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IMPACT OF TREATED WASTEWATER IRRIGATION ON SOIL PROPERTIES AND GROUNDWATER QUALITY

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DECLARATION

I, **Omar DAIM**, hereby declare that this thesis represents my personal work, realized to the best of my knowledge. I also declare that all information, material and results from other works presented here, have been fully cited and referenced in accordance with the academic rules and ethics.

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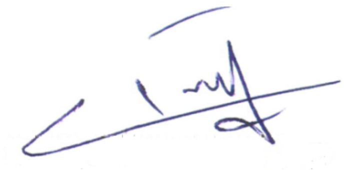

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CERTIFICATION

This thesis has been submitted with my approval as the supervisor

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Abstract

Water shortages in arid and semi-arid regions promote the reuse of water resources, and the use of treated wastewater for agricultural irrigation is the primary form of wastewater reuse. Since 2012, 912 ha is the area of Hennaya that have used treated wastewater . Many nutrients, including nitrogen, phosphorus, and potassium, are rich in sewage, and they can effectively increase soil nutrient content and promote crop growth. However, treated wastewater irrigation may pose certain environmental risks, most significantly a possible pollution of soil with heavy metals. Heavy metal pollution is seriously problematic because it is persistent, which may pose certain health risks to humans through the food.

In this thesis we have studied the different impacts of treated wastewater irrigation on the properties of soil and the quality of groundwater and we tried to involve the policy aspect as a tool to a better management of water ressources.

Key words: environment, groundwater, irrigation, soil ,policy, wastewater .

Résumé

Les pénuries d'eau dans les régions arides et semi-arides favorisent la réutilisation des ressources en eau, et l'utilisation des eaux usées traitées pour l'irrigation agricole est la principale forme de réutilisation des eaux usées. Depuis 2012, Hennaya utilise 912 ha d'eaux usées traitées. De nombreux nutriments, notamment l'azote, le phosphore et le potassium, sont riches en eaux usées et peuvent effectivement augmenter la teneur en éléments nutritifs du sol et favoriser la croissance des cultures. Cependant, l'irrigation par traitement des eaux usées traitées peut présenter certains risques environnementaux, notamment une pollution possible du sol par des métaux lourds. La pollution par les métaux lourds est sérieusement problématique car elle est persistante, ce qui peut présenter certains risques pour la santé des humains à travers les aliments.

Dans cette thèse nous avons étudié les différents impacts de l'irrigation des eaux usées traitées sur les propriétés du sol et la qualité des eaux souterraines et nous avons essayé d'impliquer l'aspect politique comme un outil pour une meilleure gestion des ressources en eau

Mots clés : Environnement, eaux souterraines, irrigation, sol, gouvernance, eaux usées.

ABBREVIATIONS

BOD5	Biochemical Oxygen Demand
CFU	Colony Forming unit
Cm	Centimeter
COD	Chemical Oxygen Demand
DI	Drip Irrigation
ds/m	Deci Siemens per meter
EC	Electrical Conductivity
EPA	Environment Protection Agency
FAO	Food and Agriculture Organization
FC	Fecal Coliforms
FI	Flood Irrigation
FW	Fresh Water
g	gram
ha	hectare
HM	Heavy Metal
IR	Infiltration Rate
Km	Kilo meter
Km^2	Square kilo meter
M	Meter
M^3	Cubic meter
M^3/y	Cubic meter per day
mg/l	Milligram Per Litre
µS cm-1	micro Siemens per cm
ml	millilitre
MOA	Ministry of Agriculture
MOH	Ministry of Health

Msl	Mean sea level
NGOs	Non Governmental Organizations.
OM	Organic Matter
TWW	Treated Wastewater
TC	Total Coliform
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UN	United Nations
UNDP	United Nations Developing Program
UNEP	United Nations Environment Programm
USDA	United States Department of Agriculture
WHO	World Health Organization
WWTPs	Wastewater Treatment Plants

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CHAPTER 1

INTRODUCTION

1.1. Background

Water is a vital resource but it is severely limited in most countries of the Mediterranean region such as Algeria. Many countries are struggling to balance water use among municipal, industrial, agricultural, and recreational uses. The population increase has not only increased the fresh water demand but also increased the volume of wastewater generated. Treated or recycled wastewater appears to be the only water resource that is increasing as other sources are dwindling. Reclaimed water is increasingly viewed as a valuable resource for the agricultural, industrial and municipal Sectors, rather than as a waste that requires disposal (**Qian, 2005**)

Since wastewater is considered as a non-ordinary source of water, its usage in the agriculture demands a unique management, which in addition to its appropriate utilization, has to have no threat to the environment, plants, soils and surface and subsurface water resources (**Najafi, 2001**).

The region of Tlemcen is one of the areas where the levels of exploitation of resources exceed the carrying capacity of the environment, especially in recent years. We can see that clearly in water resources, under heavy pressure and subject to severe over-exploitation, pollution and degradation. The scarcity of water requires the use of sustainable wastewater management. The wastewater problems are increasing each year due to increased wastewater discharges resulting from demand for freshwater for human consumption, agricultural and industrial purposes.

Water demand in Tlemcen is increasing continuously due to economic development and population increase resulting from natural growth, while the water resources are constant or even decreasing due to urban development.

Reclaimed wastewater is now being considered as a new source of water that can be used for different purposes such as agricultural production, domestic and industrial uses. Using wastewater for agriculture production will help in alleviating food shortages and reduce the gap between supply and demand.

In order to relieve pressure on fresh water resources and benefits from nutrient-rich wastewater, treated wastewater can be used as a conservation strategy contributing to agricultural production.

1.2. Problem Statement

Due to the increasing demand for water in Tlemcen for different purposes (domestic, agricultural, industrial), it has become urgent to look for new unconventional water resources (desalination of sea water, use of treated wastewater) to fill the gap in the demand for water.

Uncontrolled discharge of untreated wastewater has led to high nitrate levels in some areas, creating additional pollution of groundwater and surface water resources. The use of treated domestic wastewater could be one of the main options for developing new water resources in the Tlemcen regions as it represents an additional renewable and reliable source of water. The use of treated wastewater for irrigation would reduce the water quantity deficit and reduce the degradation of surface and groundwater quality.

In other words, the reuse of treated wastewater for agriculture offers the greatest potential for application as it generally has the capacity to meet the growing need for water and will help to reduce pollutant discharges into surface water and groundwater.

Scientific research should be conducted to define the possibility of negative impact of treated wastewater irrigation on groundwater quality and soil properties.

1.3. Study Justifications

There is a high potential use of treated wastewater in Algeria and north africa. However, it is important that the implementation of water reuse in agriculture be based on scientific proof of its effects on environment. Regardless on respecting the regulation and guidelines, the reuse of treated wastewater is not entirely a risk-free. Continued research will result in developing new technologies or improving the existent methodologies used for assessment of risk associated with trace contaminants, evaluation of microbial quality, treatment systems, and evaluation of the fate of microbial, chemical and organic contaminants.

While other treated wastewater irrigation reuse projects have been practiced in Algeria (Tlemcen,Oran, Ouargla and Bordj Bou Arreridj) needs to be better assessed with applied research for specific applications a comprehensive short term impact analysis on groundwater,. This study will carry out these analysis based on actual field analysis from Hennaya area (Tlemcen).

1.4. Scope and Objectives

The main goal of this study is to identify the most significant impacts coming from the use of treated wastewater as an alternative source of water for irrigation in the agricultural sector. The purposes of this research work are:

- To investigate the impacts of treated wastewater irrigation on soil properties.
- To examine the adverse effects on the groundwater quality as a results of treated wastewater irrigation.

1.5. Thesis Structure

Chapter one presents the introduction and describes the water sector situation in Tlemcen, the wastewater problems and the possibility and potential to reuse. It presents also the problem statement, study justification, aims and objectives of this study.

Chapter two provide a base for this study. Previous scientific research at different places in the world especially north Africa and middle east were described and discussed, Existing guidelines and different standards related to treated wastewater irrigation were presented and discussed,

Chapter three contain a brief description of the Hennaya plain and sekkak watershed (location, climate and soil) , a brief report about wastewater treatment plants of Ain Elhoutz. And at the end a description of the research methodology including the collection of samples for irrigation water, groundwater and soil , the steps that have been followed during the process , the preservation of samples and the different parameters (chemical, physical and biological)

Chapter four presented the results and discussion, the data collected from the field and laboratories were presented and discussed.

The final chapter contains the policy aspect including regulations, legislations and a policy framework that should be developed at the national level.

The Conclusions contains recommendations based on the results of this study.

CHAPTER 2

LITERATURE REVIEW

This chapter presents a literature review about wastewater reuse and particularly, the history, the current status, benefits and disadvantages of wastewater reclamation. And also reviews the results of some studies related to this non-conventional water resource for irrigation and its effects on soil physical properties and chemical as well as adverse effects on groundwater and contamination

2.1. Wastewater Compositions

Wastewater is composed of 99% water and 1% suspended, colloidal and dissolved solids. Municipal wastewater contains organic matter and nutrients (N, P, K); inorganic matter or dissolved minerals; toxic chemicals; and pathogens (Hanjara *et al.*, 2012).The pollutants belonging to the same category exhibit similar water quality impacts.

The composition of typical wastewater (Table 2.1, Ashwani.k) depends on the socioeconomic characteristics of the residential communities and number and types of industrial and commercial units, such that global demographic and economic change also has implications for environmental health protection and wastewater governance approaches.

Table 2.1: Major constituents of domestic wastewater (Bouchaala; 2017)

Constituent	Concentration mg/l		
	Strong	Medium	Weak
Total solids	1200	700	350
Dissolved solids	850	500	250
Suspended solids	350	200	100
Nitrogen (as N)	85	40	20
Phosphorus (as P)	20	10	6
Chloride	100	50	30
Alkalinity as ($CaCo_3$)	200	100	50
Grease	150	100	50
BOD_5	300	200	100

2.2. Wastewater Treatment for Reuse

Municipal wastewater treatment typically comprises preliminary treatment, primary treatment, and secondary treatment. Secondary treatment is widely considered as standard for effluent discharged to surface waters. A higher degree of treatment or "tertiary" treatment may be required at specific locations to protect health or environmental quality. Conventional municipal wastewater treatment is considered to include screening, grit removal, primary sedimentation, and biological treatment because it is the most common method **(EPA; 2012).**

2.2.1. Preliminary Wastewater Treatment:

Preliminary wastewater treatment ordinarily includes screening and grit removal. Waste-water screening removes coarse solids such as rags that would interfere with mechanical equipment. Grit removal separates heavy, inorganic, sandlike solids that would settle in channels and interfere with treatment processes.

Preliminary treatment effects minimal change in wastewater quality. Primary treatment typically removes about one-third of the BOD and one-half of the suspended solids in domestic wastewaters. Combined primary and secondary treatment is required to achieve 85 percent reduction in both BOD and suspended solids concentration to meet the regulatory definition of secondary treatment. Preliminary treatment serves to prepare wastewater for subsequent treatment, but it effects little change in wastewater quality. The residues from preliminary wastewater treatment, screenings and grit, are not ordinarily incorporated with sludges (EPA; 2012) .

2.2.2. Primary Wastewater Treatment:

Primary wastewater treatment usually involves gravity sedimentation of screened, degritted wastewater to remove settleable solids; slightly more than one-half of the suspended solids ordinarily are removed. BOD in the form of solids removable by sedimentation (typically about one-third of total BOD) is also removed. Facilities only practiced primary wastewater treatment and the primary effluent was commonly discharged to surface waters offering appreciable dilution. Now, primary treatment is used as an economical means for removing some contaminants prior to secondary treatment. The residue from primary treatment is a con-centrated suspension of particles in water called "primary sludge." Although the goal of primary wastewater treatment is to separate readily-removable suspended solids and BOD, wastewater constituents that exist as settleable solids or are sorbed to settleable wastewater solids may also be removed. Thus, primary treatment effects some reduction in the effluent concentration of nutrients, pathogenic organisms, trace elements, and potentially toxic organic compounds. The constituents that are removed are contained in primary sludge **(EPA; 2012).**

2.2.3. Secondary Wastewater Treatment

Secondary municipal wastewater treatment is almost always accomplished by using a biological treatment process. Microorganisms in suspension (in the "activated sludge" process), attached to media (in a "trickling filter" or one of its variations), or in ponds or other processes are used to remove biodegradable organic material. Part of the organic material is oxidized by the microorganisms to produce carbon dioxide and other end products, and the remainder provides the energy and materials needed to support the microorganism community. The microorganisms biologically flocculate to form settleable particles, and, following biological treat-ment, this excess biomass is separated in sedimentation tanks as a concentrated suspension called "secondary sludge" (also known as "biological sludge," "waste activated sludge," or "trickling filter humus"). Wastewater constituents can become associated with secondary sludge as a result of microbial assimilation, by sorption onto settleable solids, or by incorporation into agglomerate particles formed as a result of bioflocculation. Some of the wastewater constituents that are incidentally associated with the biomass from secondary treatment processes include pathogens, trace elements, and organic compounds **(EPA; 2012).**

2.2.4. Tertiary or Advanced Wastewater Treatment

Tertiary treatment is used at municipal wastewater treatment plants when receiving water conditions or other uses require higher quality effluent than that produced by secondary wastewater treatment. Disinfection for control of pathogenic microorganisms and viruses is the most common type of tertiary treatment. The concentrations of suspended solids and associated BOD in treated effluent can be reduced by filtration, sometimes with the aid of a coagulant. Adsorption, ordinarily on activated carbon, can be used to remove some persistent organic compounds and trace elements. The concentration of ammonia in secondary effluent can be reduced by nitrification. Tertiary treatment to remove nitrogen and phosphorus, so as to mini-mize nutrient enrichment of surface waters, is common; nitrogen is usually removed by nitrification followed by denitrification, and phosphorus is removed by microbial uptake or chemical precipitation. Not all tertiary treatment processes follow secondary treatment; nutrient removal, for example, can be achieved by design and operational variations to primary and secondary treatment processes. The residues from tertiary treatment typically become incorporated with sludges from primary and secondary treatment. There are many variations to these treatment practices. For instance, secondary treatment is rarely achieved using physical and chemical processes rather than biological treatment. Primary treatment is sometimes eliminated. Long-term retention in lagoons is sometimes sub-stituted for both primary and secondary treatment **(EPA; 2012).**

2.2.5. Treatment to facilitate crop irrigation with reclaimed water

The degree of wastewater treatment required prior to using wastewater effluent for crop production depends on the crop, local conditions, and state regulations. In considering specific

applications of reclaimed wastewater for crop production, tradeoffs may exist between degree of wastewater treatment needed and agricultural practices.

