bechki D., Bouguettaia H., Boughali S. and Meftah M.T. (2008). The underground brackish waters in South Algeria: potential and viable resources.13th IWRA World Congress, Montpellier-France.1-4.

Bouchentouf S. and Benabdeli K., (2021). Water resources and food security in Algeria: Diagnosis and new strategy proposition. African Journal of Agricultural Research, 17, 414-424, DOI: 10.5897/AJAR2020.15125

Boukhari S., Djebbar Y., Guedri A. and Guebail A.K. (2011). The impact of actual water pricing in Algeria on the environmental dimension of sustainable development. J. Mater. Environ. Sci., 2, 427-432.

Boukhari S.and de Miras C. (2019). Performance économique des services d'eau potable et d'assainissement en Algérie, cas de Souk-Ahras. "Economic performance of water supply and sanitation services in Algeria, case of Souk-Ahras". Revue des sciences de l'eau / Journal of Water Science, 32, 53–66. https://doi.org/10.7202/1059880ar

Boukherissi M. (2015). AMDEC (Analyse des Modes de Défaillances, de leurs Effets et de leur Criticité) appliquée à la STEP d'Ain El Houtz. « Analysis of failure modes, their dffects and their criticality applied to the Ain El Houtz WWTP ». Master Thesis. University of Tlemcen.

Bouziani-Boubou N. and Maliki S. (2009). Innovations technologiques et gestion de l'eau en Algérie : La maîtrise de la demande. « Technological innovations and water management in Algeria: Controlling demand ». Les cahiers du MECAS, N°5 ,26-37

Bouziani-Boubou N. and Maliki S.. (2014). La crise de l'eau : entre réalité, enjeu et perspectives. "The water crisis: between reality, issue and prospects ".Les cahiers du MECAS N°10.

Bouzid-Lagha S. and Djelita B. (2012). Etude du phénomène d'eutrophisation dans le Barrage de Hammam Boughrara (Wilaya de Tlemcen, Algérie). « Study of the eutrophication phenomenon in the Hammam Boughrara Dam (Wilaya of Tlemcen, Algeria) ». Hydrological Sciences Journal, 57, 186-201, DOI: 10.1080/02626667.2011.634417

CEDARE (2014), "Algeria water sector m&e rapid assessment report", monitoring & evaluation for water in north africa (mewina) project, water resources management program, CEDARE.

Cembrowicz R.G., Deuerlein J., Sanzenbacher G., GOMER D., and Brade R. (2004). Mängelanalyse und Rehabilitation des Wasserversorgungsnetzes einer algerischen Stadt, Beispiel Tlemcen (Deficiency analysis and rehabilitation of the water supply network of an Algerian city, example Tlemcen). GWF-Wasser/Abwasser, 145,788-797.

Chaib Draa Tani M. (2019). Acteurs de l'eau et leurs interactions dans la gestion de l'eau au niveau du bassin versant Tafna. « Water stakeholders and their interactions in water management at the level of the Tafna watershed ». Master Thesis, University of Tlemcen-Algeria.

Chareb-Yssaad I. Gestion intégrée et économie de l'eau. Cours de licence réseaux hydrauliques. « Integrated management and water saving. Hydraulic network license course ». University of Tlemcen-Algeria. https://ft.univtlemcen.dz/assets/uploads/pdf/departement/hyd/Chapitre2.pdf

Chikh H.A. Kateb Z., Bessaklia H. and Habi M. (2018). Performance and suitability study of wastewater reuse for irrigation using intensive follow-up of Tlemcen rejects. *Revue scientifique et technique 32, 20-28*

Djelouah K. (2018). Accès à l'eau et à l'assainissement en Algérie. « Access to water and sanitation in Algeria». UNCTAD multi-year expert meeting on trade, services and development water and sanitation, Energy and Food-related Logistics Services Geneva, 7-8 May.

Do Carmo Lourenço da Silva M. (2008). Effet de la variabilité du fractionnement de la pollution carbonée sur le comportement des systèmes de traitement des eaux usées par boues activées. « Effect of variability in carbon pollution fractionation on the behavior of activated sludge wastewater treatment systems ». National Polytechnic Institute of Lorraine-France.

Fecih A., Habi M. and Harrouz O. (2018). Regulation of the service water distribution by the performance indicators: case of unit Tlemcen. Larhyss Journal, 35, 133-151.

Ferah R.and Farhi K. La tarification actuelle de l'eau potable Appliquée en Algérie et Son efficacité. « The current pricing of drinking water applied in Algeria and its effectiveness ». Revue d'économie et de statistique appliquée.

Gomella C. (1985). Guide de l'alimentation en eau dans les agglomérations urbaines et rurales Tome I: La distribution. « Guide to water supply in urban and rural areas Volume I: Distribution ». Edition Eyrolles, Paris, 227 p

Habi M, Morsli B. (2011). Contraintes et perspectives des retenues collinaires dans le Nord-Ouest algérien. « Constraints and perspectives of hill reservoirs in the Algerian North-West ». Sécheresse 22, 49-56. doi : 10.1684/sec.2011.0293

Habi M. and Harrouz O. (2015). Domestic water conservation practices in Tlemcen City (Algeria). Appl Water Sci, 5, 161–169. DOI 10.1007/s13201-014-0175-9

Habi M., Klingel P., Vogel M.. (2016). Domestic water consumption in Algeria – case study Tlemcen. Larhyss Journal, 27, 125-136.

Kertous M.. (2010). La gestion de l'eau potable en Algérie, quelle stratégie face aux contraintes économiques et climatiques? 6e colloque international: Stratégies de développement: Quel chemin parcouru? Quelles réponses face aux nouvelles contraintes économiques et climatiques?, "The management of drinking water in Algeria, what strategy in the face of economic and climatic constraints? 6th international conference: Development strategies: How far have we come? What responses to new economic and climatic constraints?". 21-23 June, Hammamet, Tunisia, Report, 21 p.

Kherbache N.and Oukaci K.. (2017). Essai d'évaluation du coût économique de la réalisation des cibles des objectifs du millénaire pour le développement liés à l'eau potable en Algérie. "Trial to assess the economic cost of achieving the targets of the Millennium Development Goals related to drinking water in Algeria". Revue des sciences de l'eau, 30, 157–169. doi:10.7202/1042924ar

Kherbouche Z. and Soufi M.W. (2016). Etude des indicateurs de performance des services des réseaux d'AEP, Cas du groupement urbain de Tlemcen. « Study of performance indicators for DWS network services, Case of the Tlemcen urban group ». Master Thesis, University of Tlemcen-Algeria.

Mailler R. (2015). Devenir des micropolluants prioritaires et émergents dans les filières conventionnelles de traitement des eaux résiduaires urbaines des grosses collectivité (files eau et boues), et au cours du traitement tertiaire au charbon actif. « Become priority and emerging micropollutants in conventional urban wastewater treatment channels in large communities (water and sludge lines), and during tertiary treatment with activated carbon. Environmental engineering ». University Paris-Est-France.

Maliki S.B. (2006). Politique de l'eau en Algérie : les modèles marchands face à la pauvreté. « Water policy in Algeria: market models in the face of poverty ». Les Cahiers du MECAS, N° 2.

Maliki S.B.E., Benhabib A., and Charmes J. (2009). households poverty and water linkages: evidence from Algeria. Topics in Middle Eastern and North African Economies, electronic journal, 11, Middle East Economic Association and Loyola University Chicago, 2009, http://www.luc.edu/orgs/meea/

Mestar M. and Benaouda E-H. (2018). Contribution à l'étude de sectorisation du réseau d'AEP du chef lieu de Chetouane. « Contribution to the sectorization study of the DWS network in the capital of Chetouane». Master Thesis, University of Tlemcen-Algeria.

Metahri M., (2012). Elimination simultanée de la pollution azotée et phosphatée des eaux usées traitées, par des procédés mixtes cas de STEP de la ville de Tizi-Ouzou. "Simultaneous elimination of nitrogen and phosphate pollution from treated wastewater, by mixed processes case of WWTP in the city of Tizi-Ouzou”. Doctorate Thesis, University of Mouloud Mammeri. Tizi-Ouzou-Algeria.

Mozas M. and Ghosn A. (2013). État des lieux du secteur de l’eau en Algérie. « State of the water sector in Algeria ». IPEMED-Institut de Prospectivité Economique du Monde Méditéranéen.

Naimi-Ait-Aoudia M., Berezowska-Azzaga E.. (2018). Algiers carrying capacity with respect to per capita domestic water use. Sustainable Cities and Society, 13, 1–11. http://dx.doi.org/10.1016/j.scs.2014.03.006

National Institute of Development, (2001). Institut national de perfectionnement de l’équipement INPE. Séminaire sur l’économie de l’eau.

Office de l’eau. (2011). Rapport d’étude sur les rendements des réseaux d’eau potable des communes de l’île de la Réunion. “Study report on the yields of drinking water networks in the municipalities of Reunion Island”. 34p.

ONA. Office National de l’Assainissement. Internal Documents, not published.

Rahmoun S. (2018). Water quality indices as important tools for water quality assessment in wwtp: the case of the waste water treatment plan of Ain El Hout Tlemcen. Master Thesis, PAUWES-Tlemcen-Algeria

Renaud E. (2009). Valeurs de référence de l’indice linéaire de pertes des réseaux d’alimentation en eau potable. ‘Reference values of the linear index of losses of drinking water supply networks”. SMEGREG. 63p.

