João Rui Fernandes Gomes

Licenciado em Engenharia Civil

Safe reuse of treated urban wastewater in Praia, Cape Verde: a case study

Dissertação para a obtenção do Grau de Mestre em Engenharia e Gestão da Água

Orientador: Prof. Doutor David José Fonseca Pereira, Professor Auxiliar, Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa (Portugal)

Co-orientador: Prof. Doutor Eduardo Moreno Cuesta, Facultad de Ciencias Experimentales, Universidad de Huelva (Espanha)

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Caparica

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Agradecimentos

Este seria um dos capítulos opcionais e um dos quais pensei, injustamente, desprezar.

Contudo, a vida dá mesmo muitas voltas e pequenos acontecimentos, pequenos momentos, fazem-nos parar e pensar no que realmente importa e no que vale a pena. Sendo esta uma oportunidade única de exprimir o que sinto, não a poderia deixar passar em claro.

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Resumo

Cabo Verde é um dos países onde o desenvolvimento e o crescimento socioeconómico se encontram em travagem devido a problemas de escassez de água. As consequências são mais notórias na cidade de Praia, com uma população de cerca de 131.719 habitantes[1]. Isso deve-se ao rápido desenvolvimento urbanístico e às consequentes necessidades especiais como irrigação, indústria e turismo. A região tem sido assolada pela seca durante vários anos consecutivos, sendo este um fenómeno de risco previsível. A falta de água é assim um factor que condiciona o desenvolvimento e bem-estar da cidade. Consequentemente, é imperativo o reconhecimento do valor da água e uma boa estratégia de racionamento da sua utilização, bem como a procura de formas de mobilizar novos recursos.

O estudo apresentado foi desenvolvido segundo uma metodologia baseada no uso da tecnologia de tratamento, purificação e reaproveitamento de água residual, bem como formas da reutilização segura da mesma para fins compatíveis. O trabalho inclui ainda uma análise técnico-económica relativa ao desenvolvimento do projecto de implementação, no qual foram estudadas várias alternativas que permitirão a reutilização da água tratada da cidade de Praia para os caudais actuais, assim como para ampliações futuras. Os resultados apresentados indicam que deve ser seguida uma orientação objectiva com vista à definição dos parâmetros de qualidade e das acções complementares necessárias para garantir a reutilização de uma forma segura da água, desde o ponto de vista directo da saúde humana até às zonas verdes, tais como áreas agrícolas ou espaços de utilização pública.

Assim, é importante considerar a preparação e o desenvolvimento de campanhas de sensibilização para a população de Cabo Verde, envolvendo autoridades locais e a formação social como uma força motriz para promover o uso eficiente da água, o conhecimento dos parâmetros de qualidade e evitar doenças de veiculação hídrica. Para melhorar o controlo da qualidade da água, em geral, é fundamental planear e organizar um estudo de comparação internacional de laboratórios de qualidade da água em diferentes regiões, e promover o desenvolvimento de seminários especializados para melhorar a capacidade técnica. Para promover o tratamento e reutilização de água tratada existem plataformas de formação virtual para desenvolver e promover o intercâmbio de experiências nestes domínios. Estas iniciativas serão reforçadas com a pesquisa e assistência técnica para avaliar o potencial e desenvolver projectos específicos de auto tratamento de águas residuais e a sua reutilização.

Termos chave: Sustentabilidade, água, reutilização, desenvolvimento, economia.

[1] Dados do Instituto Nacional de Estatísticas (Censo 2010), correspondente a 26,9% do total da população nacional (491.875).

Abstract

Cape Verde is one of the countries where the socio-economic development and growth are diminishing due to problems of water scarcity. The effects are more noticeable in the city of Praia, with a population of about 131.719 inhabitants[2]. This is due to the rapid urban development and the consequent special needs such as irrigation, industry and tourism. The region has suffered for several consecutive years the phenomenon of drought, which makes this occurrence an easily predictable one and turns the lack of water into a factor that constrains the development and well-being of the city. Consequently, it is imperative to recognize the value of water and to create a good strategy to ration its use, along with finding ways to mobilize new resources.

The presented study was developed using a methodology based on the use of the treatment, purification and reuse of wastewater technology, as well as secure ways reusing it for compatible proposes. The work also includes a technical and economic analysis related to the development of the implementation project, in which were studied several alternatives that allow the reuse of treated water from the city of Praia to the current flow, as well as for future expansions. The presented results indicate that there must be followed an objective orientation in order to define the quality parameters and the complementary actions necessary to ensure a safe re-use of water from the direct point of view of human health to the green areas, such as agricultural areas or spaces for public use.

Thus, it's important to consider the preparation and development of awareness campaigns for the population of Cape Verde, involving local authorities and the social formation as a driving force to promote the efficient use of water, knowledge of the quality parameters and prevent waterborne diseases. To improve the monitoring of water quality in general is essential to plan and organize a study of international comparison of water quality laboratories in different regions, and promote the development of specialized seminars to improve technical capacity. To promote the treatment and reuse of treated water are virtual training platforms to develop and promote the exchange of experience in these fields. These initiatives will be strengthened through research and technical assistance to assess the potential and develop specific projects of self-wastewater treatment and reuse.