Special treatment to allow agricultural use of treated effluents is not always considered necessary by states that regulate the practice; effluents from conventional primary and secondary wastewater treatment are used.

In identifying appropriate wastewater treatment for crop application, it is appropriate to consider protection of health and environmental quality, water quality requirements of crops, and requirements of the irrigation water storage and delivery system (such as avoiding odors and clogging) As a practical matter, the extent of wastewater treatment required prior to food crop application ordinarily is established by health and environmental quality considerations. Disinfection and suspended solids removal are the processes most frequently used to further improve conventional wastewater treatment plant effluents for use on crops.

Disinfection of treated effluent is most often accomplished by chlorination. Chlorine is an economical disinfectant, but it reacts with organic material in wastewater effluent to form chlorinated organic compounds that are of potential concern with potable reuse of reclaimed wastewater, but not with irrigation.

Alternatives to chlorine as a wastewater disinfecting agent include ozone and ultraviolet light. The latter two processes do not provide a residual disinfectant as required by some state regulations for applying treated wastewater to food crops

Additionally, suspended solids are sometimes removed from conventional wastewater treatment plant effluent prior to using the effluent in agriculture. Removal of suspended solids aids in control of pathogenic organisms and viruses by making disinfection more effective. Suspended solid removal minimizes deposition of solids on top of soils, and reduces clogging of some irrigation water delivery systems. Further reduction of suspended solids in effluent is typically achieved by adding a coagulating chemical, settling, and filtering through granular media.

Treatment technology to produce any degree of wastewater quality perceived to be necessary for food crop production is available; however, treatment costs escalate with incremental water quality improvements. Additionally, residue (sludge) management problems accompany some processes (such as those using membranes) that might be used to improve treated wastewater quality beyond the current norms. Situations exist today in which water quality discharge requirements, the crop value and water scarcity justify the higher degrees of wastewater treatment before application to food crops.

2.3. Health impact from wastewater irrigation

Wastewater contains pathogenic microorganisms that may have the potential to cause disease, and impact human health. Protozoa and helminth eggs are most virulent and they are most difficult to remove by treatment processes **(Hanjra et al., 2012).** Improved waste-water irrigation is considered as the most effective factor in reducing the hazard of microbial exposure. Improvement process depends on the implementation of suitable farm-level practices and postharvest intervention, which are classified as non treatment options and can be divided into the following major categories:

- Crop selection and diversification in terms of market value, irrigation requirements, and tolerance of ambient stresses;
- Irrigation management based on water quality and irrigation methods rates, and scheduling
- Soil-based considerations such as soil characteristics and preparation practices, application of fertilizers and amendments if needed, and soil health aspects.

Flood irrigation is the lowest cost method and will be successful where water is not a limiting factor. Furrow irrigation provides a higher level of health protection, but requires favorable topography. Irrigation with sprinklers and watering cans are not recommended as these spreads the water on the crop surface. Sprinklers require pump and hose, have medium to high cost, and medium water use efficiency, irrigation at night and not during windy condition are important considerations. Drip irrigation, especially with subsurface drippers, can be safe by minimizing crop and human exposure, but pre-treatment of wastewater is needed to avoid clogging of emitters **(Oadir et al., 2010).**

2.4. The status of treated wastewater reuses practice in the Middle East and north Africa

2.4.1. Treated wastewater reuse in Egypt

Use of treated wastewater has become increasingly important in water resources management for both environmental and economic reasons. Since 1980, interest in the use of treated wastewater as a substitute for fresh water in irrigation has accelerated. The capacity of wastewater treatment plants has increased by more than six times in the last two decades with current capacity estimated at 12 million m3 /day. At present, 323 wastewater treatment plants exist across the country. The length of wastewater collection networks increased from 28,000 km in 2005 to 34,000 km in 2010.12 by 2017, the coverage rate is expected to increase significantly in areas outside large urban centers. Significantly, alongside instituting a policy to officially include water reuse in the national water portfolio,13 the Government of Egypt has also implemented a number of institutional reforms, which include newly issued guidelines for mixing drainage water with fresh water, regulations for sewage and industrial effluents, water reuse, cropping patterns, and health protection measures and standards specifications. With relation to institutional and financial aspects, the Holding Company for Water and Wastewater—along with 23 subsidiary companies—was established in 2004 by presidential decree to expand service delivery, introduce modern wastewater treatment and reuse technology, as well as increase the role of private sector actors in the operations and maintenance of wastewater infrastructure.

2.4.2. Treated wastewater reuse in Tunisia

In Tunisia, the total area equipped for irrigation with treated wastewater has increased steadily, while the actual area irrigated with wastewater has varied significantly. From 2000–2009, the area effectively irrigated with treated wastewater represents on average 47% of the total area equipped for irrigation—a relatively low figure. Currently, the best levels of reclaimed water reuse are recorded on fruit orchards and in the arid zones of the centre and the south of the country. Among 8065 ha that may be irrigated with reclaimed wastewater, 4646 ha (representing 59% of the total area) are equipped with saving water techniques.14 The rest is irrigated following the traditional practice of furrows and flooding. for the period (2009–2014) the program included the development of 18 new irrigated schemes on 7010 ha and the extension (1480 ha) and rehabilitation (5000 ha) of select irrigated schemes

2.4.3. Treated wastewater reuse in Jordan

The Jordan Valley Authority (JVA) has been an integral part of water reuse activities in Jordan. Established in 1977, the Authority is responsible for socio-economic development in areas that surround the Jordan River and extend into the Yarmouk and Zarqa basins, northern reaches of the Dead Sea and down to the northern border of Aqaba.

The Jordan Valley serves as one of the Hashemite Kingdom’s primary agricultural regions and comprises of 33,000 hectares of irrigated land. Yet large tracts of arable land (particularly surrounding the Dead Sea (roughly 10,000 hectares) remain to be irrigated. To expand irrigated lands and safeguard existing groundwater resources, treated wastewater effluent has increasingly been tapped for agricultural purposes. It is expected that treated wastewater effluent will comprise a significant portion of irrigation water in the future. However, the JVA maintains an outlook to ensure treated wastewater is used towards the highest value purposes. Along with instituting a number of irrigation efficiency measures, the JVA looks to allocate water towards activities demonstrating the highest financial and social returns. Such a stipulation helps promote greater water efficiency, productivity and competitiveness of the Jordanian agriculture sector. Since 2002, the Government of Jordan has been implementing several agricultural pilot projects utilizing treated wastewater with the support of international organization (i.e. Aqaba and Wadi Musa projects). The overarching objective is to demonstrate that water reuse can be reliable, commercially viable, socially acceptable, environmentally sustainable and safe. In this particular project, fodder crops (namely alfalfa) and fruit trees were irrigated. The boosted productivity of the treated wastewater irrigated lands is significant with the direct beneficiaries being farmers whose income, standards of living and economic status were elevated—thereby reducing unemployment and poverty.

2.4.4. Treated wastewater reuse in Morocco

The actual total volume of sewage in morocco is about 750 M m3 ; 48% are discharged into the rivers or applied to land; the rest is discharged as raw wastewater into the sea. The pollution load from wastewater is estimated at about 131715, 42131 and 6230 tons of organic, nitrogen and phosphorous, respectively. Most of the wastewater produced by towns is reused, mainly as raw or insufficiently treated, to irrigate about 7500 hectares. This could represent a source of public health hazards, beside the possible degradation of ground water quality. In urban area, only 70% of the population is connected to the sewerage system and about 4.5 millions using autonomous purification systems. Morocco has 100 wastewater treatment plant, more than half of them are not functional for technical, financial or human reasons. This situation represents contamination risks for receiver environment in general, and for water resources in particular. Therefore, a national sanitation program is developed to improve the sewerage system, domestic and industrial wastewater treatment, and development of the reuse practices.

The new Marrakesh WWTP, is receiving 120,000 m3 /d of wastewater (pre-treatment, primary treatment in sedimentation tank, secondary treatment employing activated sludge, tertiary treatment by sand filter and disinfection by UV). Biogas produced from sludge used for electricity generation (10.5 GWh/year) representing a part of the electricity consumed by the plant (30 GWh/year). About more than 70% of the treatment plant effluent are reused for recreational purposes. The treatment and reuse of Marrakech's wastewater is a milestone in sustainable development, which made significant progress towards attaining Morocco's national target of 60% treated wastewater by 2020.

The majority of the biotechnologies for domestic wastewater treatment implemented in several small and medium communities still not functional for financial, social, capacity building (experience staff), the production of final effluent does not comply with specified quality standards.

The application Decree (No. 2-97-875 dated Feb. 4, 1998) related to the use of wastewater stipulated that untreated wastewater use is prohibited and banished. The Norms and Standards Committee (NSC) is setting objectives for the quality of receptor medium. Among the suggested norms, there is a project related to quality standards of wastewater designed for irrigation.

The discharge of raw wastewater to the sea without proper outfalls may affect the development of tourism by degrading the sanitary quality of beaches and generating unpleasant odors and aesthetics. Major improvements are needed urgently because of the strong migration of the rural population towards the towns and the very fast demographic expansion. Studies of sanitation master plans for the main towns are currently in progress and are a first step towards meeting these requirements. The setting-up of a Liquid Sewage National Master Plan is a way of extending this procedure over the whole territory. **(Helmy T. El-Zanfaly 2015).**

2.5. Treated wastewater reuse in Algeria

2.5.1. Treated wastewater potential and reuse situation

The use of non-conventional water resources such as treated wastewater and desalinization is not yet common practice in Algeria. Wastewater treatment is neglected and there is no effective reuse of treated wastewater in Algeria. The concept of the reuse of treated wastewater, which could have a tremendous impact on water supply, has not yet been applied. However, a few trial plots have been designated to explore this possibility (Table 2.2).

Table 2.2 Description of Algerian wastewater plants and their reuse in irrigation (Bouchaala. 2017)

Treatment plant type and location	Capacity (eq hab)	Daily water flow (m^3/day)	Monthly treated water (m^3)	Monthly reused volume (m^3)	Type of culture
Activated sludge wastewater treatment plant of Boumerdes	75000	15000	484480	124765	Olives, oranges
Aerated lagoon wastewater treatment plant of Ouargla	260102	56997	991950	99195	Palm trees
Aerated lagoon wastewater treatment plant of Eloued	239134	44335	567600	33600	Trees
Activated sludge wastewater treatment plant of Tlemcen	150000	30000	510300	484785	arboriculture
Activated sludge wastewater treatment plant of Bordj Bou Arreridj	150000	30000	324720	324720	Cereals
Activated sludge wastewater treatment plant of Souk Ahrass	150000	30000	182460	182460	Arboriculture
Activated sludge wastewater treatment plant of Mascara	100000	13000	276240	276240	Olives
Aerated lagoon wastewater treatment plant of Ghriss	48000	5800	34950	34950	Olives

Aerated lagoon wastewater treatment plant of Hacine	20000	3200	24630	24630	Olives
Aerated lagoon wastewater treatment plant of Oued taria	21000	2520	19440	19440	Olives
Aerated lagoon wastewater treatment plant of tizi	12000	1440	26490	26490	Olives
Aerated lagoon wastewater treatment plant of Mohammadia	19000	2280	35100	35100	Olives
Activated sludge wastewater treatment plant of Ain El Hadjar	30000	4800	22150	22150	Arboriculture

2.5.2. Algerian regulation and standards

Algerian regulations for the reuse of treated wastewater in agriculture have been prepared for the introduction of this resource as effective alternatives against the lack of conventional water at the national level. The reuse of treated wastewater in accordance with the standards listed below **(table 2.3)** appears as a highly recommended solution.