Renou S. (2006). Analyse de cycle de vie appliquée aux systèmes de traitement des eaux usées. « Life cycle analysis applied to wastewater treatment systems ». Génie des procédés. National Polytechnic Institute of Lorraine-France.

Smail F. (2017). Ressources en eau et urbanisation cas du groupement urbain Tlemcen. « Water resources and urbanization case of the Tlemcen urban grouping ». Master Thesis, University of Tlemcen-Algeria.

SOGREAH/ICEA. (2002). Société grenobloise d'études et d'applications hydrauliques et ingenieurs conseil et economistes associes. Étude nationale sur la tarification de l’eau à usage domestique et industriel (1re partie). Ministere des Ressources en eau (MRE). “Grenoble-based company for hydraulic studies and applications, consulting engineers and associated economists. National study on the pricing of water for domestic and industrial use (Part 1). Ministry of Water Resources”. Algeria, 97 p.

Tapio S. Katkoa, and Jarmo J. Hukkaa. (2015). Social and economic importance of water services in the built environment: need for more structured thinking. Procedia Economics and Finance 21, 217 – 223

Taylor P., Gabbrielli E., and Holmberg J. (2008). Les aspects économiques dans la gestion durable de l’eau. « Economic aspects in sustainable water management ». Manuel de formation et Guide des facilitateurs, 163p.

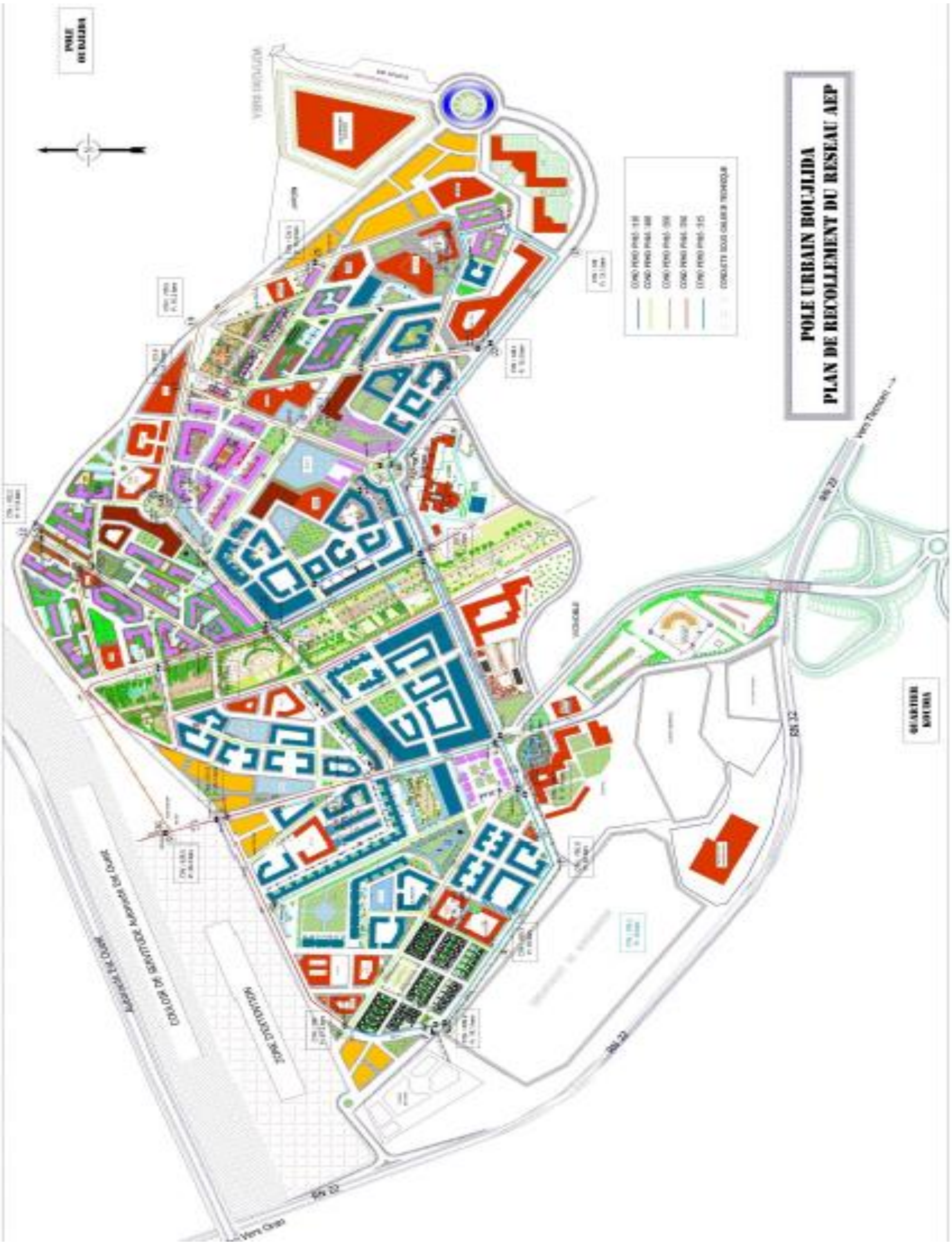
Titi Benrabah S., Kherici Bousnoubra H., Kherici N., Cote M. (2013). Assessment and management of water resources in Northeastern Algeria: case of watersheds Kebir West Safsaf and Guebli rivers, Skikda. Appl Water Sci, 3, 351–357. DOI 10.1007/s13201-013-0085-2

Valiron F. (1994). Mémento du gestionnaire de l'alimentation en eau potable et de l'assainissement, Tome 1, 2, 3. « Memento of the manager of drinking water supply and sanitation ». Edition Lavoisier, 1262 p.

Zeroual A.and Meddi M. (2013). Water distribution network leakage in Bordj-Bou-Arreridj City, Algeria. 5th International Conference on Water Resources and Sustainable Development, 24-25 fevrier 2013, Algiers, Algeria, pp. 335- 340.

APPENDICES

Appendice A: Boujlida DWS Network



Appendice B: Description of the WWTP of Ain El Houz

Description	Process
The domestic wastewater and rainwater from the city of Tlemcen are conveyed gravitationally by a collector of 1250 mm diameter. From the storm weir the wastewater will be transported gravitationally towards the treatment plant by a pipe made of concrete. During the rainy period, the exceeded wastewater to the inflow rate to be treated will be deviated laterally through a channel towards the wadi of Ain El Houtz. It is sized to handle a maximum of 3300 m^3/h	 Photo A.1: Storm weir
The station includes two screens, the first is mechanized and the second manual. • Coarse manual grid (1 unit); - Grid width: 1.8m - Incline: 70% - Distance between bars: 50 mm • Mechanized grid (2 units); - Grid width: 1.0m - Channel depth: 1.5m - Distance between bars: 20mm - Motor power: 0.37kw	 *Photo A.2: Mechanical Screening*  *Photo A.3 : Manual Screening*
The station includes two trapezoidal sand and oil separator, it is equipped with a suction bridge and skimmer 26 m long and 4 m wide.	 *Photo A.5: Desander- oil separator*
The station has four rectangular aeration tanks, each of which has the following dimensions; - Volume: 4723 m3 - Length: 55.5 m - Width: 18.5m - Water depth: 4.6 m - Concrete height: 5.6 m	 *Photo A.6: Aeration basins*

The station includes two circular settling tanks 46 m in diameter, with a surface area of 1661 m3, with a water depth of 4 m at the periphery each is equipped with a scraper bridge with a rotation speed of 0.04 m / s.	 *Photo A.7: Secondary settling tanks*
The station includes a reinforced concrete chlorination basin with a volume of 700 m^3. Following a malfunction in the chlorination tank, the injection of chlorine to the water coming from the secondary settling tank was interrupted, and since then no disinfection has been carried out.	 *Photo A.8: Chlorination tank*
The station includes an Archimedean screw to recirculate a fraction of the sludge settled in the clarifier to the aeration basins to maintain a sufficient bacterial biomass level. The second fraction is pumped to the thickener.	 *Photo A.9.: Recirculation*
The mud thickener is made of reinforced concrete, with a diameter of 14m, a useful height of 4m, and a bottom slope of 1/10.	 *Photo A.10: Mud thickener*
The station has fourteen drying beds 30 m long and 15 m wide.	 *Photo A.11: Drying beds*

Appendice C: Method of analysis of the wastewater at the WWTP of Ain El Houtz

C.1. Temperature

Among the physical parameters that characterize different environments, water temperature is one of the most important environmental characteristics, which determine, to a considerable extend, the trend of change in its quality. In the WWTP of Ain El Houtz, the temperature is measured using a thermometric probe, which is soaked carefully in the water sample. Then, the reading of the value is done after the stabilization of the thermometer.

C.2. pH

It expresses the acidity or basicity of water. The pH value of water is determined by the concentrations of H+ ion and OH- ion. Water with a pH of 7 has equal concentrations of H+ ion and OH- ion and is considered to be a neutral solution. If a solution is acidic (pH less than7), the concentration of H+ ion is greater than the concentration of OH- ion. If a solution is basic (pH greater than 7), the concentration of H+ ion is less than the concentration of OH- ion. In the WWTP of Ain El Hout, the measurement of the pH is based on the use of a WTW brand pH meter.