Key words: Development, Economy, Reuse, Sustainability, Water.

[2] Data from the National Institute of Statistics (2010 Census), corresponding to 26.9% of the total national population (491.875).

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Abbreviations list

AECID - Spanish Agency of International Cooperation for Development

INE - National Statistics Institute of Cape Verde

MDGs - Millennium Development Goals

ELECTRA - Water and Electricity Company of Cape Verde

SAAS - Autonomous Water and Sanitation Utilities

UV - Ultra Violet

PDM - Municipal Master Plan

NTMR - Technical Normative of Regulation

MAC - Madeira, Azores, Canary Islands

CE - European Commission

ITC -Technological Institute of the Canary Islands

UN - United Nations

PANA - National Action Plan for the Environment

INMG - National Institute of Meteorology and Geophysics

TCMA - Annual Average Growth Rate

UPI - Units of Informal Production

IDAM - Seawater Desalination Plant

ADA - Water Distribution Agency

INHAB - Inhabitants

WWPS - Wastewater Pumping Stations

WWTP - Wastewater Treatment Plant

DN - Nominal Diameter

PCS - Pieces

R - Reserve

INGRH - National Institute of Management of Water Resources

FAO - Food and Agriculture Organization

PAGI - Program to Improve Irrigation Management

MAHOT - Ministry of Environment, Housing and Territorial Planning

FUCAEX - Canary Foundation for External Action

ANMVC - National Association of Municipalities of Cape Verde

WHO - World Health Organization

1. Introduction

1.1 Description of the researching area: empirical context

The recycling or reuse of water is not a new concept in the history of our planet. Nature, through the hydrological cycle, have been recycling and reusing water for millions of years, with relative efficiency (Sautchúk *et al.*, 2004; Moruzzi *et al.*, 2008).

Cities, farmlands and industries use in an indirect, or at least a non-planned way, reused water resulting from the use of water for downstream users that capture waters which have already been used and returned to the rivers by users of amount. Millions of persons worldwide are supplied by this indirect form of water reuse (Crook, 1996; Sautchúk *et al.*, 2004).

For many years this system worked broadly well, however it doesn't happen anymore in many regions, because of the worsening pollution conditions, basically due to lack of adequate treatment of urban waste water, when not by its total absence (Blumenthal *et al.*, 2000).

Then it was developed a form named direct reuse, which is the one when an effluent is treated for reuse in a particular purpose, that can be internal to the enterprise itself, or external, for a purpose other than the first, as for example, the practice of reusing treated municipal wastewater for agricultural purposes (Piva, 2004; Kelman, 2004).

The direct or planned form uses technologies and practices of renewal and reuse of water, which went through a series of stages over the last two hundred years (Crook, 1996). The first phase was motivated by a conservationist concept-based form which says that the droppings of society should be conserved and used for preserving the fertility of soils, while the other, a more pragmatic approach, was directed to the elimination of rivers pollution. At the end of the 19th century, the concept of domestic wastewater treatment by disposal in soils was used in Britain, Germany and the United States with a central focus on reducing river pollution and not as a conservationist method of aquifer recharge or augmentation of nutrients to the soil (Crook 1996; Sautchúk *et al.*, 2004).

In the second phase, which can be considered until the late 1990s, the main focus was primarily the need to conserve and reuse water in arid zones (Sautchúk *et al.*, 2004). There has been considerable effort to reuse water for agricultural development in arid zones of the United States, like California and Texas, and in countries like South Africa, Israel and India.
The third phase, in which we find ourselves today, ended up overlapping the second and is based on the urgent need to reduce the pollution of rivers and lakes. As the environmental requirements were becoming increasingly restrictive, planners concluded that given the high

investments required to treat effluents, it becomes more advantageous to reuse these effluents instead of releasing them back into the rivers (Gonçalves *et al.*, 2010)

The limitation of freshwater reserves on the planet, increasing water needs to cater mainly for human consumption as for example agricultural and industrial, priority for use of available water resources for public supply and the restrictions that are being imposed in relation to the release of effluents in the environment, makes necessary the adoption of strategies aimed at rationalizing the use of water resources and mitigating negative impacts relating to wastewater generation by industries (Sautchúk *et al.*, 2004; Rio +20, 2012).

Moreover, the heterogeneity of the distribution of water resources and population in the various regions of our planet makes it increasingly difficult to supply some regions, mainly the metropolitan, with the consequence of gradual increases in the cost of providing water (Sautchúk *et al.*, 2004).

In this context, conservationist practices, such as the efficient use and reuse of water, are a smart way to expand the number of users of a water supply system, without the need for large investments in the expansion or installation of new water supply systems (Mierzwa, 2000; Gonçalves *et al.*, 2010).

1.2 Identification of the problem and research issues

The lack of water has always been a problem for some regions of the planet, in the same way that its excess is also a problem for other regions. Cape Verde has suffered by continuous threat of drought, with the lack of rainfall in some periods and in others with its irregular occurrence within the region. The phenomenon of drought occurs with great frequency, occasionally for years at a time. Because it is a phenomenon which has been repeated over the years, should be seen as a likely risk and sometimes anticipated (Gominho, 2010).