- Law 05-12: sets the principles and rules for the use, management and sustainable development of water resources as good for the national community.
- Executive Decree No. 07-149 of 3 Joumada El Oula 1428 corresponding to May 20, 2007. The purpose of this decree is to fix the specifications of treated wastewater used for irrigation purposes. The main purpose of this decree are the terms and conditions for the use of treated wastewater, the risks associated with the use of treated wastewater (prohibitions, distance to be respected, etc.), sanitary controls, the standard specifications for treated wastewater reuse (OFFICIAL JOURNAL OF THE ALGERIAN REPUBLIC, 2012).

Table 2.3 List of crops that can be irrigated with treated wastewater (Official journal, Algeria 2012)

Type of culture	Crops
Fruit trees	Dates, vine, apple, peach, pear, apricot, clover, cherry, plum, nectarine, pomegranate, fig, rhubarb, peanuts, walnuts, olive.
Citrus	Grapefruit, lemon, orange, mandarin, tangerine, lime, Clementine.
Forage crops	Corn
Industrial crops	Industrial tomato
Cereal crops	Wheat, barley, triticale and oats.
Seed production crops	Potato, beans and peas
fodder shrubs	Acacia
Floral plants to be dried or used industrially	Rose, iris, jasmine, marjoram and rosemary.

Table 2.4 Microbiological parameters (Official journal, Algeria, 2013)

	Microbiological parameters	
	Fecal coliforms CFU/100ml	**intestinal nematodes eggs/l**
• **Irrigation non restrictive.** • **Cultivation of products that can be consumed raw**	<100	none
• **Vegetables that are eaten only cooked.** • **Vegetables for canning or non-food processing**	<250	<0.1
• **Fruit trees** • **Fodder crops and shrubs** • **Cereal crops.** • **Industrial crops** • **Forest trees.** • **Floral and ornamental plants**	<1000	< 1

Table 2.5 Physico-chemical parameters (Official journal, Algeria, 2013)

Parameters		**Unit**	**Maximum allowable concentration**
Physical	PH		6.5≤PH≤8.5
	TSS	Mg/l	30
	EC	Ds/m	3
Chemical	DBO5	mg/l	30
	DCO	mg/l	90
	CL	mg/l	10
	NO_3^-	mg/l	30
	HCO3	mg/l	8.5
	Aluminium	mg/l	20
	Arsenic	mg/l	2
	Beryllium	mg/l	0.5
	Boron	mg/l	2
	Cadmium	mg/l	0.05
	Chromium	mg/l	1
	Cobalt	mg/l	5
	Copper	mg/l	5
	Cyanide	mg/l	0.5
	Fluorine	mg/l	15
	Iron	mg/l	20
	Phenols	mg/l	0.002
	Lead	mg/l	10
	Lithium	mg/l	2.5
	Manganese	mg/l	10
	Mercury	mg/l	0.01
	Molybdenum	mg/l	0.05
	Nickel	mg/l	2
	Selenium	mg/l	0.02
	Vanadium	mg/l	1.0
	Zinc	mg/l	10

2.6. World health organization agricultural Reuse Standards

Different regions and governmental agencies have adopted a variety of standards for use of reclaimed water for irrigation of crops. These rules and regulations have been developed primarily to protect public health and water resources; specific crop water quality requirements must be developed with the end users.

The WHO guidelines **(WHO, 2006)** for irrigation with reclaimed water, widely adopted in Europe and other regions, is a science-based standard that has been successfully applied to irrigation reuse applications throughout the world.

When considering the use of reclaimed water in agriculture, it is important to identify the key constituents of concern for agricultural irrigation. Plant sensitivity is generally a function of a plant's tolerance to constituents encountered in the root zone or deposited on the foliage, and reclaimed water tends to have higher concentrations of some of these constituents than the groundwater or surface water sources from which the water supply is drawn. The types and concentrations of constituents in reclaimed water depend on the municipal water supply, the influent waste streams (i.e., domestic and industrial contributions), the amount and composition of infiltration in the wastewater collection system, the treatment processes, and the type of storage facilities. Determining the suitability of a given reclaimed water supply for use as a supply of agricultural irrigation is, in part, site-specific, and agronomic investigations are recommended before implementing an agricultural reuse program.

2.6.1. Salinity and Chlorine Residual

Salinity is a key parameter in determining the suitability of the water to be used for irrigation, and the wide variability of salinity tolerance in plants can confound the issue of establishing salinity criteria. All waters used for irrigation contain salt to some degree; therefore, salts (both cations and anions) will build up without proper drainage

Salinity is determined by measuring the electrical conductivity (EC) and/or the TDS in the water; however, for most agricultural measurements, TDS is reported as EC. The use of high TDS water for irrigation will tend to increase the salinity of the groundwater if not properly managed. The extent of salt accumulation in the soil depends on the concentration of salts in the irrigation water and the rate at which salts are removed by leaching. Using TDS as a measure of salinity, no detrimental effects are usually noticed below 500 mg/L. Between 500 and 1,000 mg/L, TDS in irrigation water can affect sensitive plants; at concentrations above 1,000 to 2,000 mg/L, TDS levels can affect many crops, so careful management practices should be followed

With respect to chlorine residuals, which may be present as a disinfection residual, free chlorine at concentrations less than 1 mg/L usually poses no problem to plants; chlorine at concentrations greater than 5 mg/L can cause severe damage to most plants. However, some sensitive crops may be damaged at levels as low as 0.05 mg/L. For example, some woody crops may accumulate chlorine in the tissue up to toxic levels; further, excessive chlorine residuals can have a similar leaf-burning effect that is caused by sodium and chloride when reclaimed water is sprayed directly onto foliage. Low-angle spray heads or surface irrigation options can reduce the leaf-burning impact

2.6.2. Trace Elements and Nutrients

Thirteen mineral nutrients are required for plant growth, and fertilizers are added to soils with inadequate concentrations of these nutrients. Mineral nutrients are divided into two groups: macronutrients (primary and secondary) and micronutrients. Primary macronutrients, which include nitrogen, phosphorus, and potassium, are often lacking from the soil because plants use large amounts for growth and survival. The secondary macronutrients include calcium, magnesium, and sulfur. Micronutrients—boron, copper, iron, chloride, manganese, molybdenum, and zinc—are elements essential for plant growth in small quantities and are often referred to as trace elements. While these trace elements are necessary for plant growth, excessive concentrations can be toxi c The recommended maximum concentrations of constituents in reclaimed water for "long-term continuous use on all soils" are set conservatively based on application to sandy soils that have adsorption capacity. These values have been established below the concentrations that produce toxicity when the most sensitive plants are grown in nutrient solutions or sand cultures to which the constituent has been added. Thus, if the suggested limit is exceeded, phytotoxicity will not necessarily occur; however, most of the elements are readily fixed or tied up in soil and accumulate with time such that repeated application in excess of suggested levels is likely to induce phytotoxicity. The trace element and nutrients criteria recommended for fine-textured neutral and alkaline soils with high capacities to remove the different pollutant elements are provided in **Table 2.6**

Table 2.6 Maximum concentration allowed of trace element (Bouchaala. 2017)

Constituent	Maximum Concentrations for Irrigation (mg/L)	Remarks
Aluminum	5.0	Can cause nonproductiveness in acid soils, but soils at pH 5.5 to 8.0 will precipitate the ion and eliminate toxicity
Arsenic	0.10	Toxicity to plants varies widely, ranging from 12 mg/L for Sudan grass to less than 0.05 mg/L for rice
Beryllium	0.10	Toxicity to plants varies widely, ranging from 5 mg/L for kale to 0.5 mg/L for bush beans
Boron	0.75	Essential to plant growth; sufficient quantities in reclaimed water to correct soil deficiencies. Optimum yields obtained at few-tenths mg/L; toxic to sensitive plants (e.g., citrus) at 1 mg/L. Most grasses are tolerant at 2.0 - 10 mg/L
Cadmium	0.01	Toxic to beans, beets, and turnips at concentrations as low as 0.1 mg/L; conservative limits are recommended
Chromium	0.1	Not generally recognized as an essential element; due to lack of toxicity data, conservative limits are recommended
Cobalt	0.05	Toxic to tomatoes at 0.1 mg/L; tends to be inactivated by neutral and alkaline soils
Copper	0.2	Toxic to a number of plants at 0.1 to 1.0 mg/L
Fluoride	1.0	Inactivated by neutral and alkaline soils
Iron	5.0	Not toxic in aerated soils, but can contribute to soil acidification and loss of phosphorus and molybdenum
Lead	5.0	Can inhibit plant cell growth at very high concentrations

Lithium	2.5	Tolerated by most crops up to 5 mg/L; mobile in soil. Toxic to citrus at low doses—recommended limit is 0.075 mg/L
Manganese	0.2	Toxic to a number of crops at few-tenths to few mg/L in acidic soils
Molybdenum	0.01	Nontoxic to plants; can be toxic to livestock if forage is grown in soils with high molybdenum
Nickel	0.2	Toxic to a number of plants at 0.5 to 1.0 mg/L; reduced toxicity at neutral or alkaline pH
Selenium	0.02	Toxic to plants at low concentrations and to livestock if forage is grown in soils with low levels of selenium
Tin, Tungsten, and Titanium	-	Excluded by plants; specific tolerance levels unknown
Vanadium	0.1	Toxic to many plants at relatively low concentrations
Zinc	2.0	Toxic to many plants at widely varying concentrations; reduced toxicity at increased pH (6 or above) and in fine-textured or organic soils

2.7. Economic considerations

To optimize the net benefits from implementation of waste water reuse, a well designed integrated planning process, as described before is essential. Conceptual level planning for wastewater reuse typically involves definition of the project, cost estimation, and identification of a potential reclaimed water market. Furthermore social and economic benefits of agricultural wastewater reuse have to be assessed (BAHRI A. 1999; HARUVY NAVA 1997,1998; HARUVY ET AL.1999 among other studies). A distinction between economic and financial analysis has to be made. The objective of the economic analyses of wastewater reuse projects is to quantify impacts on society, whereas financial analysis are targeted on the local ability to raise money from project revenues, governmental grants, and loans to pay for the project. o Economic analysis: Focus on the value of resources invested in a project to construct and operate it, measured in monetary terms and computed in terms of present value estimations o Financial analysis: determines if a favoured economic option is financially viable (PORTER, 1984). The marginal financial analysis to be considered consists of the following costs: Capital costs (include leads payments, dept serving), operation and maintenance costs, energy costs, revenue and timing of expenditure and receipts .

2.8. Main management actions to improve irrigation with treated wastewater

Wastewater reuse in agriculture is a complex issue: The main management actions to improve health and safety, efficiency and competitiveness in irrigation with treated wastewater can be summarized as follows.

Table 2.7 Main management actions to improve irrigation with treated wastewater (Bouchaala. 2017)

	Policy, Regulation, Institutional Initiatives	**Engineering Practices**	**Agronomic Practices**
Measures for Health Protection	• Set water quality guidelines • Provide guidelines enforcement • Introduce crop restrictions • Restrict public access to irrigated areas • Establish monitoring and supervision system	• Improve design and operation of WWTPs • Construct and operate storage facilities and distribution networks • Improve water quality monitoring • Select an adequate irrigation and drainage method	• Select crops according to water & soil quality • Control the timing of irrigation • Introduce harvesting measures
Improve Food Production	• Provide incentives for crop production, connection to TWW and land reclamation • Set limits on groundwater or surface extraction	• Improve efficiency of irrigation systems • Adapt irrigation timing to crop needs and climatic conditions • Apply appropriate measures to control salinity (leaching, drainage, blending with fresh water)	• Select tolerant crops • Introduce good crop rotation • Apply land levelling • Irrigate according to crop water requirements • Apply soil amendments if necessary
Improve Economic Efficiency	• Review water price and TWW charges • Introduce cost recovery measures • Provide funding and financial incentives	• Improve and optimise O&M of wastewater reuse systems • Enhance users' involvement in wastewater reuse management • Improve public education	• Select crops with high market value • Develop landscape irrigation and other uses of TWW to avoid seasonal demand

Wastewater is steadily produced but cannot be steadily reused for irrigation, in particular because of the seasonality of demand in agriculture. Therefore intermediate storage facilities have to be provided. The intermediate storage of reclaimed wastewater is important for peak equalization and to allow bridging between different periods, as demand for irrigation water is generally high during the dry season. Intermediate storage facilities (e.g. reservoirs) increase the costs of wastewater reuse schemes but have the advantage of contributing to pathogen die-off and thus reducing the risks for agricultural use. The dimensions and costs in each case have to be the subject of site-specific feasibility studies. The distribution infrastructure for reclaimed water is a key aspect in planning wastewater reuse projects. It is estimated at 8% of the total construction costs of a project, while the O&M cost of pipelines and storage tanks amounts to 2% of the capital cost (source AQUAREC Handbook, 2006). More important even than the investment costs are the longterm operation and maintenance costs for pumps, collection and distribution systems and storage facilities. These can only be covered sustainably by adequate water tariffs. Quite often, the agricultural users are not willing or able to pay the real provision costs, so that the government needs to subsidise the water price, as is the case for conventional water sources.