Photo C.1: *pH Meter*

C.3. Electrical Conductivity

Conductivity is the measure of the capacity of a water to conduct an electric current. Expressed in micro Siemens per centimeter, its value varies according to the temperature. It is measured at 20 °C and related to the concentration of total dissolved salts. In the WWTP of Ain El Houtz, the conductivity is measured using a HANNA brand conductivity meter.

Photo C.2: *Electrical Conductivity Measurement*

C.4. Suspended Solids (SS)

Total suspended matters are composed of organic and mineral fine particles, insoluble and are the source of the turbidity of water. They limit the penetration of light into the water, decrease the dissolved oxygen content, and harm the development of aquatic life. The materials and experimental procedure used to determine the total suspended matters in the laboratory are explained below:

- Vacuum pumps
- Filtration unit
- Micro fiberglass filters
- Stove
- Desiccator
- Analytical balance
- Pliers

- **Experimental Procedure**

a. The filter is washed in the vacuum filtration unit by passing distilled water, then placed in the stove at a temperature of 103 to 105 °C, during 2 hours. It will then be kept in a desiccator and weighed.

b. After that, the filter is placed in the funnel of the filtration device, and connected to a vacuum suction device.

c. A sample volume of the treated wastewater is filtered in a few seconds.

d. We carefully remove the filter from the funnel using flat-ended pliers. It is then weighed using the analytical balance.

e. Then the filter is dried at about 105 °C, cooled, and finally weighed to get the suspended matter results.

The following formula is used to obtain the results:

TSS (mg/l) = (M2-M1)*1000/V

Where:

TSM: Total suspended matters (mg/l)

M2: Mass of the filter after drying (mg)

M1: Mass of the empty filter, before filtration (mg)
V: Volume of the water sample filtered (ml)

Photo C.3: Micro Fiberglass Filters, Analytical Balance, Filtration Unit, Desiccator (left to right)

C.5. Dissolved Oxygen (DO)

The amount of oxygen gas dissolved in water (DO) is important for the survival of most aquatic organisms as it provides them with oxygen to carry out cellular respiration. In the WWTP of Ain El Hout, dissolved oxygen is measured using a HANNA brand oximeter. The oximeter probes are placed in the water sample. The reading of the value is done after the stabilization of the oximeter.

Photo C.4: *Dissolved Oxygen Measurement*

C.6. Biological Oxygen Demand (BOD_5)

The concentration of organic matter in wastewater is measured by the biological oxygen demand (BOD) value. BOD measures the amount of dissolved oxygen the microorganisms require to oxidase or decompose the organic matter present in the wastewater. In the laboratory, the amount of oxygen is expressed under the conditions of the test (incubation for 5 days at 20 °C in the darkness).

- **Principle**

The measurement of the BOD_5 is based on the measurement of the pressure in a closed system where microorganisms consume oxygen in the sample and generate carbon dioxide (CO_2) emissions. The carbon dioxide CO_2 is absorbed with sodium hydroxide (NaOH), and negative pressure is created then measured directly by the transmitter. The transmitter transforms the pressure value directly to the BOD_5 (mg /l). With sample volumes, we regulate the amount of available oxygen which can make a complete determination of BOD at different concentrations and with different volumes.

- **Materials and Reagents**

For the BOD system, we have:
- Measuring heads (BOD sensors)
- Measuring bulbs brown
- Magnetic stirrers
- Pliers
- Rubber carcass for the necks of the bulbs
- Sodium hydroxide (NaOH) lenses
- Thermostatic incubator with constant temperature at 20 degree Celsius
- Inhibitor of nitrification.
- Containers and pipettes of several sizes
- Distilled water
- Calibration tablet for system controls VELP: D (+) glucose $C_6H_{12}O_6$ and L-glutamic acid $C_5H_9NO_4$.

- **Experimental Procedure**

a. A sample volume corresponding to the desired BOD to be obtained is selected.
b. We clean the bulbs with distilled water to lighten them, then with the sample of the treated water.
c. Add a quantity of the homogenized sample.
d. Agitate each bulb with a magnetic stirrer.
e. Put on the neck of the bulb a rubber carcass. Inside, add with the pliers the lenses of NaOH. Then fill with the treated water up to the limit without exceeding.
f. The bulbs are placed in an incubator for the measurement of BOD_5.The incubator is set to zero value and starts working for five days at 20°C. The result of the value will be displayed directly on the device.

Photo C.5: *Biological Oxygen Demand Measurement*

C.7. Chemical Oxygen Demand (COD)

Chemical oxygen demand represents the quantity of oxygen required to chemically stabilize the carbonaceous organic matter using strong oxidizing agents under acidic conditions. The method used to determine the COD in the laboratory of Ain Temouchent is described below:

- **Principle**

The test consists of a chemical oxidation of the organic matter by a strong oxidant (acid) at high temperature and by the potassium dichromate ($K_2Cr_2O_7$).Oxidizable substances react with a sulfuric acid (H_2SO_4) solution and potassium dichromates in the presence of silver sulphates (Ag_2SO_4) as a catalyst. The presence of chloride is masked with mercury sulfate ($HgSO_4$). We measure the decrease of the yellow coloring of Cr6+. The result is expressed in mg O_2 /l (milliliter ppm O_2).

- **Materials and Reagents**

The following material are used:
- COD measurement kits
- Distilled water (dissolution cleaning).
- Digester HACH COD REACTOR
- Spectrophotometer DR 2000
- Gradette support
- Graduated pipette 2 ml
- Pipette aspirator 2 ml

- **Experimental Procedure**

a. We select the COD program: this program heats the vat for 2 hours at 150 °C. During the cooling phase, four sound signals indicate that the vats have been cooled to a temperature of 120°C.

b. The vats are prepared by mixing the kit contents to have a homogeneous solution and 2 ml of water sample are pipetted carefully.

c. The thermostat heats up to the set temperature. Two sound signals indicate that the required temperature has been reached.

d. Then the vats are placed in a heating block HACH COD REACTOR , while closing the protective cover. We put the vats in the conventional COD digester during two hours at 150 °C.
e. We remove the hot vat and invert carefully twice.
f. The vat is cooled at room temperature in the vat support.
g. Finally, we clean the outside part of the vat and measure it with a HACH brand spectrophotometer.

Photo C.6: *Chemical Oxygen Demand Measurement*

C.8. Phosphates (PO_4^{3-})

Phosphorous is a macronutrient essential to all plants and microorganisms growth. Phosphorous concentration determines the level of eutrophication phenomena. Total phosphorous exist in organic (combined with organic matter) and inorganic (orthophosphates and polyphosphates) forms. Agricultural wastes fertilizers contain high levels of phosphates that enter the water through runoff and erosion. Phosphorus in the form of phosphate (PO_4^{3-}) is an essential plant nutrient and is a major component of most fertilizers. 56

- **Principle**

Phosphate ions react in acidic solution with molybdate ions to give an antimony molybdate phosphorus complex. The ascorbic acid to phosphorus-molybdenum blue reduces this.

- **Materials and Reagents**

- Measuring kit HACH DR 2000
- Distilled water.
- HACH DR 2000 spectrophotometer.
- Graduated pipette 2 ml.
- Aspirators pipette 2 ml.

- **Experimental procedure**

a. Enter a stored program number for reactive phosphorus powder pillow
b. Press 490 READ/ENTER, the display will show: DIAL nm TO 890
c. Press: READ/ENTER the display will show: mg/l PO_4^{3-} PV or mg/l P PV
d. Fill a sample cell with 25 mL of sample
e. Add the contents of one PhosVer3 phosphate Powder Pillow to the sample cell (the prepared sample). Swirl immediately to mix.
f. Press: SHIFT TIMER, A 2-minute reaction will begin.
g. Fill another sample cell (the blank) with 25 mL of sample. Place it into the cell holder
h. Whene the timer beeps, this display will show: ml/l P PV, Press ZERO the display will show: WAIT, then 0.00 mg/l PO_4^{3-} PV or 0.00 mg/l P PV.
i. Place the prepared sample into the cell holder. Close the light shield.
j. Press: READ/ENTER the display will show: WAIT the results in mg/L P will be display.

NOTE: for conversion of Phosphorus:
• mg/l PO_4^{3-} PV = mg/l P* 3.07
• mg/l P_2O_5 =mg/l P* 2.25
• mg/l P_2O_5 =mg/l PO_4^{3-} 0.75

Photo C.7: *Phosphates Measurement*

C.9. Nitrites (N-NO_2^-)

Nitrite (NO_2^-) is the degrardation of Nitarates and it toxic to human health.

- **Principle**

Nitrite reacts with p-aminophenylmercaptoacetic acid in the presence of hydrochloric acid to form a diazonium cation, which is subsequently coupled with N-(1-naphthyl) ethylenediamine dihydrochloride in acidic medium to form a stable bluish violet azo dye.

- **Materials and Reagents**

- Measuring kit HACH DR 2000
- Distilled water.
- HACH DR 2000 spectrophotometer (Photo V.7)
- Graduated pipette 2 ml.
- Aspirators pipette 2 ml.