Since 1975 (the date of Independence of Cape Verde), begins a clear prioritization policy in the water sector that focuses on providing the population in amounts that meet basic household needs. In spite of its limitations, efforts in Cape Verde to meet the needs of water for domestic consumption and for productive activities have brought good coverage of potable water supply to the population through public systems and the maintenance of area irrigated with groundwater. This process has played an important role in water desalination. Currently underway is a major reform in the water sector, with the implementation of the National Plan for Water Resources Management in 2020, particularly in the institutional and legal framework aimed at developing the new demands and expectations of the population and the dynamic growth (Rodríguez *et al*., 2011).

Cape Verde currently carries a very special dynamic private sector participation in the production and supply of drinking water and the process of decentralization and autonomy of the water sector, however you still need to exist create an enabling environment to promote the private sector. The country has made great strides in offering not only the population, but also in terms of increasing the availability of water for agriculture and tourism and its rationalization by introducing new irrigation technologies and water use. In recent years they have built new facilities, among which the first dam of Cape Verde on the island of Santiago (in the framework of cooperation of China), the country's largest hydropower project that marked a milestone in the approach to managing surface water in Cape Verde (AECID, 2012).

In general, access to water in Cape Verde is problematic and its effects are transversal. Moreover, internationally referred to the progress made by the country in the past 35 years and future challenges to satisfy their service population with a reasonably good water and sanitation (Rodríguez *et al*., 2011). In 2007, according to the National Statistics Institute (INE, 2007) of Cape Verde, this year reached the targets set by the Millennium Development Goals (MDGs) in how to access to drinking water, which the other surrounding countries hope to achieve by 2015. The biggest challenge is to maintain these achievements and combat inequalities that have occurred, especially among those between the countryside and cities.

According to data published by the INE (INE, 2007), Cape Verde has, in terms of water supply and sanitation, a coverage rate consistent with the goals outlined in the MDGs, in spite of the enormous regional and even local differences. About 85% of households are served by Cape Verdeans safe sources of drinking water; this scenario is not uniform when compared with coverage rates between the urban and rural areas. In cities, the coverage rate of access to drinking water is approximately 93% and in rural areas the rate is 74%. The municipalities of Sal with 99.4%, Maio with 98%, Boavista with 93.3%, Ribeira Brava and Tarrafal with 92.6%, São Vicente with 87.4% and Brava with 87%, are listed in the "ranking" of the municipalities better supplied.

The scenario is less attractive when analyzing the data by county and by type of water source. In fact, only 40% of Cape Verdean families have access to piped water, which is distributed through the public network provided by Electra or Autonomous Water and Sanitation Utilities (SAAS).

Consequently, the data do not guarantee that the objectives envisaged in the short term can be achieved without massive public investment (government and municipalities) focused on a strategy specifically to water and sanitation. The average coverage rate of the public in urban areas is approximately 56% while in rural areas the coverage rate is only 13%. This discrepancy shows the effort still must devote to rural areas. Another indicator analyzed was the weight of public sources of water supply to households. In urban areas the rate corresponding to 30%

while in rural areas, public fountains are still supply means for 63% of households. The tankers (tanker trucks) also supply water to a significant number of people.
The analysis of this indicator is important for evaluating the effort remains to be done in the field of water supply in Cape Verde, not only in the context of the MDGs, but mainly as a way to further democratize unrestricted access large stores of society are still not properly. Their analysis also allows understanding the degree and extent of regional disparities in the supply of household water.

As can be seen in Cape Verde (particularly in Praia), population growth, urban development and increasing needs for irrigation, tourism and industry, coupled with drought in recent years has caused deprivation, which tend to worsen over time if urgent and necessary measures are not taken. Thus, the water becomes a feature, both the quantity and the quality, condition for economic development and social welfare of this county.

The current problems that arise in the field of water resources in Praia impose the need to seek to prevent the increasing scarcity of water, can hinder the desirable socio-economic development. Along with the growing demand for ways to mobilize new resources, you must define all possible means to draw on in the future to rationalize the use of water in order to obtain the maximum benefit for all Cape Verdeans.

It is therefore essential to adopt a suitable management policy that aims not only to a better utilization of the available water, but also a careful management of the use and recognition of the importance of water as a factor of production in the various sectors of social and economic activity: agriculture, industry, commerce, sanitation, environment, public works, tourism, and so on.

1.3 Description of the methodological approach: scope and work objectives and study methodology

1.3.1 Scope and objectives

In the city of Praia, about 30% of the population privately benefits of a sewage disposal system, of which 9% are linked to a sewage system. The most widely used form of evacuation is the septic tank. The city has a wastewater treatment plant, managed by Electra, where it is the primary treatment, secondary and tertiary treatment of a part. This includes UV treatment and chlorination. They produce about 800 m^3/day of treated water with tertiary level but into the sea due to lack of infrastructure for reuse (Suárez *et al.*, 2011).