Location of wastewater production Water stress or water scarcity, as one of the decisive preconditions for the successful implementation of wastewater reuse schemes, is fairly unevenly distributed between and even inside the South Mediterranean countries. All target countries have a more or less elongated, densely populated coastal strip, mostly with sufficient rainfall and limited agricultural activities. The direct wastewater reuse options in these areas are mainly landscape irrigation (e.g. for golf courses and hotel gardens, forests, greenbelts and similar), groundwater recharge (e.g. for combating saltwater intrusion and for replenishing overpumped aquifers) and all types of industrial reuse. Big agglomerations/cities produce the largest amount of domestic wastewater, which is often contaminated with industrial influents, particularly in the majority of South Mediterranean countries, where no on-site treatment for industrial wastewater is available. Central high-tech WWTPs are needed for the necessary treatment. For reuse in large-scale agricultural schemes located far from human agglomerations, the water has to be transported from the wastewater treatment plant concerned to the irrigation areas. This can be done via pipes/sewers/drains, constructed as gradient or pumping systems. The systems have to be appropriately designed and dimensioned, taking into account potential technical problems such as clogging. Such distribution systems are technically feasible, but these long-distance (pumping) pipelines are very expensive. Such investments could be beneficial if the water is used to irrigate cash crops (such as biofuel, vegetables and high value fodder).

This chapter provides a base for this study. Previous scientific research at different places in the world especially north Africa and middle east were described and discussed, Existing guidelines and different standards related to treated wastewater irrigation were presented and discussed,

In the next chapter we will provide a brief description of the Hennaya plain and sekkak watershed (location, climate and soil), a brief report about wastewater treatment plants of Ain Elhoutz. And a description of the research methodology.

CHAPTER 3

DESCRIPTION OF THE STUDY AREA AND RESEARCH METHODOLOGY

3.1. Geography and Location:

The hennaya plain is an agricultural area with great potential. It is located north of the town of Tlemcen (**Figure 3.1);** it is limited to the east by Oued Sikkak, to the west by Oued Khallouf, in the North by Oued Isser. This plain occupies an area of 28 km2 and it is located in the sekkak watershed which has an area of 463 km2 for a perimeter of 116 km; this basin is moderately long, extensive cultivation occupies more than half of the watershed area.

The plain of Hennaya is located at the outlets of two ravines: The ravine of Hennaya also known as ravine sources in the watershed occupies an area Approximately of 14 km2, and the ravine formed of Chabet Sidi Kannoun whose basin area is approximately 8 km2. It extends, in the North, by the plain of gossels and in the North-East by the plain or of Zenata. The flat relief gradually drops to the North (from 400m to 240).

It is crisscrossed by two parallel oueds :oued khalouf and oued sekkak that descend to the northeast, all tributaries of the Tafna (**Figure 3.2);** .

The Oued Sikkak originates from Terni hills at the source of Ain Rhannous and pours into the Sekkak dam.

3.2. Climate

3.2.1. Rainfall

Rainfall is one of the most important climatic parameters of the water cycle, it is the primary factor that determines the type of climate.

Rainfall assessment will be done by making a variability study of annual and monthly rainfall data.

Precipitation data was provided by Zenata Station over a period of 35 years (1980-2014).

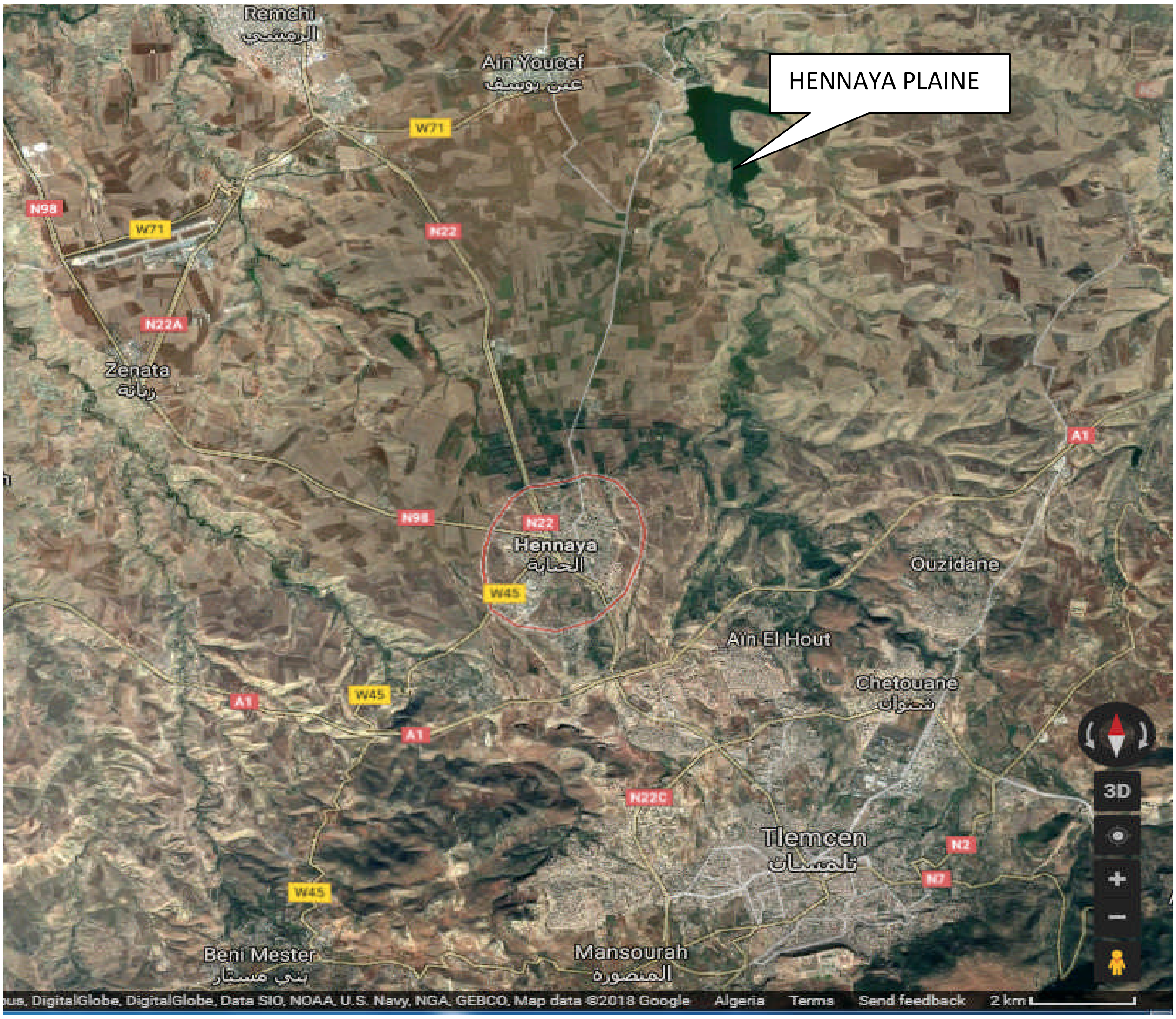


Figure 3.1 Hennaya plain location.

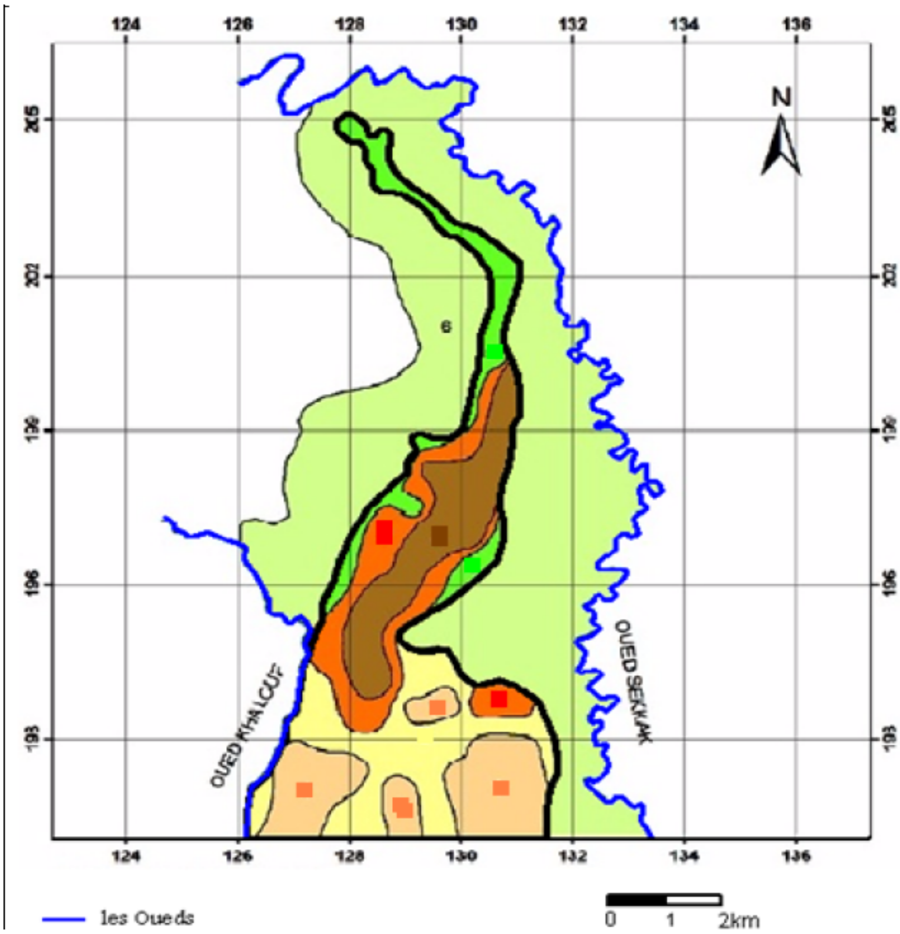


Figure 3.2 The two main oued crossing hennaya plain.

- **<u>Interannual variability</u>**

Figure 3.3 shows significant fluctuations in the curve, with a minimum of 80.25mm observed in 1981-1982, a maximum of 569.3mm in 1986-1987 and an interannual average of 316.6mm.

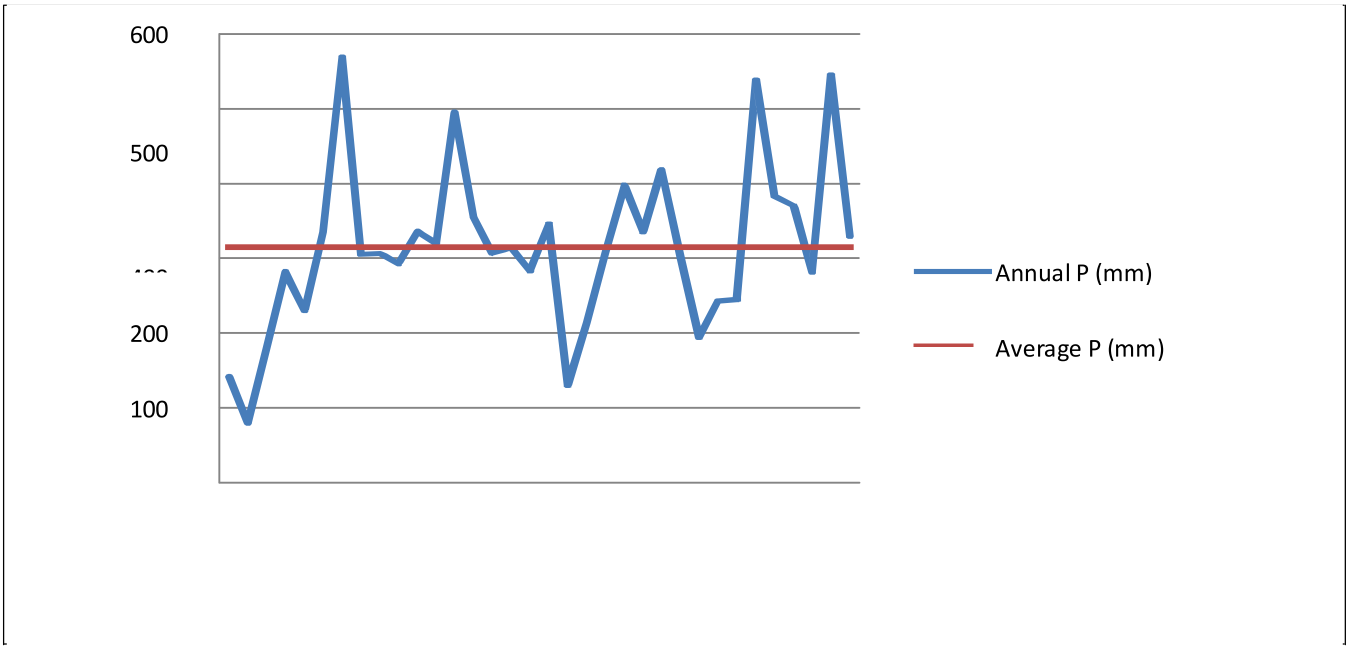


Figure 3.3 Inter annual rainfall variability

- **<u>Monthly Variability</u>**

Figure 3.4 shows that November is the rainiest month with a mean monthly precipitation value of 46.8mm and the driest month is July with a value of 1.13mm.