- **Experimental Procedure**

1. Enter a stored program number for reactive of Nitrate small concentration.
2. Press 351 READ/ENTER, the display will show: DIAL nm TO 507
3. Press: READ/ENTER the display will show: mg/l NNO_2^-
4. Fill a sample cell with 25 mL of sample
5. Add the contents of one NitriVer3 phosphate Powder Pillow to the sample cell (the prepared sample). Swirl immediately to mix.
6. Press: SHIFT TIMER, A 15 minutes reaction will begin.
7. When the timer beeps, this display will show: mg/l NNO_2^-, Fill another sample cell (the blank) with 25 mL of sample. Place it into the cell holder
8. Press ZERO, the display will show: WAIT, then 0.00 mg/l N NO2- L
9. Place the prepared sample into the cell holder. Close the light shield.
10. Press: READ/ENTER the display will show: WAIT the results will be display.

C.10. Nitrates Nitrogen (N-NO_3^-)

Nitrogen is a macronutrient essential for plants and microorganism's growth. Nitrate-nitrogen is the final product in the oxidation of ammonia produced in the first stage of the decomposition of nitrogen. Nitrates are non-hazardous inorganic compounds but when degraded to nitrite (NO_2^-) becomes very toxic to human health.

- **Principle**

In a sulfuric acid solution and phosphoric, nitrates react with the dimethylphenol to give nitro-dimethyl phenol.

- **Materials and Reagents**

- Measuring kit HACH DR 2000 (Photo V.7)
- Distilled water.
- HACH DR 2000 spectrophotometer.
- Graduated pipette 2 ml.
- Aspirators pipette 2 ml.

- **Experimental Procedure**

1. Enter a stored program number for reactive of Nitrate small concentration.
2. Press 351 READ/ENTER, the display will show: DIAL nm TO 507
3. Press: READ/ENTER the display will show: mg/l N-NO_3^-
4. Fill a sample cell with 30 mL of sample
5. Add the contents of one Nitrate Ver6 phosphate Powder Pillow to the sample cell (the prepared sample). Swirl immediately to mix.
6. Press: SHIFT TIMER, A 3-minute reaction will begin.
7. When the timer beeps press: SHIFT TIMER a second period of reaction of 2 min will begin to allow cadmium to be settle
8. When the timer beeps fill another sample cell (the blank) with 25 mL of sample
9. Add to it one Powder Pillow of Nitrite Ver3
10. Press: SHIFT TIMER, A 10-minute reaction will begin.

11. When the timer beeps, this display will show: mg/l NO_3^-, Fill another sample cell (the blank) with 25 ml of sample. Place it into the cell holder
12. Press ZERO
13. Place the prepared sample into the cell holder. Close the light shield.
14. Press: READ/ENTER the display will show: WAIT the results will be display.

C.11. Ammonium Nitrogen N-NH_4^+

Nitrogen from wastewater is in organic and inorganic forms. Inorganic forms are immediately available to the plant while microorganisms must mineralize organic forms. The mineral forms of nitrogen are ammonium and nitrate.

- **Principle**

In the presence of sodium acting as a catalyst and at a pH value of about 12.6, the ammonium ions react with hypochlorous and salicylic ions to give a blue color.

- **Materials and Reagents**

- Nitrite measurement kit
- Distilled water.
- Spectrophotometer HACH DR 2000 (Photo V.7)
- Graduated pipette 2ml.
- Aspirator pipette 2ml.

- **Experimental Procedure**

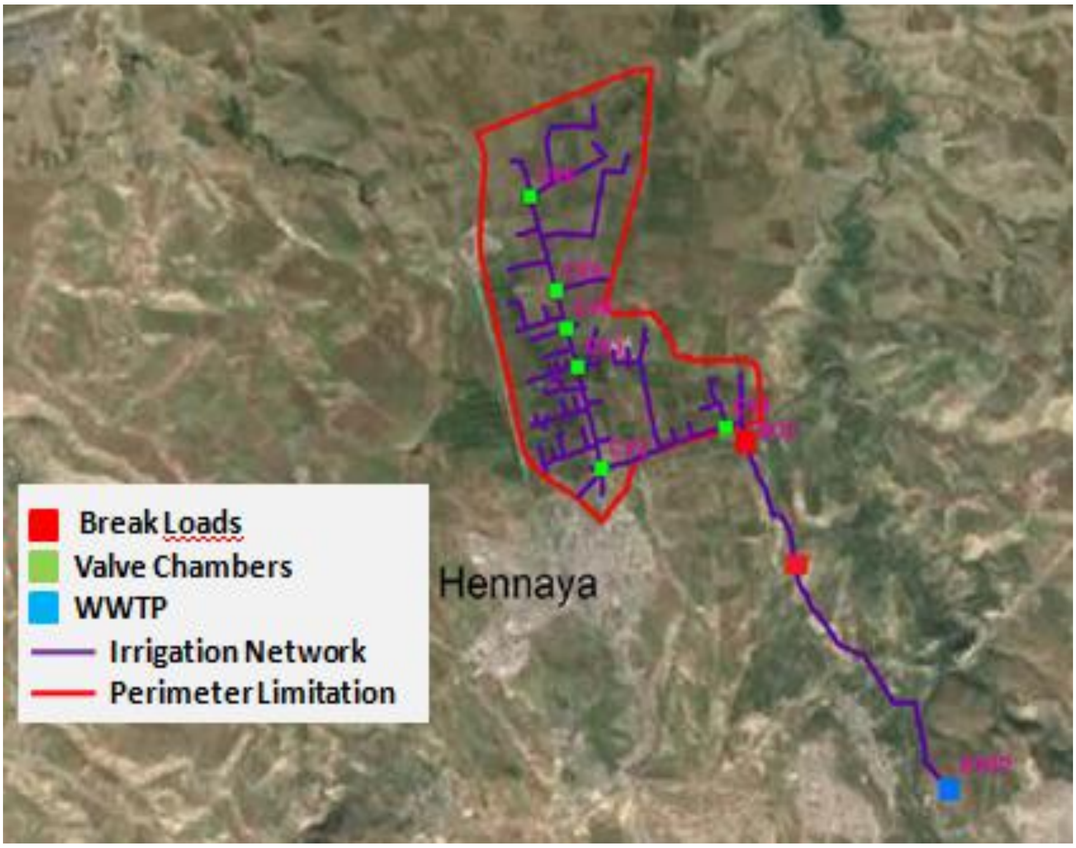
1. Enter the stored program number for Ammonia Nitrogen (NNH_3^-), Press: 380 READ/ENTER, the display will show: DIAL nm 425
2. Press: READ/ENTER the display will show: mg/l N NH_3 Ness
3. Fill a sample cell with 25 ml of sample
4. Fill another 25 ml mixing graduated cylinder with demineralized (the bank)
5. Add three drops of Mineral Stabilizer to each cylinder. Invert several times to mix. ADD three drops of polyvinyl Alcohol Dispersing Agent to each cylinder.
6. Pipette 1.0 ml of Nessler Reagent into each cylinder. Stopper. Invert several time to mix.
7. Press: SHIFT TIMER, 1 minute reaction will begin.
8. Pour each solution into respective blank and prepared sample cells.
9. When the timer beeps, the display will show: mg/l N NH_3 Ness Place the blank into the cell holder. Close the light Shield.
10. Press ZERO the display will show: WAIT, then 0.00mg/l N NH_3 Ness
11. Place the prepared sample into the cell holder. Close the light shield.
12. Press: READ/ENTER, the display will show WAIT then the result will be displayed

Photo C.8: *Samples from the Inlet (left) and Outlet (right) of the WWTP to be Analyzed*

NB:

- Raw Water means water at the inlet of the WWTP took from the storm spillway, the treated water means the water at the outlet of the WWTP took from the chlorination basin, and the discharge norm is the limitation values to be respected before discharging or reusing.
- The analysis of Temperature, SS, DO, pH, Turbidity, and Conductivity are made daily, however, for the COD, BOD, N-NO_2, N-NO_3, PO_4 are analyzed four times per month, generaly on Thursday.

Appendice D: Hennaya Irrigation Perimeter



Appendice E : Algerian Norms for Treated Wastewater Reuse in Irrigation

Paramètres	Normes
pH	6.5 à 8.5
Conductivité électrique (ms/cm)	<3*
MES (mg/1)	<70*
DCO (mg/1)	<40*
$DB0_5$	<30*
$N0_3^-$ (mg/1)	<50*
$N0_2^-$ (mg/1)	<1*
$P0_4^3$-(mg/l)	< 0.94*
HCO_3 (mg/1)	500**
$S0_4^{2+}$ (mg/1)	400**
CL" (mg/1)	1065**
Ca^{2+}(mg/l)	400**
Na^+ (mg/1)	920**
Mg^{2+}(mg/l)	60.75**
Cd^{2+} (mg/1)	0.01*
Pb^{2+} (mg/1)	0.05*
Zn^{2+}(mg/l)	2*
Cr^{6+}	0.1*
NH_4^+ (mg/1)	<2*

Source: *OMS (1989), ** FAO (2003)

Appendice F : Questionnaire (French Version)

Q1 : Personne Enquêtée

Femme Homme

Q2 : Quelle profession exercez-vous ?

Artisan, commerçant, chef d'entreprise Prof, libéral, intellectuelle supérieur

Agriculteur Retraité Etudiant Femme au foyer Autre

Q3 : Age de la personne enquêtée ....

Q4 : Type d'habitat

Villa sans jardin Villa avec jardin Appartement Maison individuelle

Q5 : Si vous habitez un appartement, quel étage occupez-vous ?