In this sense and with the purpose of finding a solution aimed at sustainable use of water available, the Study of the safe reuse of urban wastewater treated in Praia (Cape Verde) will be developed, following the main objectives summarized below:

- Promote the awareness of the use of drinking water, quality control capacities of water resources, encouraging treatment and reuse of treated water;
- Technical and economic analysis for the development of the final design that enables the reuse of treated water from the City of Praia, for current flows and future upgrades;
- Define the required quality parameters and actions needed to ensure safe reuse from the point of view of health and in green areas such as agriculture or agroforestry;
- Propose and analyze the development of awareness campaigns to the population in Cape Verde, involving local and social facilitators training to promote efficient water use, knowledge of the quality parameters and prevent waterborne diseases;
- Organizing an international study comparing water quality laboratories in different regions, as well as encourage the development of specialized seminars to strengthen the technical capacity;
- In order to promote the treatment and reuse of treated water in Cape Verde are proposed studies to assess the potential and develop autonomous suggestions of wastewater treatment and reuse of treated wastewater;
- Evaluate the economic impact of the project for the Cape Verde's population;
- Apply a good practices rules manual of awareness for using and preservation of treated wastewater.

1.3.2 Methodology

The methodology to be followed for the Study of safe use of urban treated wastewater in Praia (Cape Verde) follows the objectives and specifications defined in the ISLHáGUA Project, which has essentially the ground of progress of the Municipal Master Plan (PDM) of Praia, which is expected to do the complete irrigation of the city with recovered water.

Following the terms of the plan which aims to secure reuse of treated waste water for irrigation, seen as an opportunity for the development of Praia, and taking into account the intended purposes (irrigation of gardens and squares; irrigation of urban market gardens; irrigation of ornamental plants; manufacture of concrete) the study methodology is the following:

- **Preliminary Work:** collection and analysis of existing information and documents of the study field; of the initial field work and study of existing criteria, standards or legislation in this area, nationally and internationally;
- **Diagnosis of the existing system and future potentialities:** study of the sanitation system conditions and existing treatments, through a diagnosis of treatment processes and facilities;

- **Determining the quality of the recovered water:** calculation of the minimal quality of recovered water in order to regard the criteria of health, respecting the standards of the World Health Organization, but also to the agronomic criteria.
- **Study of requirements and needs:** identification, study and precise water characterization from a quantitative point of view and taking into account the seasonality, potential uses for irrigation of green areas, parks and gardens and agricultural irrigation (gardens and urban gardens);
- **Proposal for improvements in sanitation, purification and regeneration:** calculation of the necessary improvements and actions to ensure that the treatment system, sanitation and tertiary treatment can guarantee the minimal conditions laid down as requirements;
- **Proposal for the creation of infrastructure for collection, storage, transport and distribution:** analysis, planning and identification of necessary infrastructure to capture, control, transport, treatment, storage and distribution network to ensure the supply, in quality and quantity, optimizing the system in terms of energy and economic efficiency.
- **Proposal for an infrastructure of irrigation and pressure control (in the sectors of irrigation) or primary network:** analysis, planning and identification of necessary infrastructure for irrigation systems, allowing the monitoring and optimization of network performance;
- **Establishment of an indicative index for future municipal directing technical regulations for the re-use of treated water, as well as the development of a good practice guide:** establish an index to the Technical Normative of Regulation (NTMR) on reuse of treated water and developing a good practice guide, pursuing the aim of ensuring the safe reuse of treated water, for the protection of human health sanitary safety, to minimize the ecological and environmental impacts and ensure the rational, efficient and economic use of water. Develop measures and criteria for the design of new green areas to promote a balanced water use.

2. Literary review

As in any work, and in this case of a real project, the literary review plays a key role in addressing the particular issue, because it is through it that I intend to situate my work within the large area of research which it is part of, contextualizing it in order to frame the issue with a credible research proposal.

With the first guidelines of the work already outlined and with previous knowledge acquired about the situation of water resources in Cape Verde, I sought to frame the issue from the perspective of awareness on the use of drinking water, enhancing the ability to control the quality of water resources, encouraging treatment and reuse of treated wastewater and desalination with more efficiency and use of renewable energy.

These guidelines, led to scientific literature. This research based on facts previously identified and reported by credible researchers and authors, primarily in published papers with internationally recognized value, being subject to an anonymous and very careful review by experts in the field, has directed me to one of the axes of the *Transnational Cooperation Programme (MAC 2007-2013)*, published by the European Commission (CE): strengthening the capacities and skills relating to the management of water resources in the islands.

Regarding the study area in question, the document stresses the importance of managing water resources through projects that have developed innovative techniques for sustainable water management, as well as tools for awareness and sensitization of citizens.

Improve the sustainable management of water resources, energy and waste, meets the overall objective that underpins the strategy adopted in the current Program that is, on the one hand, increase levels of development and socio-economic integration of the three archipelagos, fostering a strategy that will aim to boost the knowledge society and sustainable development, and, second, to improve the levels of socio-economic integration of space cooperation with countries of geographical and cultural proximity, thus integrating the overall strategy of the program, one of strategic priorities with clear objectives and indicators.

It is important that the regions of this cooperation space may know the quality and quantity of its energy resources available to thereby carry out management practices optimal for the water resources; make a correct use of renewable energy (solar, wind, hydro ...) and implement an integral waste management, sustainable, efficient and of quality.