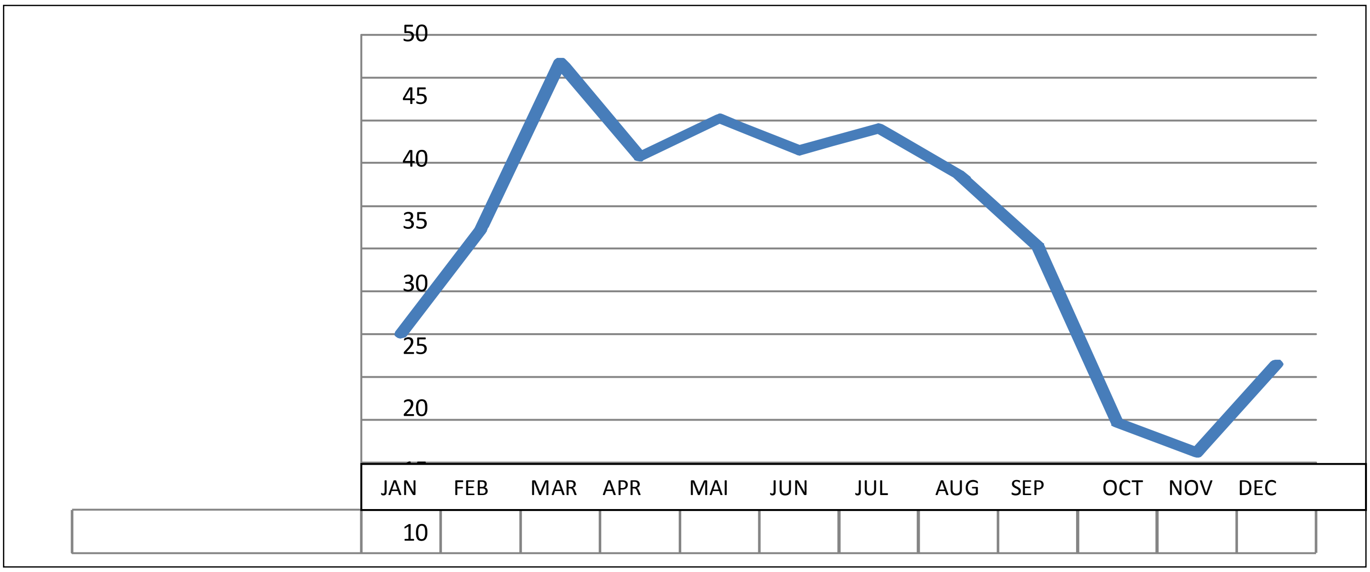


Figure 3.4 Monthly rainfall variability

- **Seasonal variation**

The histogram of seasonal precipitation (figure 3.5) indicates that winter and spring are the wettest seasons, while summer is the driest season.

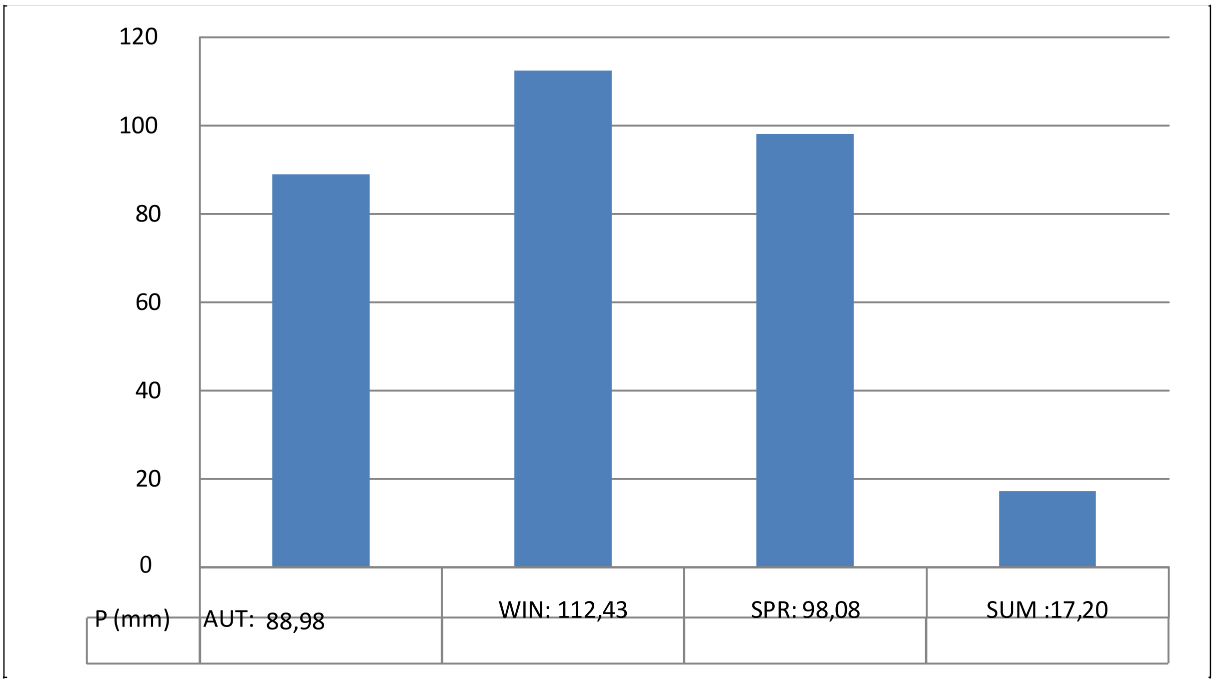


Figure 3.5 Seasonal rainfall variability

3.2.2. Temperature

- **Annual Temperatures**

Mean annual temperatures during this period do not vary widely. They are between 16.16 and 18.58 ° C (figure 3.6), with a minimum of 16.16 ° C recorded in 1980-1981 and a maximum of 18.58 ° C recorded in 2009-2010

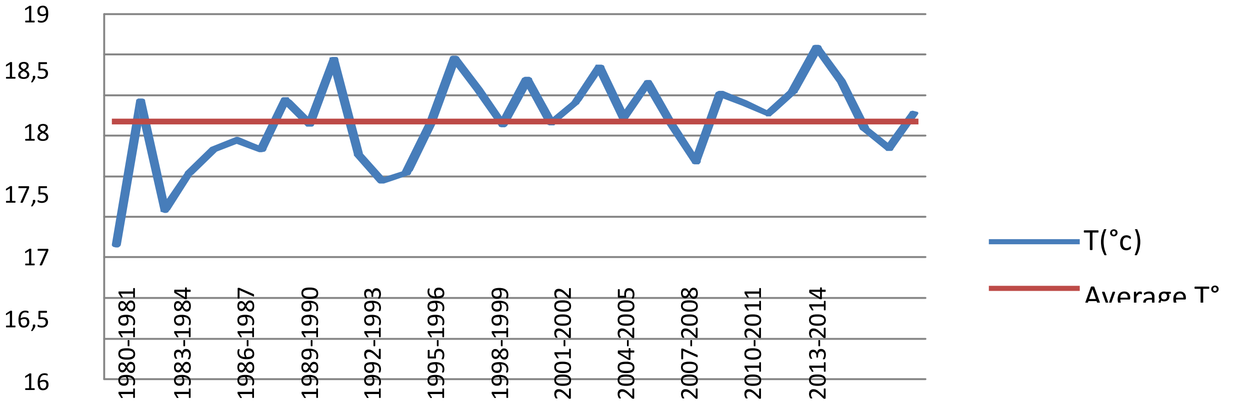
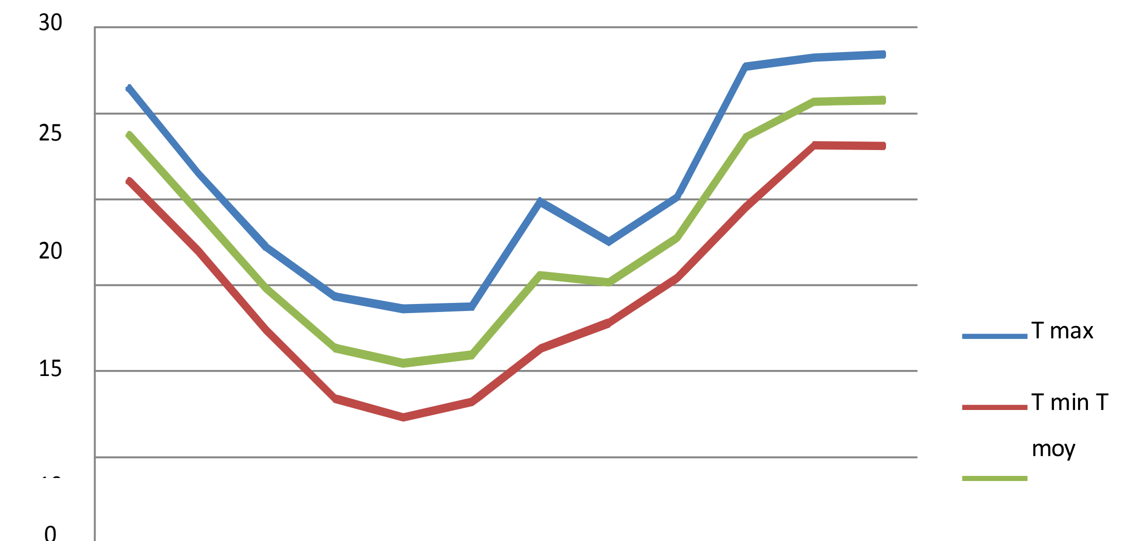


Figure 3.6 Annual temperatures

- <u>**Monthly Temperatures**</u>

The graphical representation of the variation in mean monthly temperatures (figure 3.7) shows that the month of January is coldest (7.3 ° C) and that of August is the warmest (28.4 ° C).



	S	O	N	D	J	F	M	A	M	J	JU	
T max	26,	21,	17,	14,	13,	13,	19,	17,	20,	27,	28,	28,
T min	21	17	12,	8,4	7,3	8,2	11,	12,	15,	19,	23,	23,
T mean	23,	19,	14,	11,	10,	11	15,	15,	17,	23,	25,	25,

Figure 3.7 Monthly temperatures

3.3. Geology

The plain of Hennaya, corresponds to a tectonic depression whose filling consists of Plio-Quaternary formations (Clays, conglomerates and travertines) and Miocene formations (Sandstone sandstone and Serravalian marl) resting on a Jurassic bedrock (dolomite and limestone) (Yahyaoui Z., 2007).

- **Lithostratigraphic analysis**

The litho stratigraphic series is composed as follows:

- Helvetian: is represented by the marls that form the impervious substratum of the plains of the plain [Yahyaoui Z., 2007]. The marls are gray or bluish series, becoming ocher by alteration, within this series are intercalated many upright scales of yellow sandstone [Hayane SM, 1983].
- Tortonian: is represented by cracked yellow sandstones, the sandstones are subhorizontal and hard, sometimes little consolidated and badly read, their power is of the order of 25m.
- Pliocene (conglomerates): At the outlet of the Hennaya water table (AinBoukoura, Ain Ouahab, Ain Halilifa and Ain El Kahla), the conglomerates form a continuous band that goes from the north of the Hennaya agglomeration to Ain Halilifa [Bourbaba L. & TorchI M., 2014].

The conglomerates of the plain of Hennaya, are either immediately posterior to the Tortonian sandstone, they correspond to the regressive phase that ended the Miocene, ie Pliocene [Hayane S.M., 1983].

- Quaternary:
  - Travertines: the resurgences, resulting from the Jurassic massifs, are underlined by sometimes consolidated travertines. In the North, they are much less thin.
  - Carapace limestone: this carapace covers the Miocene formations and forms the horizontal entablature of the trays.
  - Crust limestone: this small crust, formed by encrusting light tint and lamellar crusts. This encrustation is well marked on the plain of Hennaya where it partially masks the tortonian sandstones [Yahyaoui Z., 2007].

The formations that characterize our area of study are of age: Helvetian who are represented by the marls that form the impermeable substratum, Tortonian that are represented by cracked yellow sandstones, Pliocene which are represented by the conglomerates form a continuous band, and the Quaternary which are represented by the Travertines and the Carapace limestone, and also the calcareous crusts.
The formations which constitute essentially the aquifer of the plain of Hennaya are the tortonian sandstones and the conglomerates.

3.4. Hydrogeology

The hydrogeological study of the Hennaya plain consists of knowing the hydrodynamic and hydrogeological characteristics of the aquifer. This zone is characterized by activities in the field of agriculture which announces a major exploitation of the aquifer by several wells.