Rez-de-chaussée 1er étage 2ème étage 3ème étage 4ème étage 5ème étage

Q6 : Equipement de la maison

Douche Baignoire Machine à laver Lave vaisselle

Q7 :Fréquence de distribution de l'eau

Tous les jours 1fois/semaine 2fois/semaine 3fois/semaine
4fois/semaine 5fois/semaine 6fois/semaine

Q8 : Buvez-vous de l'eau du robinet ?

Oui Non

Q9 : Si vous ne buvez pas l'eau du robinet, est ce que vous

Achetez de l'eau Remplissez l'eau d'une source

Q10 : Utilisez-vous l'eau du robinet pour cuisiner ?

Oui Non

Q11 : L'eau du robinet a-t-elle un goût ?

Oui Non

Q12 : L'eau du robinet a-t-elle une couleur

Oui Non

Q13 : Est-ce que la pression de l'eau du robinet est
Trop forte Adéquate Trop faible

Q14 : A quel moment de la journée pensez-vous consommer le plus d'eau

De 6h à 11h De 12h à 14h De 15h à19h De 20h à minuit

De minuit à 5h

Q15 : Pensez-vous que votre consommation en eau est

Elevée Moyenne Basse

Q16 : Pensez-vous que la quantité d'eau que vous recevez dans votre robinet suffit à vos besoins ?

Oui Non

Q17 : Pensez-vous que la facture de l'eau est

Très cher Cher Prix raisonnable Pas cher

Q18 : Avez-vous un réservoir ?

Oui Non

Q19 : Si vous avez un réservoir, il est de quelle capacité ....

Q20 : Nombre de personnes qui occupent le logement ....

Q21 : Etes-vous branché au réseau d'assainissement (réseau d'égout) ?

Oui Non

Q22 : Sur une échelle de 1 à 10, comment évaluez-vous la gestion de l'eau ....

Q23 : Sur une échelle de 1 à 10, comment évaluez-vous la qualité de l'eau ....

Appendice G: Questionnaire (English Version)

Q1 : Surveyed person

Woman Man

Q2 : What is your profession ?

Artisan, Retailer, Business Executive Teacher, liberal, Professor

Farmer Retired Student Housewive Other

Q3 : Age of the surveyed person ....

Q4 : Housing Type

Villa without garden Villa with garden Appartment Detached house

Q5 : If you live in an appartment, which floor do you occupy ?

Ground floor 1st 2nd 3rd 4th 5th

Q6 : House Equipement

Shower Bathtub Washer Dishwasher

Q7 : Water Distribution Frequency

Everyday Once a week Twice a week 3 times/week 4 times/ week
5 times/week 6 times/week

Q8 : Do you drink tap water ?

Yes No

Q9 : If you do not drink tap water, do you

Buy Bottled Water Fill water from a fountain

Q10 : Do you use tap water for cooking ?

Yes No

Q11 : Does water have a tase ?

Yes No

Q12 : Does tap water have a color ?

Yes No

Q13 : Does the tap water water pressure

Too high   Adequate   Too low

Q14: Time Slot Corresponding to the Highest Water Consumption

6am-11am   12am-2pm   3pm-7pm   8pm-midnight   midnight-5am

Q15 : Do you think that your water consumption is

High   Average   Low

Q16 : Do you think that the tap water that you receive is enough to cover you water needs ?

Yes   No

Q17 : Do you think that the water bill is

Very expensive   Expensive   Reasonable   Not exspensive

Q18 : Do you have a water tank ?

Yes   No

Q19 : If you have a water tank, what is its capacity ....

Q20 : Number of persons occupying the housing ....

Q21 : Are you connected to the sewage network ?

Yes   No

Q22 : On a scale from 1 to 10, how do you evaluate the water management ....

Q23 : On a scale from 1 to 10, how do you evaluate the water quality ....

Appendice H : Responses of the Questionnaire

Q1	Q2	Q3	Q4	Q5
W	Other	26	Appartment	5
M	Teacher, liberal, Professor	42	Appartment	4
W	Other	32	Appartment	5
M	Retired	78	Appartment	2
W	Other	29	Appartment	3
W	Teacher, liberal, Professor	42	Appartment	5
M	Artisan, Retailer, Business Executive	63	Detached House	GF
M	Student	33	Appartment	3
M	Student	32	Appartment	3
M	Other	42	Detached House	GF
W	Other	24	Appartment	2
W	Teacher, liberal, Professor	38	Detached House	GF
W	Other	38	Appartment	3
M	Other	32	Appartment	1
W	Student	18	Appartment	1
M	Artisan, Retailer, Business Executive	45	Villa with Garden	GF
W	Housewive	45	Appartment	GF
M	Farmer	52	Appartment	3
W	Housewive	45	Appartment	4
M	Other	36	Appartment	3
W	Teacher, liberal, Professor	36	Appartment	4
M	Retired	53	Appartment	2
W	Housewive	38	Appartment	5
W	Housewive	36	Appartment	2
M	Artisan, Retailer, Business Executive	46	Villa without Garden	GF
M	Retired	60	Villa without Garden	GF
M	Teacher, liberal, Professor	55	Appartment	4
W	Student	19	Appartment	2
M	Teacher, liberal, Professor	38	Appartment	3
W	Student	23	Appartment	5
M	Other	35	Appartment	4
M	Artisan, Retailer, Business Executive	28	Villa without Garden	GF
W	Student	19	Appartment	5
M	Artisan, Retailer, Business Executive	40	Villa without Garden	GF
W	Other	34	Appartment	3
M	Teacher, liberal, Professor	44	Appartment	3
M	Retired	60	Villa without Garden	GF
W	Retired	61	Appartment	GF
M	Student	22	Appartment	GF
W	Teacher, liberal, Professor	50	Detached House	GF
W	Teacher, liberal, Professor	46	Appartment	2
W	Student	24	Appartment	5

M	Other	35	Villa without Garden	GF
M	Retired	65	Appartment	2
W	Artisan, Retailer, Business Executive	28	Detached House	GF
W	Teacher, liberal, Professor	48	Appartment	4
M	Retired	72	Appartment	3
W	Other	32	Appartment	1
W	Artisan, Retailer, Business Executive	32	Appartment	1
W	Retired	65	Villa with Garden	GF
M	Retired	68	Villa without Garden	GF
M	Other	39	Appartment	3
M	Teacher, liberal, Professor	40	Appartment	GF
W	Retired	75	Appartment	4
W	Teacher, liberal, Professor	52	Appartment	4
M	Retired	63	Appartment	3
W	Housewive	56	Villa without Garden	GF
M	Artisan, Retailer, Business Executive	62	Appartment	GF
M	Retired	75	Appartment	4
M	Retired	62	Appartment	2
W	Retired	62	Appartment	1
M	Retired	67	Appartment	3
M	Teacher, liberal, Professor	41	Appartment	2
M	Teacher, liberal, Professor	48	Appartment	4
W	Other	38	Appartment	4
W	Other	44	Appartment	5
M	Other	38	Appartment	3
W	Other	32	Appartment	5
W	Artisan, Retailer, Business Executive	38	Appartment	2
M	Student	28	Appartment	3
W	Housewive	45	Appartment	2
M	Retired	78	Appartment	1
W	Other	28	Villa without Garden	GF
M	Other	48	Appartment	5
W	Other	32	Appartment	3
W	Other	46	Appartment	3
M	Teacher, liberal, Professor	42	Appartment	5
W	Housewive	40	Villa with Garden	GF
W	Other	22	Appartment	3
M	Retired	68	Appartment	1
M	Teacher, liberal, Professor	41	Appartment	3
M	Artisan, Retailer, Business Executive	58	Villa without Garden	GF
W	Housewive	42	Appartment	1
W	Housewive	48	Appartment	3
W	Housewive	58	Appartment	2
W	Teacher, liberal, Professor	36	Appartment	1
M	Student	21	Appartment	5

M	Retired	58	Appartment	GF
W	Housewive	38	Appartment	5
W	Teacher, liberal, Professor	48	Villa with Garden	4
M	Other	51	Appartment	GF
W	Teacher, liberal, Professor	41	Appartment	3
W	Retired	72	Appartment	1
M	Artisan, Retailer, Business Executive	56	Detached House	GF
W	Housewive	41	Appartment	3
M	Other	35	Appartment	4
W	Student	24	Appartment	5
M	Artisan, Retailer, Business Executive	58	Appartment	1
M	Teacher, liberal, Professor	48	Appartment	4
W	Other	42	Appartment	3
W	Teacher, liberal, Professor	40	Appartment	1
W	Teacher, liberal, Professor	38	Appartment	4
W	Housewive	40	Appartment	5
M	Student	28	Appartment	3
W	Retired	80	Appartment	3
M	Other	43	Appartment	3
M	Teacher, liberal, Professor	44	Appartment	3
W	Other	44	Appartment	1
W	Other	45	Appartment	1
W	Other	25	Appartment	1
M	Other	24	Villa with Garden	GF
M	Retired	65	Appartment	5
W	Other	30	Appartment	1
M	Retired	79	Villa with Garden	GF
W	Housewive	43	Villa with Garden	GF
M	Artisan, Retailer, Business Executive	54	Villa without Garden	GF
W	Housewive	45	Appartment	4
W	Housewive	64	Appartment	5
M	Other	43	Villa with Garden	GF
W	Housewive	43	Appartment	2
M	Farmer	32	Appartment	2
M	Artisan, Retailer, Business Executive	52	Detached House	GF
M	Teacher, liberal, Professor	42	Appartment	4
W	Retired	66	Detached House	GF
W	Other	36	Appartment	GF
W	Other	39	Appartment	5
M	Other	36	Appartment	2
W	Other	32	Appartment	GF
M	Teacher, liberal, Professor	43	Appartment	3
M	Artisan, Retailer, Business Executive	49	Detached House	GF
W	Other	40	Appartment	4
W	Other	34	Appartment	3