Aimed to improve the efficiency of the management of natural resources, mainly those related to water, waste and energy, following the *MAC* framework, and in order to consider the preparation and development of awareness campaigns for the population of the Canary Islands and Cape Verde involving local authorities and the social formation as a driving force to promote the efficient use of water; knowledge of quality parameters and prevent waterborne diseases, especially in Cape Verde, arises *ISLHáGUA Project*, developed in a partnership between *Technological Institute of the Canary Islands (ITC)* and the *Canary Islands Government*. This publication aims to improve the monitoring of water quality in general, it is planning to organize an international comparison study of water quality laboratories in different regions, and promote the development of specialized seminars to improve technical ability. To promote the treatment and reuse of treated water and desalination with renewable energy in arid areas of the Canary Islands and Cape Verde, there are virtual training platforms to develop and promote the exchange of experience in these fields. These initiatives will be strengthened through research and technical assistance to assess the potential and develop specific projects of wastewater self-treatment, reuse of treated wastewater and desalination with renewable energies, which lead to study of *safe reuse of treated urban wastewater in Praia, Cape Verde.*

This study was handled by the Spanish company, *Aqualogy – Aqua Ambiente (AGBAR Group),* which I had the opportunity to integrate.

Scientifically, this study is based on the two previous references and further scientific documentation, technical reports, meeting minutes and studies "*in situ*" provided by entities involved in the project. Among this documentation, there is a publication in order to support regional issues of research that stands out, with local focus: the *Preliminary Municipal Master Plan of Praia - Santiago Island.*
In depth and selective analysis of the existing literature, oriented to the objective, and with a high level of critical spirit, should be noted that in Cape Verde there is no specific regulation of water quality criteria for irrigation reuse. Therefore, the sources to determine the quality criteria to reuse water in irrigation schemes in Praia are exposed on Annex I.

Regarding the research area, the adopted orientation tends to justify the relevance of the topic, considering some of the research and work done previously. Firstly there is to consider the *Conference Report RIO +20 (United Nations Conference for Sustainable Development),* which covers the territory under study, Cape Verde, in the context of sustainable development. The complexity of water management in Cape Verde, where there are still many obstacles and challenges, since the ownership of the water is not clear, making it difficult to watershed management; social conflicts are frequent regarding the use of water and in relation to pollution, the rural population is not adequately addressed in the management of water resources. However, it is noted herein that Cape Verde has the necessary tools for the evolution of water management, which is the Water Code that allows aspire to a good scientific approach in this regard (Gominho, 2010).

A further highlight is to the publication of the Ministry of Environment , Agriculture and Fisheries of Cape Verde with the *Segundo Plano de Acção Nacional para o Ambiente 2004-2014* (*2^nd^ National Action Plan for the Environment 2004-2014*), where the sustainable management of water resources is a priority and which will be followed and analyzed in the context of this work, considering always a great futuristic vision, beyond the year 2014 , seeking to mobilize resources; construction of hydraulic infrastructures that allow people's access to water in good health and hygiene conditions and reduction of water losses in agriculture. The protection of water resources against pollution is also a factor to consider.

Also bearing in mind specific publications in the area of the use and reuse of treated wastewater, including Portuguese scientific publication *Série GUIAS TÉCNICOS 14 – Reutilização de Águas Residuais* (Wastewater reuse), detailing the various procedures required to implement successful projects for the reuse of treated wastewater, revealing itself to be a basis of support essential to this study.

Irrigation being one of the basic guidelines of the study, it is essential to refer to the publication *"L'utilisation Des Eaux Usées Épurées En Irrigation – 2011"*, a technical paper with international content extremely useful regarding the system of irrigation with treated wastewater.

Consider will be also possible new data that may be provided by the company responsible for this work.

3. Territorial context

3.1 The archipelago of Cape Verde

The Cape Verde archipelago is formed by ten Islands and thirteen islets and it is located about 1.300 km south of the Canary Islands and about 500 miles west of Dakar, Senegal.

The Western Islands are relatively high and with rugged topography, meanwhile the Oriental Islands present a low and flat structure. The archipelago is divided into two groups according to their geographical location: Sotavento and Barlavento.

Barlavento is located to the North of the archipelago and includes the islands of Santo Antão, São Vicente, Santa Luzia, São Nicolau, Sal and Boa Vista. The latter two lie more to the East, as well as the islanders Branco and Raso and.

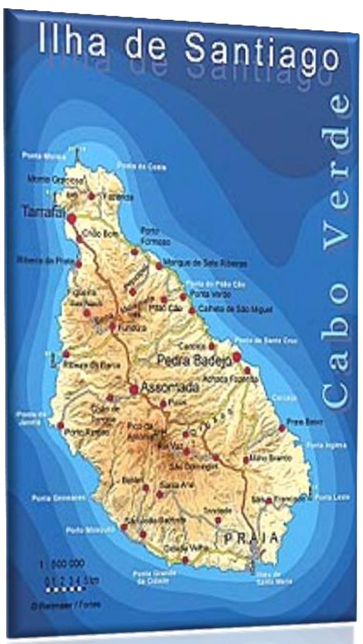
The islands of Maio, Santiago, Fogo and Brava and the islet Rombo belong to the Sotavento group. The surface of the archipelago is approximately some 4.033 km^2, more than half of the Canary Islands and has a total resident population around the half a million inhabitants, virtually, less than a quarter of the total population of Canaries.