3.4.1. Tortonian aquifer horizon

Located south of the plain, it is inexistent on the north. The total thickness is 10m observed in boreholes and existing wells; the flows obtained from this aquifer level are low, Part of the aquifer is occupied exclusively by friable sandstones. On the surface, the horizon is free and fed by righteous waters. In depth, it receives water from the Jurassic dolomites and limestones that are the main source of alimentation of the Tortonian aquifer reaching Part of the aquifer horizon. It is covered with gravel and clayey gravels, a common aquifer horizon. Infiltration by infiltration is difficult in the parts where the cover consists of clay and calcareous crusts. [A.benmoussat. 2012]

3.4.2. Alluvial aquifer horizon

Conglomerates represent the most important aquifer forming with the travertines, gravels and argillaceous stones, a common aquifer complex The flow rates obtained in the wells and soundings are important. Thickness decreases northward. It is noted that the conglomerates in the area of Ain Boukora and Ain Wahab are important dimensions and can be considered as karst. [A.benmoussat. 2012]

- **The travertines**

The travertines are located in the central and northern part of the aquifer also with cavernous ground, but they are important to me in comparison with the conglomerates, conglomerates,

- **Gravel and clay gravels**

Located above the conglomerates, they cover almost all the aquifer this horizon is covered with clay and calcareous crusts. The latter are more important to the south where they reach a thickness of 22.6 m.

3.4.3. Non-aquifer horizon

The fine-grained Helvetian marls are covered with calcareous clay. They are very few where there are no aquifers.

3.4.4. Geometry of the aquifer

- **The limits of the aquifer**

  -To the west by impervious Helvetian marls.

  -To the north: the aquifer horizon is drifted towards the surface by springs

  -To the south by the karst terrains of the Upper Jurassic of Tlemcen

- **outlets**

The sources appear in conglomerates in contact with the substaratum immpermiable. With the exception of the source of Hennaya which emerges at the sandstone level Tortonian. The most important sources are those of Ain Boukoura with an average flow of (50L / s) and Ain Ouahab with an average flow of (20L / s), they are considered as the outlet of the Hennaya water table.

We can say that The Hennaya plain contains an alluvial aquifer consisting of tortonian sandstones in the south and conglomerates surmounted by travertines and argillaceous gravels in the north, they have a capacity of about 22 million m3 with a large thickness in the central part and lower we are going north. According to the hydrogeological study on the aquifer of the plain of Hennaya, The water table is recharged by feeding laterally, by the Tlemcen dolomites which are outcropping to the south of the Hennaya plain.

The majority of sources emerge in conglomerates, with the exception of the source from Hennaya which emerges at the level of the tortonian sandstone. The source of Ain Boukoura with an average flow of (50L / s) is the main outlet of the aquifer. the flow is generally from South-West to North-East. [A.benmoussat. 2012]

3.5. Wastewater treatment plant of Ain El Houtz

It is located in the west of Chetouane on the road leading to Ain El Houtz. It has a capacity of 30 000 m3 / day; it was carried out by the National Hydro treatment Company. It has been managed and operated by the National Office of Sanitation (ONA) since 2005. This plant is designed to purify domestic wastewater and rainwater by activated sludge purification process. **(Figure 3.8)**
The plant includes the following equipments:

Figure 3.8 Ain El houtz wastewater treatment plant

- **Spillway storm:**

It is installed upstream, it discharges the excess of the admissible flow into the general bypass of the station. The overflow height will be adapted to accept a load of 3300 m3 / h. The wastewater to be treated gravitarily arrives at the head of the first treatment channel using an 800 mm pipe. **(FIGURE 3.9)**

Figure 3.9 Spillway storm

- **Traveling screen:**

It has two types of screens: A rough manual screen with a width of 1.8 m, its inclination is 70%. The distance between the bars is 50 mm and another mechanized screen there are 2 units whose width is 1.0 m. The depth channel length is 1.5 m, the distance between the bars is 20 mm.

The plant is also equipped with a manual bypass screen which is next to the mechanized grilles. This screen ensures the smooth operation of the plant in case of problems with the mechanized grids: clogging, failure. **(figure 3.10)**

Figure 3.10 Traveling screen

- **<u>Sandtrap</u>**

This structure is of longitudinal type with two compartments, it consists of a reinforced concrete channel of trapezoidal shape. The air is blown by suppressors to cause an emulsion to improve the separation of sand and grease. There are separation blades that allow the separation of oils and greases to the scraping area. Pretreated water is discharged gravitationally through an open channel for subsequent treatment. It has the following unit dimensions - length: 26m, - width: 4m, - height: 9m. The entrance is equipped with cofferdams to allow separation in case of interventions. The sands decant and are found at the bottom in a deep part. The sand grains decanted in the pit are extracted by the air lift system and stored in sandboxes. Floating material and grease will accumulate on the surface and be scraped up to the entrance of grease well, and then transported to the Technical burying center **(figure 3.11).**

Figure 3.11 Sand trap

- **Aeration-tank**

The tank has a rectangular shape, is fed with denitrified water. Aeration in the tank is performed using slow speed surface aerators. Each tank is equipped with three aerators. This favorable environment causes the development of bacteria that by physicochemical action retain organic pollution and feed on the level of each tank. There is a dissolved oxygen sensor to automatically trigger aeration in case of failure of the concentration of the latter. Each rectangular basin has a length of 55.5 m, a width of 18.5 m, a water depth of 4.6 m and a height of 5.6m. The volume of a 4723 m3 basin

the aeration tank is designed to ensure a uniform mixing of the mud, avoid deposits of suspended matter and erosion of the bottom or walls of the structure. The aeration tanks are equipped with a vertical axis type surface aerator with a slow rotation speed. Each aerator is mounted on a reinforced concrete bridge with guardrail. The footbridges rest on four reinforced concrete posts.**(figure 3.12)**

Figure 3.12 Aeration tank

- **<u>Nitrification denitrification</u>**

The pretreated water arrives firstly in this tank to eliminate nitrogen pollution from specific bacteria. The tank with a rectangular shape is equipped with a bottom mixer to ensure agitation of the medium, and after the nitrified denitrified water is discharged to the aeration tank. Each tank has the following dimensions: - Volume 725 m3, - Length 17,56 m, - Width 8,5 m, - Height of concrete 5,6 m, - Height of water 4,9 m **(figure 3.13)**

Figure 3.13 Nitrification denitrification tank

- **Secondary clarifier**

its role is to ensure a better separation of biomass from the treated water and to allow a first thickening of decanted organic sludge. The mixed activated sludge liquor formed in the biological reactor is then directed to the secondary settling structure which is fed from the center through a feed line.

The purpose of this operation is the separation of the purified water from the sludge it contains. The mixed liquor is introduced at its center. The clarified water overflows in the periphery in a double recovery chute and the settled sludge is deposited on the slab and will be scraped towards the center where they thicken slightly.

The plant contains two secondary clarifiers and each equipped with a scraper bridge at a rotation speed of 0.04 m / s. They are circular in shape, with a diameter of 46 m and a surface of 1661 m2. The water depth is 4 m **(figure 3.14)**

Figure 3.14 Secondary clarifier

- **Chlorination tank**

The station is equipped with a chlorination treatment to disinfect the treated water. But this treatment is not used. The basin is made of reinforced concrete and has a volume of about 700 m3. **(Figure 3.15)**

Figure 3.15 Chlorination tank

- **Sludge pumping**

The sludge is piped to two pits of recirculating sludge and excess sludge for efficient biological treatment. It is necessary to maintain a stable rate of suspended matter in the aeration tank of the order of 4g / l . For this, it is necessary to recirculate a portion of the sludge that is extracted from the secondary clarifier to the entrance of the aeration tank. This sludge is referred to as return sludge or recirculation sludge **(figure 3.16)**

Figure 3.16 Sludge pumping

- **Sludge dryer**

The sludge is pumped and evacuated to the drying tank. Sludge tanks carried out outdoors in areas of 30 m in length and 15 m wide. There are 14 drying tanks made of concrete equipped with a perforated drainage pipe, to allow the evacuation of filtered water to the entrance of the plant **(figure 3.17)**

Figure 3.17 Sludge dryer

3.6. Research methodology

3.6.1. Irrigation system

Drip irrigation system was selected in some areas based on its higher safety for a water irrigation coming from wastewater treatment as a resource for irrigation, The possible problems facing the use of drip irrigation system is:

- Sometimes maybe the existence of some suspended solids in the treated wastewater which will request very efficient filtration systems.
- For long term irrigation, the possibility of Risks of bacteria occupying the irrigation system.

Sprinkler irrigation system was excluded in some areas based on the possibilities of contamination of people working in the farm, and in some case even animals existence nearest the farm or neighbor maybe in risks of contamination .

3.6.2. Experiment Design

Two plots already were selected, in order to investigate effects of irrigation with treated wastewater on soil properties and groundwater quality. Fresh water was used to irrigate the first plot and treated Wastewater was used for the irrigation of the second plot.

The quantity of irrigation water (fresh water and treated wastewater) was not taken into consideration, as the irrigation system already exists and it is difficult to control accurately.

3.6.3. Materials

The main reason of this research study is to assess the impact of treated wastewater reuse on soil properties and groundwater quality. Test program was carried out to obtain field and laboratory data needed for determining the impact of TWW on both soil and plant seven years of using treated wastewater for irrigation. To attain perspective about treated waste water impact and in addition to our analysis, previous analysis established by private farmers was discussed and assessed, this analysis containing historical results data of soil and groundwater for different years.

3.6.4. Sampling time

Samples were taking during the second week of Mai, the sampling process started from Mai 14^{th} until Mai 17^{th} 2018. This operation took 4 days, and samples were taking during the early hours of the morning.

3.6.5. Water sampling

Samples of groundwater and treated wastewater were taken, manual grap samples were collected from private wells and storage basin of treated wastewater, one liter clean acid-washed polyethylene bottles used to collect groundwater and treated wastewater samples for physiochemical analysis, while 250 ml sterile bottles were used for microbiological analysis, using paper label to prevent sample misidentification.

After the collection of groundwater and treated wastewater samples, they were transported immediately to a private laboratory and analyzed for the physiochemical and biological parameters.

the Standard Methods for the Examination of Water and Wastewater. Chemical, physical and biological analysis was conducted and the results will be presented in the next chapter.

3.6.6. Soil Sampling

The sampling technique that was used during this study aims to take into account different points on the study area on different depths. Samples collection was done on different depths on two point's distant one to another on the plains of Hennaya, the first is irrigated with treated wastewater and the second is irrigated with fresh water. Samples were taken at two depths (0-30, 30-60 cm). Plastic bags were used to collect different labeled samples depending on the sampling location and the sampling depth. Soil samples were cleaned off any stones and plant residues.

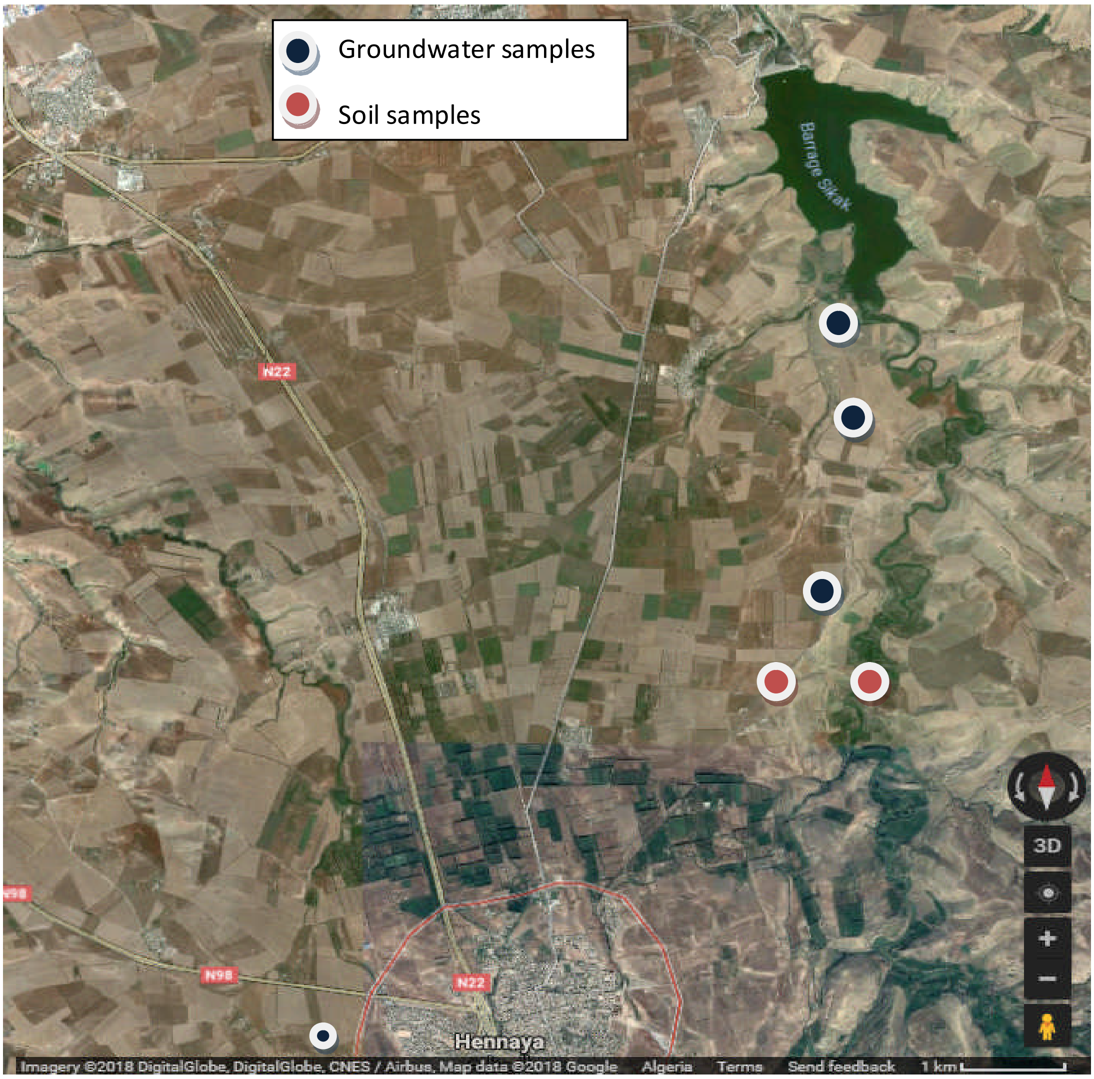


Figure 3.18 Groundwater and soil samples location

After the description of the research methodology including the collection of samples for irrigation water, groundwater and soil , the steps that have been followed during the process , the preservation of samples. We will present in the next chapter all the results and discussion, the data collected from the field and laboratories will be presented and discussed and all the recommendations will be introduced at the end.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1. Introduction

Analyses of treated wastewater, groundwater and soil for treated wastewater reuse in Hennaya plaine , will be presented and discussed in this chapter in order to investigate effects on the groundwater quality as a results of short term irrigation by treated wastewater, and to investigate the effect of treated wastewater irrigation on soil physical and chemical properties .