M	Teacher, liberal, Professor	39	Appartment	5
M	Teacher, liberal, Professor	46	Appartment	4
W	Other	44	Appartment	4
W	Teacher, liberal, Professor	38	Appartment	3
W	Retired	78	Appartment	2
M	Artisan, Retailer, Business Executive	41	Detached House	GF
W	Teacher, liberal, Professor	42	Appartment	GF
W	Teacher, liberal, Professor	38	Appartment	3
W	Other	32	Appartment	5
W	Other	28	Appartment	4
W	Other	32	Appartment	4
M	Teacher, liberal, Professor	48	Appartment	3
W	Teacher, liberal, Professor	38	Detached House	GF
W	Teacher, liberal, Professor	38	Appartment	3
W	Other	30	Appartment	5
W	Housewive	40	Appartment	4
M	Other	42	Appartment	4
M	Student	28	Appartment	3
M	Teacher, liberal, Professor	40	Appartment	5
W	Other	35	Appartment	3
W	Other	30	Appartment	2
W	Housewive	27	Appartment	5
W	Teacher, liberal, Professor	33	Appartment	5
M	Artisan, Retailer, Business Executive	38	Appartment	2
M	Student	28	Appartment	2
M	Teacher, liberal, Professor	25	Appartment	5
W	Teacher, liberal, Professor	41	Appartment	2
W	Other	28	Appartment	3

W: women, M: man, GF: ground floor

Q6	Q7	Q8	Q9	Q10	Q11
Shower,Washer,Dishwasher	4	No	Buy	Yes	No
Shower,Washer	5	No	Buy and Fill	Yes	No
Shower,Washer	5	No	Buy and Fill	Yes	No
Shower,Washer	5	No	Buy and Fill	Yes	No
Shower,Washer	6	No	Buy and Fill	Yes	No
Shower,Washer	5	No	Buy and Fill	Yes	No
Shower,Washer,Dishwasher	6	No	Buy and Fill	Yes	No
Shower,Washer	5	No	Buy and Fill	Yes	No
Shower,Washer	4	No	Buy and Fill	Yes	No
Shower,Washer,Dishwasher	4	No	Buy and Fill	Yes	No
Shower,Washer	4	No	Buy and Fill	Yes	No
Shower,Washer,Dishwasher	5	No	Buy and Fill	Yes	No
Shower,Washer	5	No	Buy and Fill	Yes	No
Shower,Washer	5	Yes	/	Yes	No

Shower	4	No	Fill	Yes	Yes
Shower, Bathtub, Washer	4	No	Buy	No	Yes
Shower	3	No	Buy	Yes	Yes
Shower	2	No	Buy	Yes	Yes
Shower,Washer	3	No	Buy	Yes	Yes
Shower	4	No	Fill	Yes	Yes
Shower, Bathtub, Washer,Dishwasher	3	No	Buy	Yes	Yes
Shower,Washer	3	No	Fill	Yes	Yes
Shower	3	No	Buy	Yes	Yes
Shower,Washer	3	Yes	/	Yes	No
Shower, Bathtub, Washer	6	No	Buy	No	Yes
Shower, Bathtub, Washer,Dishwasher	7	No	Buy	Yes	Yes
Shower,Washer	5	No	Buy	No	Yes
Shower,Washer	5	No	Buy	Yes	Yes
Shower,Washer	3	No	Buy and Fill	Yes	No
Shower, Bathtub, Washer	4	No	Fill	Yes	Yes
Shower,Washer	3	No	Fill	Yes	Yes
Shower,Washer,Dishwasher	7	No	Buy	Yes	Yes
Shower, Bathtub, Washer	2	No	Buy	Yes	Yes
Shower	7	No	Fill	Yes	Yes
Shower,Washer,Dishwasher	3	No	Buy and Fill	Yes	No
Shower,Washer,Dishwasher	3	No	Buy and Fill	Yes	No
Shower, Bathtub, Washer	3	Yes	/	Yes	No
Shower	3	No	Fill	Yes	No
Shower,Washer	3	No	Fill	Yes	Yes
Shower,Washer,Dishwasher	3	No	Buy and Fill	Yes	Yes
Shower,Washer	3	No	Buy	Yes	Yes
Shower,Washer,Dishwasher	2	No	Buy and Fill	Yes	Yes
Shower, Bathtub, Washer,Dishwasher	7	No	Buy	Yes	Yes
Shower, Bathtub, Washer,Dishwasher	3	No	Fill	Yes	Yes
Shower,Washer,Dishwasher	7	No	Buy	Yes	Yes
Shower, Bathtub, Washer	2	No	Buy	Yes	Yes
Shower,Washer	1	Yes	Fill	Yes	Yes
Shower, Bathtub, Washer,Dishwasher	2	No	Buy and Fill	Yes	Yes
Shower,Washer	3	No	Fill	Yes	Yes
Shower, Bathtub, Washer,Dishwasher	7	No	Buy	Yes	Yes
Shower, Bathtub, Washer,Dishwasher	4	No	Buy	Yes	Yes
Shower,Washer,Dishwasher	2	No	Buy and Fill	Yes	Yes
Shower	4	No	Fill	Yes	Yes
Shower,Washer	2	No	Buy	Yes	Yes
Shower	3	No	Buy	Yes	Yes
Shower	3	Yes	Fill	Yes	Yes
Shower,Washer,Dishwasher	6	No	Buy	Yes	No
Shower	3	No	Buy	Yes	No
Shower, Bathtub, Washer	5	No	Buy	No	No

Shower,Washer	5	Yes	Buy	Yes	No
Shower,Washer	6	Yes	/	Yes	Yes
Shower,Washer	5	No	Fill	Yes	No
Shower,Washer	4	No	Fill	Yes	Yes
Shower,Washer	3	No	Buy	Yes	No
Shower,Washer	5	No	Buy and Fill	Yes	Yes
Shower,Washer	3	No	Buy and Fill	Yes	No
Shower,Washer	3	No	Buy and Fill	Yes	No
Shower,Washer	5	No	Buy and Fill	Yes	Yes
Shower,Washer	7	No	Buy	Yes	No
Shower	1	No	Buy	No	No
Shower, Bathtub, Washer	5	No	Buy	Yes	Yes
Shower, Bathtub, Washer	5	No	Buy	Yes	Yes
Shower, Bathtub, Washer	3	No	Buy	Yes	Yes
Shower,Washer,Dishwasher	2	No	Buy	Yes	Yes
Shower,Washer	3	No	Buy and Fill	Yes	Yes
Shower,Washer	3	No	Buy and Fill	Yes	Yes
Shower,Washer,Dishwasher	3	No	Buy and Fill	Yes	No
Shower, Bathtub, Washer,Dishwasher	5	No	Buy	Yes	No
Shower,Washer	2	No	Buy	Yes	Yes
Shower,Washer	5	No	Fill	Yes	Yes
Shower,Washer	5	No	Buy	Yes	Yes
Shower, Bathtub, Washer	5	No	Buy	Yes	No
Shower, Bathtub, Washer	5	No	Buy	Yes	Yes
Shower, Bathtub, Washer	5	No	Buy	Yes	No
Shower,Washer	5	Yes	/	Yes	No
Shower,Washer	3	No	Buy	Yes	No
Shower	4	No	Fill	Yes	Yes
Bathtub, Washer	2	No	Fill	Yes	Yes
Shower,Washer	3	No	Fill	Yes	Yes
Shower	4	Yes	/	Yes	No
Shower	4	No	Fill	No	Yes
Bathtub, Washer	2	No	Buy	Yes	Yes
Shower	4	Yes	/	Yes	No
Shower,Washer	3	No	Fill	Yes	Yes
Shower,Washer	3	No	Buy	Yes	Yes
Shower,Washer	3	No	Buy	Yes	Yes
Bathtub, Washer,Dishwasher	4	No	Fill	Yes	No
Shower	3	No	Buy	No	Yes
Shower	3	No	Fill	Yes	No
Shower,Washer	4	No	Buy	Yes	No
Shower,Washer	4	No	Buy	Yes	No
Shower,Washer,Dishwasher	4	No	Buy and Fill	Yes	No
Shower,Washer	4	No	Buy and Fill	Yes	No
Shower,Washer	5	No	Buy and Fill	Yes	No