The rainfall in Cape Verde are a result of the Intertropical Front that causes a wet season from July to October, concentrating the largest quantities between the months of August and September, during which time you can register between 60% to 80% of the amount of annual rainfall, which varies according to the topography and latitude of the island. The rainiest islands are Fogo, Santiago, Brava and Santo Antão. The islands of Sal, Boa Vista and Maio receive a lesser amount of precipitation. The remaining islands have an intermediate rainfall conditions.

Table 3.1 - Physical characteristics of the Cape Verde inhabited islands; source: National Institute of Meteorology and Geophysics (INMG)

PHYSICAL CHARACTERISTICS OF THE CAPE VERDE INHABITED ISLANDS						
Island	Surface (km²)		Altitude (m)	Precipitation (mm/year)	Arable Land (ha)	
Fogo	470	12%	2.829	475,4	5.900	14%
S.Antão	785	19%	1.979	367,6	8.800	21%
Santiago	1007	25%	1.394	297,5	21.500	52%
Brava	63	2%	976	201,2	1.060	3%
S.Nicolau	347	9%	1.312	199,4	2.000	5%
Maio	275	7%	437	139	660	2%
S.Vicente	230	6%	750	82,79	450	1%
Sal	221	5%	406	46,9	220	1%
Boa Vista	628	15%	387	57,06	500	1%
Source: Instituto Nacional de Metereologia e Geofísica – Delegacão da Praia						

3.2 Santiago Island: Praia



The present case study is located in the city of Praia. Praia is placed in the southern part of Santiago, it is the largest island of the archipelago of Cape Verde, and it is sited in the Western African Coast (West Africa) - 500km from the Mainland.

According to the latest data from the National Institute of Statistics - 2010 Census, it is estimated that in the municipality of Praia reside approximately 131.719 people, 26.9% of the total national population (491.875). The county territory extends from sea level up to elevation of 435m altitude in the formation of Monte Vaca, the highest point in the county.

Has an extension of coast of about 46km, plus 1.800 meters of coastal perimeter of its single islander (Santa Maria), which is 150 meters to the South, in the central part of the Bay of Praia, in the area of Gamboa.

The geomorphology of Praia is characterized by a set of hills, plateaus and valleys. The cliffs of the plateaus receive the designation of '*accads'* (Accad of Santo António, Accad of São Filipe, Accad Eugénio Lima, Accad Grande, Achadinha, and so on.).

Plateau is a word of French origin but it is written and spoken in Cape Verde as *Platô*, being normal appearing printed as *Planalto*[3] or *Platô*. City of Praia is usually called as Plateau because it was on the base of the formation and evolution of all human settling in Cape Verde. In general urban occupation was made not only on plateaus, but also on the slopes and along the valleys that form the main streams that constitute the 5 basins.

In addition to the geographical area of 101.8 km^2 located within the perimeter of the island of Santiago (≈1.000km^2), the county territory of Praia also has the area of islanders of Santa Maria with about 6 hectares (ha).

For a long time, at least until the first decades of independence period, only Plateau (Praia) was considered City. Being relegated to the category of suburb all the remaining neighborhoods, which to some extent helps to explain the care for an adequate urban and formal occupation of the city center, with its own equipment and infrastructure, in contrast to the organic development and seemingly chaotic of the remaining neighborhoods.

Although there is currently some decentralization of services and even some trade offer in the neighborhoods (concentrated more in the Central and Southern areas), Plateau (Praia) continues to be a great attraction and daily commuting Center, along with the greatest commercial zone of the country - the market in Sucupira.

There are still a significant concentration of services and trade in the Plateau (Praia) – with especial significance to the oldest market in the city - Market Town of Pelourinho. Peripheral areas have yet to achieve full autonomy, sufficiently capable of freeing them from the stigma of "dormitory neighborhoods" of Praia, although today they are far more populous and with largest areas of occupation that Plateau (Praia).

The county has important infrastructures (Airport and Port, both international); holds the political Capital of Cape Verde and it is where the main services are concentrated, trade and corporate headquarters and network of embassies.

[3] *Planalto* = plateau in portuguese, Cape Verde's official language.

4. Population study and economic situation

Below are summarized the results of the detailed analysis of domain characterization, exhibited at the *Municipal Master Plan*, but only in those areas that are crucial for the proper development of the following phases of the study of reuse, these are:

- Population Study;
- Prognosis of population;
- Economy.

In the municipality in question, the population of Praia had, in 2010, a population of about 131,719 inhabitants, representing 27% of the total population of Cape Verde.

Table 4.1 - Estimated population by neighborhoods by source: INE – Census 2010

ESTIMATED POPULATION 2010		
ZONE AND GROUPING OF NEIGHBORHOODS	**AREA (km²)**	**POPULATION**
PRAIA NORTE (U1)	12,89	47.648
PRAIA CENTRO (U2)	1,14	5.537
PRAIA SUL (U3)	6,82	31.969
PRAIA ORIENTAL (U4)	14,09	6.612
PRAIA OCIDENTAL (U5)	9,85	36.060
PRAIA COROA/ARCO NORDESTE (R1)	21,24	1.216
PRAIA COROA/ARCO NOROESTE (R2)	22,17	492
PRAIA COROA/ARCO SUDOESTE (R3)	13,26	2.185
TOTAL NEIGHBORHOODS	**101,46**	**131.719**
TOTAL PRAIA	**258,1**	**131.719**
TOTAL CAPE VERDE		**491.575**

Figure 4.1 - Mapping of support and reasoning of grouping neighborhoods by source: INE

The evolution of the population of Praia since 1940 is shown below.