4.2. TWW and groundwater characteristics

4.2.1. Treated wastewater samples analysis results:

Results of analysis for three treated waste water samples are presented in the following tables (table 4.1, table 4.2, and table 4.3).

Table 4.1 Treated wastewater sample -1- analysis results

Parameter	**Treated wastewater sample -1-**
PH	7.20
Turbidity(NTU)	5.90
EC (µS/cm)	980
TSS (mg/l)	24
BOD5	18.8
COD	41.3
NO_3^-	7.25
Ca^{2+}	280
Mg^{2+}	65
K^+	33.83
PO_{43}^-	5.75

Table 4.2 Treated wastewater sample -2- analysis results

Parameter	Treated wastewater sample -2-
PH	7.40
Turbidity(NTU)	5.60
EC (µS/cm)	938
TSS (mg/l)	21
BOD5	17.3
COD	44.7
NO_3^-	7.35
Ca^{2+}	298
Mg^{2+}	65
K^+	33.83
PO_{43}^-	5.75

Table 4.3 Treated wastewater sample -3- analysis results

Parameter	Treated wastewater sample -3-
PH	7.12
Turbidity(NTU)	5.80
EC (µS/cm)	966
TSS (mg/l)	22
BOD5	18.1
COD	41.6
NO_3^-	7.75
Ca^{2+}	298
Mg^{2+}	70
K^+	33.23
PO_{43}^-	5.15

4.2.2. Groundwater samples analysis results

Results of analysis for three groundwater samples are presented in the following tables (table 4.4, table 4.5, and table 4.6).

Table 4.4 Groundwater sample -1-analysis results

Parameter	Groundwater sample -1-
PH	7.6
Turbidity(NTU)	2.70
EC (µS/cm)	1820
TSS (mg/l)	3
BOD5	0
COD	0
NO_3^-	49.4
Ca^{2+}	85
Mg^{2+}	67
K^+	12.98
PO_{43}^-	2.39

Table 4.5 Groundwater sample -2-analysis results

Parameter	Groundwater sample -2-
PH	7.4
Turbidity(NTU)	2.52
EC (µS/cm)	1845
TSS (mg/l)	1
BOD5	0
COD	0
NO_3^-	48.4
Ca^{2+}	70
Mg^{2+}	59
K^+	11.01
PO_{43}^-	2.47

Table 4.6 Groundwater sample -3-analysis results

Parameter	Groundwater sample -3-
PH	7.6
Turbidity(NTU)	2.60
EC (µS/cm)	1770
TSS (mg/l)	2
BOD5	0
COD	0
NO_3^-	45.7
Ca^{2+}	77
Mg^{2+}	61
K^+	9.81
PO_{43}^-	2.03

4.2.3. PH

The results show that pH value of groundwater was not affected, PH value of treated wastewater and groundwater was 7.58 and 7.41 respectively. These values are in the normal range for irrigation water. The normal pH range for irrigation water is from 6.5 to 8.4. Irrigation waters having pH outside this range may still be satisfactory but other problems of nutrition or toxicity become possible.

4.2.4. EC

Current EC of treated wastewater don’t have a restriction on use. While EC of groundwater has slight to moderate degree of restriction on use and it can be used for irrigation with precaution and crops should be selected.

According EPA guidelines Current EC values of groundwater must be applied in excess for leaching, salt tolerant plant should be selected and soil must be permeable.

4.2.5. BOD_5 and COD

The BOD5 and COD values for treated wastewater in the present study refer to an over loading of Ain El Houtz wastewater treatment plant, causing decrease of the efficiency of this plant.

4.2.6. Calcium (Ca+2) and Magnesium (Mg+2) Hazard

The results show that there is no significant impact for Ca+2 and Mg+2 concentrations. Based on EPA the maximum limits were 400 mg/l and 60 mg/l for Ca+2 and Mg+2 respectively. Ca+2 values were below the maximum limit, while values of Mg+2slightly exceed the maximum allowable value (60 mg/l) of guidelines. High concentration of Ca+2 and Mg2 + ions in water can increase soil pH, resulting in reducing of the availability of phosphorous PO4+2 .

4.2.7. Nitrogen (N) and Potassium (K)

Results indicate that Nitrate NO3 value is 47.4 mg/l for treated wastewater, while it have higher values for groundwater 7.75 mg/l, as shown Figure 5.3, there is significant variation between treated wastewater and fresh water . It is obvious that nitrate level of groundwater increased with time and this may be due to the efficiency of Ain Elhoutz wastewater treatment plant as the organic load increases with time. However, nitrate values of groundwater and treated wastewater were lower than usual limits stated by EPA which is reported to be 50 mg/l..

The value of k^+ are 33.23 and 10.08 mg/l for treated wastewater and groundwater receptively, these values were lower than recommended by different standards for irrigated water quality which reported to be 40mg/l. Therefore, it is classified as a major nutrient

4.2.8. Trace Elements

Results indicate that, heavy metals concentrations in groundwater have very low value; because even treated wastewater that have been used for irrigation contain a very low value of heavy metals that comply with the standards of reused wastewater in agriculture. This results revealed that domestic wastewater influent contains a low amounts of heavy metals.

4.3. Soil characteristics

4.3.1. Soil physical properties

The soil texture for both experimental fields, the first that has been irrigated with fresh water and the second that has been irrigated with treated wastewater shows a uniform and balanced texture for both fields, The clayey fraction varies between 35 and 40 %; the silt fraction is also between 35% and 40%; the sand fractions vary between 18 % and 23% as shown in table 4.7

These soils have a homogeneous composition and the high percentage of clay fraction made the possibility of pollutants adsorption relatively high.

4.3.2. Soil chemical properties

Soil chemical properties for both fields (the first that has been irrigated with fresh water and the second that has been irrigated with treated wastewater) are listed in table 4.7

Table 4.7 Physical and chemical properties for soil irrigated with fresh water and soil irrigated with treated wastewater

Soil properties		Soil irrigated with treated waste water		Soil irrigated with fresh water	
		Depth [0-30cm]	Depth [30-60cm]	Depth [0-30cm]	Depth [30-60cm]
Soil texture	% clay	50	47	45	46
	% silt	27	29	30	29
	% sand	23	24	25	25
PH		7.77	7.93	7.6	7.76
CE(ds/m)		0.26	0.30	0.18	0.20
Na^{+}(mé/100g)		2.4	2.46	1.85	1.96
Mg^{++}(mé/100g)		0.61	0.49	0.39	0.28
Ca^{++}(mé/100g)		17.63	14.26	13.13	11.18
K^{+}(mé/100g)		1.13	1.22	1.66	1.72
Zn (ppm)		15	15	12	12
Pb (ppm)		0	0	0	0
Cu (ppm)		7.5	7.5	9	9
Mn (ppm)		36.7	36.7	3.9	3.9
Co (ppm)		17.5	17.5	7	7
Cd (ppm)		0	0	0	0
Cr (ppm)		0	0	0	0

4.4. Effects of treated wastewater irrigation on soil properties

4.4.1. Soil pH

The pH values of all soil layers were varied between 7.6 and 8 as shown in Table 4 which is the most desired range in agricultural soils, there were no significant effects on soil pH due to reclaimed wastewater , results indicated also that pH was higher in the lower soil layer (30-60 cm) than the surface one (0-30 cm).

4.4.2. Electrical Conductivity (EC)

Soil Electrical conductivity is an indication of soluble salt concentration in soil. Treated wastewater irrigation had an effect on Soil Electrical conductivity in the first (0–30 cm) and second (30–60) layers. Soil Electrical conductivity was affected by irrigation with Treated wastewater. In general, Soil Electrical conductivity increased by irrigation with treated waste water due to the significant chloride concentration observed with treated wastewater application.

Higher Electrical conductivity values were found in (0-30cm) layer than in the lower layers (30-60 cm) in both soil with treated wastewater irrigation and fresh water irrigation, which might be due to salts in treated wastewater and subsequent evaporation at the soil surface.

4.4.3. Potassium (K+)

Results revealed variability in the concentration of potassium in the soil layers, K+ concentration in the surface layer of treated wastewater irrigated soil was significantly lower. This reduction in K+ concentration can be related to plant uptake or movement of K+ ions from the surface layer.

4.4.4. Sodium (Na^+)

In both soil layers, the Na^+ concentration with treated wastewater irrigation soil was significantly greater. High Na^+ concentration in the soil can lead to a dispersion of clay particle and the deterioration of soil physical conductivity. As noted earlier, degradation of the structural stability of the surface layer may lead to a reduction in soil permeability and the consequent reduction in infiltration rate, lower water storage capacity, with ensuing problems for plant growth and soil use, and greater probabilities of erosion.

4.4.5. Exchangeable cations Calcium (Ca^{+2}) and Magnesium (Mg^{+2})

Results show that $Ca^{+2}$and Mg^{+2} were increased in the surface layer more than the bottom layer. These variations of the exchangeable cations are explained by the combined effects of fertilizers, leaching after heavy rains and root uptake.

Calcium can be removed by deep percolation of water, plant uptake, and precipitation .is also known that high concentrations of sodium reduces the uptake of important mineral nutrients, K^+ and Ca^{+2} which further reduces cell growth especially for roots.

In this chapter we have seen all the results obtained from the field for the irrigation water, ground water and soil. Results have been discussed and reviewed.

In the next and final chapter we will present the policy aspect including regulations, legislations and a policy framework that should be developed at the national level.

CHAPTER 5

POLICY ASPECTS

Safe management of the use of wastewater in agriculture is facilitated by the existence of appropriate policies, legislation, institutional frameworks and regulations at the international, national and local levels.

The present chapter examines the different national strategies for developing, at each level, adapted frameworks that will help promote the safe use of wastewater in agriculture. It is important to develop an appropriate policies based on national conditions.

5.1. National policies on wastewater use

The national policy on the use of wastewater in agriculture must take into account various points, including:

•The health consequences of the use of wastewater in agriculture (requirement an assessment of the health impact of a project before its implementation in large scale ;) and definition of standards and regulations;

• The scarcity of water;

• The availability of wastewater in the current situation and in the future;

• The place where wastewater is generated;

• Acceptability of the use of wastewater in agriculture;

• The extent of the uses of wastewater currently practiced and their types;

• The ability to effectively manage the use of wastewater;

• Downstream impacts if the wastewater was not used for agriculture;

• The number of people dependent for their livelihood on the use of water used in agriculture;

• The commercial implications of exporting crops produced with Wastewater. (WHO, 2006)

5.2. Legislation

Legislation can both facilitate the safe use of wastewater, for example by putting in place economic incentives for treatment facilities and wastewater use, as well as monitoring responsibilities. In many cases, it is sufficient to modify the existing legislation, but sometimes that we must legislate again. Particular attention will be paid to following:

• Definition of institutional responsibilities or allocation of new powers existing entities;

• Establishing roles and relationships between national governments and local in the area;

• Creation of rights of access and ownership for wastewater, including a regulation public about their use;

• Establishment of property rights on land;

• Development of legislation for public health and agriculture, standards quality of wastewater, product restrictions, methods of spreading, occupational health and food hygiene (Helmy,2015).

5.3. Roles and responsibilities of the institutions

Enabling legislation may be necessary to set up a national coordination for the use of wastewater and to establish local entities responsible for the management of different schemes. This assumes that these entities have authority to charge the wastewater they distribute or to sell any product.

Working within the existing institutional framework may be preferable to creating new ones institutions.

At the national level, the use of wastewater in agriculture is a work for several departments or agencies. As examples of departments or agencies that may exercise jurisdiction over the use of wastewater in agriculture, mention may be made of especially:

• The Ministry of Agriculture: general planning of projects; Management state-owned land; installation and operation of irrigation infrastructure ; agricultural research and its extensions, including training; control of marketing activities.