Shower,Washer	5	No	Buy and Fill	Yes	No
Shower,Washer	5	No	Buy and Fill	Yes	No
Shower,Washer,Dishwasher	4	No	Buy	Yes	No
Shower	2	Yes	/	Yes	No
Shower	2	Yes	/	Yes	No
Shower	2	Yes	/	Yes	No
Shower	2	Yes	/	Yes	No
Shower,Washer,Dishwasher	6	No	Buy	No	Yes
Shower,Washer	2	Yes	/	Yes	No
Shower,Washer,Dishwasher	5	Yes	/	Yes	Yes
Bathtub, Washer,Dishwasher	6	Yes	/	No	Yes
Bathtub, Washer,Dishwasher	1	Yes	/	Yes	No
Shower,Washer,Dishwasher	2	Yes	/	Yes	No
Shower,Washer	5	Yes	Fill	Yes	No
Bathtub, Washer,Dishwasher	4	No	Buy	No	Yes
Shower	1	Yes	/	Yes	No
Shower,Washer	5	Yes	/	Yes	No
Shower,Washer,Dishwasher	4	No	Buy and Fill	Yes	No
Shower,Washer,Dishwasher	4	No	Buy and Fill	Yes	Yes
Shower,Washer,Dishwasher	7	No	Buy and Fill	Yes	No
Shower,Washer	4	No	Buy and Fill	Yes	Yes
Shower,Washer	4	No	Fill	Yes	Yes
Shower,Washer	2	No	Buy and Fill	Yes	No
Shower,Washer	5	No	Buy	Yes	No
Shower,Washer	3	No	Fill	Yes	No
Shower, Bathtub, Washer,Dishwasher	6	No	Buy and Fill	Yes	No
Shower,Washer	5	No	Buy and Fill	Yes	No
Shower,Washer	4	No	Buy and Fill	Yes	No
Shower,Washer,Dishwasher	5	No	Buy and Fill	Yes	No
Shower,Washer	4	No	Buy and Fill	Yes	No
Shower,Washer	4	No	Buy and Fill	Yes	No
Shower,Washer	4	No	Buy	Yes	No
Shower,Washer	4	No	Buy	Yes	No
Shower, Bathtub, Washer,Dishwasher	5	No	Buy	Yes	No
Shower,Washer	4	No	Buy and Fill	Yes	No
Shower,Washer,Dishwasher	5	No	Buy and Fill	Yes	No
Shower,Washer,Dishwasher	5	No	Buy and Fill	Yes	No
Shower,Washer	4	No	Buy and Fill	Yes	No
Shower,Washer,Dishwasher	5	No	Buy	Yes	No
Shower,Washer	5	No	Buy and Fill	Yes	No
Shower,Washer,Dishwasher	5	No	Buy and Fill	Yes	No
Shower,Washer,Dishwasher	5	No	Buy and Fill	Yes	No
Shower,Washer	4	No	Buy and Fill	Yes	No
Shower,Washer	2	No	Fill	Yes	No
Shower,Washer	3	No	Buy and Fill	Yes	Yes

Shower,Washer,Dishwasher	5	No	Buy and Fill	Yes	Yes
Shower, Bathtub, Washer,Dishwasher	4	No	Buy and Fill	Yes	Yes
Shower,Washer	3	No	Buy and Fill	Yes	No
Shower,Washer	2	No	Buy	Yes	No
Shower	4	No	Buy	No	No
Shower,Washer	3	Yes	Fill	Yes	No
Shower	2	No	Buy	Yes	Yes
Shower,Washer	3	No	Buy and Fill	Yes	Yes
Shower	3	No	Buy and Fill	Yes	Yes
Shower	4	No	Fill	Yes	No
Shower,Washer	5	No	Buy	Yes	No

Q12	Q13	Q14	Q15	Q16
No	Too High	16/23h	High	Yes
No	Too High	16/23h	Average	Yes
No	Too High	16/23h	Average	Yes
No	Too High	6/15h	Average	Yes
No	Too High	6/15h	Average	Yes
No	Too High	16/23h	Average	Yes
No	Too High	6/15h	Average	Yes
No	Too High	16/23h	Average	Yes
No	Adequate	6/15h	Average	Yes
No	Too High	16/23h	Average	Yes
No	Too High	6/15h	Average	Yes
No	Too High	6/23h	Average	Yes
No	Too High	16/23h	Average	Yes
No	Adequate	6/15h	High	Yes
No	Adequate	6/23h	Average	Yes
No	Adequate	6/23h	Average	No
No	Too High	6/23h	Average	Yes
No	Adequate	6/23h	Average	Yes
No	Too Low	6/23h	High	No
No	Adequate	6/23h	High	No
No	Adequate	6/23h	High	No
No	Adequate	6/23h	Average	No
No	Adequate	6/23h	Average	No
No	Adequate	6/5h	High	Yes
No	Adequate	6/5h	High	Yes
No	Adequate	6/23h	High	Yes
Yes	Too Low	6/23h	High	No
No	Adequate	6/23h	High	Yes
No	Too High	16/23h	Average	No
No	Too High	6/23h	High	Yes
No	Adequate	6/23h	Average	Yes

Yes	Adequate	6/23h	Average	Yes
No	Adequate	6/23h	High	No
Yes	Adequate	6/15h	High	Yes
No	Adequate	16/23h	Average	Yes
No	Adequate	16/23h	Average	Yes
No	Adequate	16/23h	Average	No
No	Too High	6/15h	Average	Yes
No	Too High	6/15h	Average	Yes
No	Adequate	6/23h	Average	Yes
Yes	Adequate	16/23h	Average	Yes
Yes	Too Low	16/23h	Average	No
Yes	Too High	6/15h	High	Yes
No	Adequate	6/15h	High	No
Yes	Too Low	6/15h	Average	No
No	Adequate	6/15h	Average	Yes
No	Too Low	6/15h	High	No
Yes	Adequate	16/23h	Average	No
No	Adequate	6/15h	High	Yes
Yes	Too High	6/15h	Average	Yes
Yes	Too High	6/15h	Average	Yes
Yes	Too High	16/23h	High	Yes
No	Too High	6/15h	Average	Yes
No	Adequate	16/23h	Average	No
No	Too High	6/23h	High	Yes
No	Adequate	6/23h	High	Yes
Yes	Too High	6/15h	Average	Yes
Yes	Too High	6/15h	High	Yes
No	Adequate	16/23h	High	Yes
No	Adequate	16/23h	High	Yes
Yes	Too High	6/15h	High	Yes
No	Adequate	16/23h	High	Yes
No	Adequate	16/23h	High	Yes
No	Adequate	16/23h	High	Yes
No	Adequate	16/23h	Average	Yes
No	Adequate	16/23h	Average	Yes
No	Adequate	16/23h	Average	Yes
Yes	Adequate	16/23h	Average	Yes
No	Adequate	6/15h	Average	No
Yes	Too Low	16/23h	Average	No
No	Adequate	6/23h	High	Yes
No	Adequate	6/23h	High	No
No	Too High	16/23h	Average	No
No	Adequate	16/23h	Average	Yes
No	Adequate	16/23h	Average	Yes
Yes	Adequate	16/23h	Average	Yes

No	Adequate	16/23h	Average	Yes
No	Too High	6/15h	Average	Yes
No	Adequate	6/15h	Average	Yes
Yes	Adequate	6/15h	Average	Yes
Yes	Adequate	16/23h	High	Yes
No	Adequate	16/23h	High	Yes
No	Adequate	6/15h	High	Yes
No	Adequate	6/23h	High	Yes
No	Adequate	6/23h	High	Yes
No	Adequate	6/23h	High	Yes
No	Too High	6/23h	Average	Yes
No	Too High	6/5h	High	No
No	Too High	6/23h	Average	No
No	Too High	6/15h	Average	Yes
No	Adequate	6/23h	Average	No
No	Too High	6/23h	Average	Yes
No	Too High	6/23h	Average	Yes
No	Adequate	6/23h	High	Yes
No	Adequate	6/23h	High	Yes
No	Too High	6/23h	Average	Yes
No	Too High	6/23h	High	No
No	Adequate	6/23h	Average	Yes
No	Adequate	6/23h	High	No
No	Adequate	16/23h	Average	Yes
No	Too High	6/23h	Average	Yes
No	Too High	6/15h	Average	Yes
No	Too High	6/15h	Average	Yes
No	Too High	16/23h	Average	Yes
No	Too High	6/15h	Average	Yes
No	Adequate	6/15h	Average	Yes
No	Too High	16/23h	Average	Yes
No	Adequate	16/23h	Average	Yes
No	Adequate	16/23h	Average	Yes
No	Adequate	16/23h	Average	Yes
No	Adequate	6/15h	Average	Yes
No	Too High	16/23h	High	Yes
No	Adequate	6/15h	Average	Yes
No	Adequate	6/5h	High	Yes
No	Adequate	6/5h	High	No
Yes	Adequate	6/5h	Average	Yes
No	Too Low	6/15h	Average	Yes
No	Adequate	6/5h	High	Yes
Yes	Too High	6/15h	High	Yes
No	Adequate	6/23h	High	Yes
No	Adequate	6/23h	High	Yes