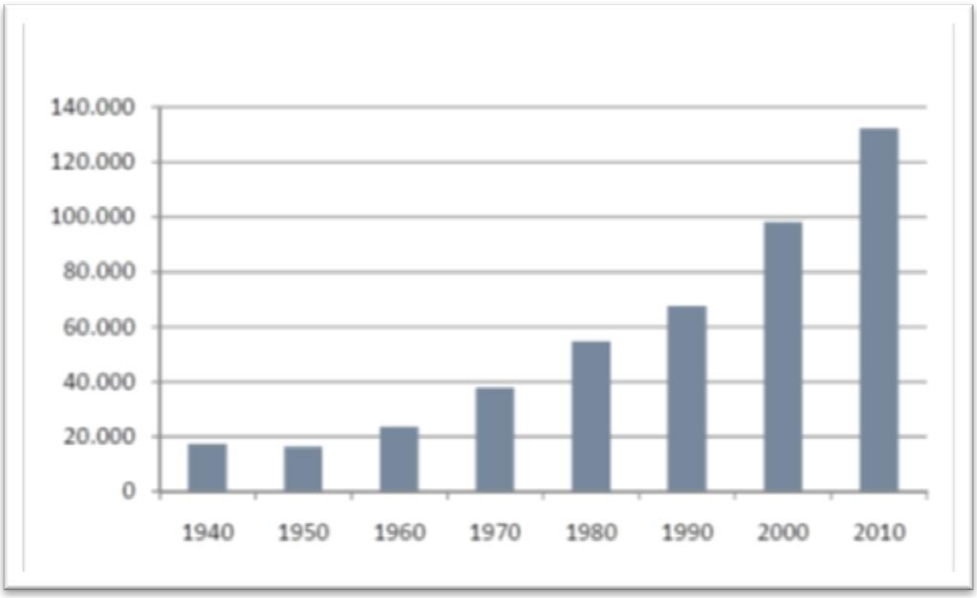


Figure 4.2 - Chart - Population evolution of the Municipality of Praia 1994 – 2010 by source: INE

It is concluded that, with the exception of 1950 when there was a decrease of population driven by drought and famine occurring in that time, the trend of population growth in the municipality of Praia has been exponential, with an average annual rate of 3.0%. This growth rate is justified by the fact that municipality is cosmopolitan and it is target of migration, internal and external.

The demographic pressure has increased, contributing to the emergence of areas of illegal constructions.

The evolution of the population of Praia from 2000-2010 has been:

Table 4.2 - Evolution of the population by source: INE

Evolution of the population		
Population		***TCMA***
2000	2010	
98.118	131.719	3,00%

In about 10 years, from 2000 to 2010, the share of the population of Praia in the total national population increased by about 4.3%, almost the entire population decline in other counties. This demographic pressure is also facilitated because the municipality of Praia feature is predominantly urban (about 97% urban), very different from the national average.

The population is distributed spatially within municipal area of 102km^2, according to the following distribution of Urban/Rural occupation:

Table 4.3 – Population distribution by source: INE

Distribution of occupation: Urban / Rural		
Urban Population (City of Praia)	127.826	97%
Rural Population	3.893	3%

The number of urban and rural populations is inversely proportional to the area of occupancy of the respective spots, becoming realities diametrically opposed, as explained in the following figure.

Figure 4.3 - Actual scenario by source: INE

In the city of Praia, the evolution of the average household size has had a decreasing trend, from about 5 persons per household in 1900 to about 3.7 in 2010, justified by the success of family planning policies.

The population density of the city of Praia increased from 962 to 1.297 inhabitants per km^2 in the period 2000-2010. This value is of concern for the negative socio-economic consequences, including employment, transport and security.

The value of population density of Praia, is comparable to the largest cities of the world, however the density distribution is not uniform, differing according to the administrative zones.

The zone of higher housing and population density corresponds to *Praia Sul* (South part of Praia), Zone U3 of the proposed administrative division, where the population density is of the order of 1.124 housing per square kilometer (km^2), corresponding to a density of about 4.100 inhabitants per km^2, if we consider the average family size. Note that, within some administrative zones, there are different distributions of population and housing densities. For example in the U1, the average housing density is between [601-1000] dwellings per km^2, but there are neighborhoods with housing density exceeding 1.000 dwellings per km^2.

At that rate of growth, the population of Praia will reach 12 years from now, approximately 195.000 inhabitants.