• Ministry of the Environment: setting standards for treatment wastewater and the quality of effluents on the basis of environmental concerns ; put in place practices to protect water resources (water surface and groundwater) and the environment; establishing protocols monitoring and analysis.

• The Ministry of Health: health protection and in particular the definition of standards of quality and "good practice" (for treated wastewater, products, health protection measures); monitoring methods and application schedules for treated wastewater; monitoring of implementation health protection measures; validation of health protection measures for irrigation with small-scale wastewater; impact assessment sanitation of new wastewater projects; health education; surveillance and treatment of diseases.

• Ministry of Water Resources: Integration of Water Use used in the planning and management of water resources.

• The Ministry of Education: development of new curricula concerning sanitation, personal and household hygiene and safe practices associated with the use of wastewater in agriculture.

• The Ministry of Public Works or Local Government: collection, treatment and use of excreta and wastewater.

• The Ministry of Finance and Economic Planning: Economic Evaluation and financial projects; import control (equipment, fertilizer); development of financial mechanisms for water transport and treatment used and the infrastructure of use. Other ministries and government agencies - for example, those concerned by land ownership, rural development, cooperatives and the status of women may also be involved.

Collaboration is needed between the agencies involved, and in particular between the technical staff involved. Some countries, particularly those affected by a lack of water, may find it advantageous to set up an executive body such as a permanent inter-agency technical committee, under the aegis of a lead ministry (Ministry of Agriculture or responsible for water resources) or possibly a separate organization (benefiting from both public and private funding), such as wastewater recycling service, to take responsibility for development, planning and program management.

The local body managing a use scheme, or at least the agency collecting wastewater, is often placed under the control of the municipality. If use wastewater should be promoted in the context of a public policy national level, this operation requires careful coordination and relations between local and national governments. In addition, it may be necessary the national government to offer incentives to local authorities to promote safe use of wastewater; certain forms of punishment may also must be applied to ensure the implementation of schemes without excessive risk for public health.

Local authorities must have the capacity to issue permits for use wastewater in agriculture from a public distribution network. These permits may be issued by the local administration responsible for agriculture or water resources, local governments or the body controlling the water distribution network waste.

In many urban and peri-urban areas, the use of wastewater (frequently untreated) for irrigation is widespread. These activities appear often spontaneously and are usually not controlled by health authorities local. Due to the small scale and dispersion of these operations, it can be difficult to ensure adequate supervision. Local authorities may be able to to set rules governing the issuing of authorizations for land use the application of specified health protection measures, namely compliance with sanitary conditions concerning the spreading methods, the restrictions on products and the limitation of exposure.

It is common for the entity administering the distribution of wastewater to user associations, which can develop from conventional institutions, to deal with the landowners. Wastewater use permits may associations, which simplify the administrative task of dealing with separately with a large number of small users. In the context of such provisions, associations are also delegated to enforce the regulations which must be respected for a renewal of the permit.

A joint committee or board of directors, which may include representatives of these associations and all the particularly important users, the responsible authorities the collection and distribution of wastewater and local health authorities, must be put in place. Even in the case of small organizations, it is important certain provisions, such as a committee comprising community representatives, be planned for users to participate in project management.

In some cases, farmers are able to negotiate contracts directly on a specific supply of wastewater treated with the utilities treating wastewater.(WHO, 2006)

5.4. REGULATIONS

Regulations governing the use of wastewater in agriculture should be practical and focused on the protection of health (other aspects are also concerned like the protection of the environment). Most important point: the regulations must be applicable in the light of local circumstances.

A regulatory framework should be put in place around the different measures health protection (ie wastewater treatment, restrictions on products, sewage treatment, and limitation of exposure, vaccination or chemotherapy).

There may already be regulations governing certain measures protective. Without a number of complementary measures such as a regulation controlling market hygiene (availability of sanitation facilities
and appropriate water supply, market inspection, analysis periodic laboratory irrigated crops with wastewater), food products healthy, grown in accordance with the regulations on the use of wastewater could easily be re-contaminated in the

markets, which reduce the effect of previous health protection measures. (Helmy, 2015)

5.5. DEVELOPMENT OF A NATIONAL POLICY FRAMEWORK

In the development of a national policy framework to facilitate safe use wastewater in agriculture, it is important to define the policy objectives, to evaluate the current political environment and develop a national approach.

5.5.1. Goals definition

The use of wastewater in agriculture may have one or more objectives. The definition of these goals is an important step in the development of a national policy framework. The main objectives can be:

- strengthen national or local economic development;
- increase agricultural production;
- to increase freshwater supplies and, moreover, to take full advantage of value as a wastewater resource;
- eliminate wastewater in an environmentally friendly manner and expensive;
- improve household income, food security and / or nutrition.

When wastewater is already being used, the introduction of health and the environment in management strategies or improved yields culture through improved practices may be part of sub-objectives.

5.5.2. Assessment of the political environment

The existence of appropriate policies can facilitate the safe use of the waters used in agriculture. It is common for policies to be in place and influencing negatively and positively on the use of wastewater in agriculture. He is often useful to carry out an evaluation of existing policies to develop a new national policy or to revise existing policies. This evaluation must be carried out according to two approaches: that of the political decision-maker and that of the project. Policy makers will want to evaluate national policies, legislation, the institutional framework and regulations to ensure that they fit in with national targets for the use of wastewater (maximize returns on investment without harming public health or the environment).

Coordinators projects will want to ensure that current and future patterns of wastewater use are able to satisfy all national and local laws and regulations relevant. The main points to consider are:

• Policy: Are there clear policies regarding the use of wastewater in agriculture? Should this use be encouraged or not?

• Legislation: Is the use of wastewater regulated by law? What are the rights and responsibilities of the different stakeholders?

• Institutional framework: Which agency, which ministry or which organization is important exercises supervisory authority over the use of wastewater at the level of national and the district or community? The responsibilities of the different Are departments or agencies clearly defined? Is there a ministry or is control exercised by several ministries or agencies whose jurisdictions overlap? Which department or agency is responsible for regulatory development? Is responsible for ensuring compliance with the regulations? Is responsible for enforcing it?

• Regulation: Is there regulation? Is the current regulation sufficient to achieve the goals of wastewater (protect public health, prevent deterioration of the

environment, satisfy quality standards for national and international trade, preserve livelihoods, conserve water and nutrients, etc.)? Regulations
is it applied? Which department or agency is responsible for to enforce it?
It is easier to develop a regulation than to enforce it. When development of new regulations (or selection of regulatory requirements to apply), it is important to provide the institutions, staff and necessary means to ensure that this regulation is respected.

It is also important to ensure that this regulation is realistic and applicable in the context in which it must be. It is often advantageous to adopt a stepwise approach or test a new set of regulatory requirements by persuading a local government to vote them as arrested before they are extended to the rest of the country (WHO, 2006).

CONCLUSION AND RECOMMENDATIONS

In this research, impacts of irrigation with treated wastewater on soil properties and groundwater quality in Hennaya area, Tlemcen, Algeria, was studied and evaluated. The research concentrated on characterization and assessment of treated wastewater, which used for irrigation during study period; physiochemical properties of two layers of soils irrigated by treated wastewater and fresh water were carried out. The results show a number of important conclusions.

The main conclusions drawn from the present study are summarized below:

- Irrigation with waters having pH that exceed the obtained value may still be satisfactory but other problems of nutrition or toxicity become possible.
- Current EC values of groundwater must be applied in excess for leaching, salt tolerant plant should be selected and soil must be permeable.
- Ain El Houtz wastewater treatment plant is over loaded, causing decrease of the efficiency of this plant.
- The domestic wastewater influent contains a low amount of heavy metals and it complies with the standards of reused wastewater in agriculture.
- The pH values of all soil layers are in the most desired range in agricultural soils.
- The presence of salts in treated wastewater and subsequent evaporation at the soil surface has an impact on soil EC
- Treated wastewater used for irrigation in this research have a significant salinity hazard, this is limiting factor for using this type of water for irrigation wide range of plant types
- No significant differences in soil inorganic composition were observed as a result of irrigation with treated waste water.

It can be concluded, that based on the outcome of this study, proper management of treated wastewater irrigation and periodic monitoring of soil fertility and quality specification are recommended to ensure successful, safe and long term reuse of treated wastewater for irrigation.

The final conclusion that can be made from this study is that land application of treated wastewater can be designed and operated in a way such that to minimize negative effects on the environment, this research should be collected over a long period (10 years) to truly evaluate long-term effects of treated wastewater application.

Recommendations

In institutional and regulatory matters:

- The establishment of a multisectoral network (agriculture, health, hydraulics, environment, interior, etc ...) to take care of the problematic of the use of unconventional water for irrigation and the creation of a database capitalizing on all national experiences and International law;
- The involvement of all partners in the most complete and the most transparent so that everyone finds his interest;
- The application of the Water Code and the Water Pretreatment Act industrial waste before being discharged into treatment plants and wadis;
- Ensure regular and sustainable monitoring of the quality of treated wastewater;
- To encourage the associative movement in view of the creation of associations of farmers using treated wastewater.
- For sustainable management of integrated treatment and reuse projects sewage and by-products, it becomes imperative to put in place nationally an organization and an institutional structure capable of well design integrated projects. It would also define the tasks, roles and responsibilities of the various stakeholders in ongoing projects functioning (monitoring, control ...).

- It is essential that the acceptance by the user is ensured. Clear information based on relevant scientific observations as well effective extension and support for farmers on the field and technical assistance can ensure this. On the socio-institutional level, it is necessary to integrate all the actors, since waste water producers to users. The public authorities are called upon to integrate this approach into the national strategy.
- In the interest of the sustainability of projects for the treatment and reuse of wastewater, it is imperative to put in place a system for monitoring and monitoring. Monitoring is carried out by regular monitoring of the different components of the wastewater treatment and reuse system, sludge and agricultural products. Organizational measures adequate to put in place.
- Involvement of all stakeholders for the success of the project in know: Client - Manager - Users - ...).
- Implementation of all accompanying measures to ensure assistance technical, training and retraining of operating personnel, control health, compliance with the regulations.

In research and development, training, and extension

- Encourage research programs to be carried out in line with the constraints encountered (related to human, animal and plant health, the preservation of resources, natural resources and the environment) and socio-economic development objectives;
- Encourage the idea of multidisciplinary, integrated vision of projects, and the approach participatory when it comes to conducting research projects;
- The establishment of a system for monitoring the evaluation of the impacts of water use purified waste on natural resources, on the environment, on crops, on health human and animal, on agricultural yields, on farmers' incomes.

- The development of specific training programs for the benefit of technicians and farmers in the field of the use of treated wastewater;
- Think, develop and implement school awareness programs use of treated wastewater;
- Develop and implement population awareness programs in order to overcoming the psychological barrier of consuming irrigated agricultural products from treated wastewater;
- Develop and implement an extension program for the benefit of farmers in normalized use of treated wastewater.
- it is better to opt for systems of low cost treatment with good treatment efficiency (lagooning, filtration-percolation). For the Infiltration - Percolation process, it is preferable that it be accompanied by a denitrification process in order to ensure the protection resources against pollution. Indeed, it turns out those extensive systems, low cost are relatively better adapted to the socio-economic context of the region.
- Since wastewater treated by lagooning is relatively loaded with micro-organisms, it would be appropriate to extend their time stay and carry out periodic cleaning to reduce the negative impact possible at the level of reuse.
- It is recommended to continue research on the algal channel treatment process high efficiency for better results.

In agronomic techniques

- The use of drip irrigation to reduce risks to human health (eliminate the contact of water with the plant);
- To prevent sprinkler irrigation because of the risk of contamination and burns vegetable;
- Dotate irrigated areas and areas, using unconventional waters, adequate drainage;

- Take into consideration the nitrate contribution conveyed by these waters during the reasoning of the fertilization

At the socio-economic level

- Develop the most economically efficient wastewater treatment techniques;
- Encourage the multiplication of WWTP near agricultural areas with high irrigable potential;
- Taking the emphasis on sludge and other nutrients in wastewater cleansed;
- Encourage the private sector to invest in wastewater treatment.

Finally we can say that the recovery and reuse of wastewater has proven to be a realistic option to cover the water deficit and the growing needs in the latter in our country but also to comply with the wastewater discharge regulations, with a view to protection of the environment, and public health. In addition, from the point of view environmental impact, recovery and reuse of treated urban wastewater for irrigation are probably the most realistic and realistic approach to elimination.

This reuse is not a new concept. With the increase of the demand for water, linked to the increase of the population and the improvement of the standard of living, the reuse of wastewater acquires a growing role in planning and development additional water supplies. This is especially important for our country since it is mostly arid or semi-arid. He enjoys low precipitation, mostly seasonal, and irregular distribution. Moreover, water quality deteriorates sharply.

Water is available at any time in the case of the use of water unconventional, especially refined; this may be possible taking into account the capacity of existing treatment plants

It remains for farmers to submit to this new reality of use unconventional waters, as this may give them regularity in availability, able to manage wastewater treatment plants through the concession and, in particular, periodically carry out the necessary monitoring and analyzes. Water is a limited resource, we must act to conserve and preserve this heritage common irreplaceable.

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