No	Too High	16/23h	Average	Yes
No	Adequate	16/23h	Average	Yes
No	Too High	6/15h	Average	Yes
Yes	Adequate	6/23h	Average	Yes
Yes	Too Low	6/15h	Average	Yes
Yes	Adequate	16/23h	Average	Yes
No	Adequate	6/23h	Average	Yes
No	Adequate	16/23h	Average	Yes
No	Too High	6/23h	Average	Yes
No	Adequate	16/23h	Average	Yes
No	Adequate	16/23h	Average	Yes
No	Adequate	16/23h	Average	Yes
No	Adequate	6/23h	Average	Yes
No	Adequate	6/23h	Average	Yes
No	Too High	6/23h	Average	Yes
No	Adequate	6/15h	Average	Yes
No	Too High	16/23h	Average	Yes
No	Adequate	6/15h	Average	Yes
No	Adequate	16/23h	Average	Yes
No	Adequate	16/23h	Average	Yes
No	Adequate	16/23h	Average	Yes
No	Adequate	16/23h	Average	Yes
No	Adequate	16/23h	Average	Yes
No	Adequate	16/23h	Average	Yes
No	Adequate	16/23h	Average	Yes
No	Adequate	16/23h	Average	Yes
No	Adequate	16/23h	Average	Yes
No	Adequate	16/23h	Average	Yes
Yes	Adequate	16/23h	Average	Yes
Yes	Adequate	6/23h	Average	Yes
No	Adequate	6/15h	Average	Yes
No	Adequate	6/15h	Average	Yes
Yes	Too High	16/23h	Average	No
No	Too High	6/15h	Average	No
Yes	Too High	6/15h	Average	No
No	Adequate	16/23h	Average	Yes
Yes	Adequate	16/23h	Low	No
No	Too High	6/23h	Average	Yes
No	Adequate	16/23h	Average	Yes

Q17	Q18	Q19	Q20	Q21	Q22	Q23
Reasonable	Yes	1000	5	Yes	7	4
Reasonable	Yes	800	3	Yes	6	7
Reasonable	Yes	600	4	Yes	8	8

Reasonable	Yes	200	3	Yes	7	4
Reasonable	No	0	2	Yes	6	6
Reasonable	Yes	800	4	Yes	8	6
Reasonable	Yes	1000	4	Yes	7	6
Reasonable	No	0	3	Yes	8	7
Reasonable	Yes	400	5	Yes	5	7
Reasonable	No	0	4	Yes	8	8
Reasonable	Yes	400	3	Yes	8	7
Reasonable	No	0	4	Yes	9	6
Reasonable	Yes	800	3	Yes	7	4
Reasonable	Yes	2000	9	Yes	4	9
Reasonable	No	0	4	No	6	3
Expensive	Yes	1000	6	No	3	2
Reasonable	No	0	3	No	5	5
Reasonable	Yes	10000	4	Yes	7	5
Expensive	Yes	800	6	No	4	7
Reasonable	No	0	3	No	3	6
Expensive	No	0	5	No	2	5
Expensive	No	0	6	No	0	5
Reasonable	No	0	4	No	3	7
Reasonable	No	0	4	No	5	5
Reasonable	No	0	3	No	8	7
Reasonable	Yes	200	4	No	7	4
Expensive	No	0	7	No	3	4
Expensive	No	0	4	No	5	6
Reasonable	No	0	3	Yes	5	5
Reasonable	Yes	1000	5	No	5	7
Reasonable	No	0	3	No	3	5
Reasonable	Yes	1000	6	Yes	8	5
Expensive	Yes	500	5	No	4	3
Expensive	Yes	2000	4	OUI	5	5
Reasonable	No	0	4	Yes	6	3
Reasonable	Yes	600	6	Yes	5	4
Expensive	Yes	1500	7	Yes	8	9
Reasonable	No	0	1	Yes	5	4
Expensive	Yes	1000	10	Yes	7	5
Reasonable	Yes	1200	7	Yes	8	8
Expensive	Yes	600	5	Yes	5	5
Reasonable	Yes	800	6	Yes	9	9
Expensive	Yes	1000	5	Yes	8	8
Very Expensive	Yes	1500	6	Yes	5	6
Expensive	Yes	1000	10	Yes	5	7
Expensive	No	0	10	Yes	5	6
Expensive	Yes	600	5	Yes	4	3
Expensive	Yes	1000	3	Yes	6	5

Reasonable	Yes	600	6	Yes	9	6
Reasonable	Yes	1200	6	Yes	9	9
Expensive	Yes	1500	6	Yes	9	7
Very Expensive	Yes	800	4	Yes	10	8
Expensive	No	0	5	No	3	6
Expensive	No	0	7	No	1	5
Expensive	No	0	7	No	2	5
Reasonable	No	0	4	No	2	5
Not Expensive	No	0	11	No	10	4
Expensive	No	0	4	No	2	4
Expensive	Yes	600	5	No	5	5
Reasonable	Yes	400	3	No	7	7
Reasonable	No	0	3	No	7	7
Reasonable	No	0	3	No	5	5
Reasonable	No	0	5	No	7	7
Reasonable	No	0	2	No	7	7
Reasonable	Yes	800	4	Yes	6	3
Reasonable	Yes	1000	5	Yes	8	8
Reasonable	Yes	800	4	Yes	6	2
Reasonable	Yes	1000	7	Yes	6	6
Reasonable	No	200	2	No	5	5
Very Expensive	No	0	4	No	5	5
Reasonable	No	0	10	No	4	3
Reasonable	No	0	5	No	5	4
Expensive	Yes	1000	6	No	3	5
Reasonable	Yes	500	4	No	2	3
Reasonable	No	0	6	Yes	6	3
Reasonable	Yes	600	4	Yes	5	5
Expensive	Yes	800	6	Yes	4	2
Reasonable	Yes	1000	4	Yes	6	8
Reasonable	No	0	2	Yes	3	2
Reasonable	No	0	3	Yes	2	2
Reasonable	No	0	7	No	4	3
Expensive	No	0	5	No	7	7
Reasonable	Yes	2500	7	No	5	5
Reasonable	No	0	2	No	7	7
Reasonable	No	0	5	No	8	7
Reasonable	No	0	7	No	7	6
Reasonable	No	0	3	No	5	6
Reasonable	No	0	4	No	7	4
Reasonable	No	0	2	No	6	8
Reasonable	No	0	1	No	10	8
Reasonable	No	0	3	No	5	7
Reasonable	Yes	800	4	No	8	9
Reasonable	No	0	5	No	5	8

Reasonable	Yes	1000	3	No	4	6
Expensive	No	0	4	No	8	7
Reasonable	No	0	6	No	3	8
Expensive	Yes	2000	5	No	4	5
Reasonable	No	0	4	No	4	5
Reasonable	No	0	6	No	1	5
Reasonable	No	0	4	Yes	4	6
Reasonable	Yes	400	3	Yes	6	8
Reasonable	Yes	1000	6	Yes	4	6
Reasonable	No	0	4	Yes	7	8
Reasonable	No	0	4	Yes	6	6
Reasonable	No	0	2	Yes	4	4
Reasonable	Yes	1000	5	Yes	8	6
Reasonable	No	0	3	Yes	6	8
Reasonable	Yes	1800	8	No	5	7
Reasonable	Yes	1900	4	No	6	3
Reasonable	Yes	1800	8	No	5	7
Reasonable	Yes	1300	7	No	4	7
Very Expensive	Yes	1900	5	No	5	9
Reasonable	Yes	1800	7	No	5	7
Very Expensive	Yes	1800	5	No	3	5
Very Expensive	Yes	1700	9	No	3	9
Very Expensive	No	0	8	No	3	4
Expensive	No	0	4	No	2	9
Very Expensive	No	0	5	No	2	3
Very Expensive	No	0	8	No	3	2
Reasonable	Yes	1900	5	No	3	6
Expensive	Yes	1700	4	Yes	4	2
Reasonable	Yes	1000	6	Yes	5	5
Reasonable	No	0	6	Yes	4	2
Reasonable	Yes	2000	8	Yes	9	9
Reasonable	Yes	600	5	Yes	6	6
Reasonable	No	0	8	Yes	2	1
Reasonable	Yes	200	5	Yes	6	5
Reasonable	No	0	3	Yes	4	4
Reasonable	No	0	4	Yes	6	4
Not Expensive	Yes	1000	6	Yes	8	9
Reasonable	No	0	4	Yes	4	3
Reasonable	Yes	400	6	Yes	6	6
Reasonable	Yes	1000	6	Yes	4	6
Reasonable	No	0	3	Yes	6	8
Reasonable	Yes	800	6	Yes	8	7
Reasonable	Yes	600	5	Yes	6	7
Reasonable	Yes	200	3	Yes	4	4
Reasonable	Yes	2000	8	Yes	10	9

Reasonable	Yes	400	6	Yes	8	6
Reasonable	Yes	800	6	Yes	9	6
Reasonable	No	0	5	Yes	9	5
Reasonable	Yes	200	2	Yes	6	8
Reasonable	Yes	400	5	Yes	6	8
Reasonable	Yes	200	4	Yes	8	8
Reasonable	No	0	6	Yes	6	6
Reasonable	No	0	3	Yes	4	4
Reasonable	No	0	4	Yes	6	6
Reasonable	Yes	600	3	Yes	6	6
Reasonable	Yes	400	4	Yes	6	6
Reasonable	Yes	800	6	Yes	6	8
Reasonable	Yes	1000	6	Yes	5	4
Reasonable	Yes	400	5	Yes	4	3
Reasonable	No	0	4	Yes	4	4
Expensive	No	0	5	Yes	7	4
Not Expensive	Yes	500	4	Yes	4	8
Expensive	Yes	400	5	Yes	3	2
Expensive	Yes	1000	4	Yes	4	5
Not Expensive	Yes	900	5	Yes	4	2
Reasonable	Yes	1000	5	No	6	7
Reasonable	Yes	1000	5	Yes	8	6