Projected Population by districts (2010 to 2023) is:

Table 4.4 - Projection by neighborhoods; source: INE

PROJECTION BY NEIGHBORHOODS			
ZONE AND GROUPING OF NEIGHBORHOODS	**AREA (m²)**	**POPULATION 2010**	**PROJECTION 2023**
PRAIA NORTE (U1)	12.886.072	47.648	69.973
PRAIA CENTRO (U2)	1.141.782	5.537	8.131
PRAIA SUL (U3)	6.819.382	31.969	46.947
PRAIA ORIENTAL (U4)	14.089.115	6.612	9.710
PRAIA OCIDENTAL (U5)	9.853.031	36.060	52.955
PRAIA COROA/ARCO NORDESTE (R1)	21.243.845	1.216	1.786
PRAIA COROA/ARCO NOROESTE (R2)	22.174.062	492	723
PRAIA COROA/ARCO SUDOESTE (R3)	13.257.302	2.185	3.208
TOTAL	**101.464.591**	**131.719**	**193.433**

Based on projections made with the 2010 Census data from INE, is expected to grow at an average annual rate of 3%, which means that in 2023 the municipality of Praia will have 193 433 inhabitants, representing an increase of 61,714 persons compared to 2010, 5.142 new residents per year, equivalent to a total of 15.423 families, 1.286 families/year.

It appears that U1, U3 and U5 are the Pools Neighborhoods with the largest trend in the population, an increase of approximately 22.300, 15.000 and 17.000 new inhabitants respectively.

These values should be crossed with other indices and indicators that define the parameters of urban occupation, from which one can infer the current trend verified in order to more balanced growth in the neighborhoods and their spatial grouping of neighborhoods.

4.1 Economic situation

According to the results of the Informal Sector Survey, existed in Cape Verde in 2010, about 24.060 Units of Informal Production (*UPI),* with 25.6% located in Praia. Note that there is more UPI in urban (63.6%) than in rural areas (36.4%). It was also found that 65% of UPI located on the island of Santiago.

In the City of Praia, in the most developed sector by UPI, It is worth to highlight activities of the retail trade in the food area. In the industrial sector stand out activities in manufacturing and in services sector, there is hotel and catering.

Regarding to the employment created in the informal sector, it appears that both nationally and in the city of Praia, 82% of UPI employ one person, i.e. owners themselves (self-employment), 10% employ two people and only 3% employ 3 people.

5. Analysis and diagnosis of sanitation systems, purification and regeneration

5.1 Infrastructure of supply

Below are described the existing infrastructure system of drinking water supply in Praia, since it influence the sanitation needs and wastewater treatment, both infrastructures must grow following the same strategic axes.

Access to drinking water is primarily made through residential connections, founts and cisterns. It is estimated that water consumption from the public network, covers about 56.4% of households. Founts and trucks of water, cover the remaining 36.4% of consumption, which is a considerably weigh.

From 2000-2008 the average annual growth rate of supply through the public network was around 15%, in contrast to the downward trend of the other sources of supply.

In Praia, the growth rate of water supply to households (water coverage rate), has evolved at an annual rate of 4.8%, higher than the growth rate of the population of this city. Therefore, it could be estimated that if this rate is maintained in the next seven years, at Praia's population will be around 163.381 inhabitants, the entire population will be supplied through the public network, produced by Electra.

The average production of drinking water for the public in the city of Praia is about 260.000m^3/month. The 85% comes from central production of desalinated water by reverse osmosis from *Palmarejo Grande* (exploited by Electra). The rest of drinking water comes from water wells, galleries, founts, and so on. According to Municipal Master Plan this Seawater Desalination Plant *(IDAM)* has a nominal capacity of 7.400m^3/day and guaranteed a water production of 5.000m^3/day.

According to the operator ELECTRA, current production capacity is 6.200m^3/day, and the expansion plan is to increase more 5.000m^3/day.

The supply network consists of 140 km of pipelines. Only about 35% of families have access to piped water network.

The rest of the population is supplied through *ADA, Water Distribution Agency* which manages the sales and distribution services of water trucking, founts, and so on. In 2010 ADA supplied about 103.000m^3/year of drinking water for population of the municipality.

With the aim of comparing consumption between network water and cistern water, were calculated the following allocations:

- Taking into account the total population, the scope of delivery is 66 l/inhab.day.
- Given that it supplies only 56.4% of the population, resulting in allocation of supply 117 l/inhab.day.
- Given network losses of 40%, the estimated supply envelope 70 l/inhab.day.
- The potable water supply of the population that is supplied with ADA (36.4%) was of 103.000m^3/year in 2010, resulting in a supply allocation of 6 l/inhab.day, instead of the 70 l/inhab.day provided by public network.

5.1.1 Synthesis of the problem

The system of drinking water supply is faulty. It is noted the following:

- Production capacity of drinking water for the public supply network is insufficient to meet current demands and logically future ones.
- The supply network does not cover the entire territory, which must be supplied by tanker or local wells and founts.
- The supply network is undersized, in poor condition and a projected percentage of significant losses in some cases 50%.
- There is a huge imbalance of the availability of water between the populations. It is found that water consumption of the population connected to the public network is more than 10 times higher than the one supplied by cisterns. Still, drinking water consumption of public network are considered low, estimated at 70 l/inhab.day of water consumed from public network and 6 l/inhab.day of water consumed from cisterns.
- High cost of drinking water, from 2.5 €/m^3 for domestic use up to 5.3 €/m^3 for tourism.

5.2 Sanitation infrastructures

Wastewater management in the city of Praia is also granted by Electra. The disposal of sewage is mainly around the house, noticing however an improvement in the use of septic tank and a decrease in the use of nature. The conditions of wastewater in this county in 2009, presented the following situation.

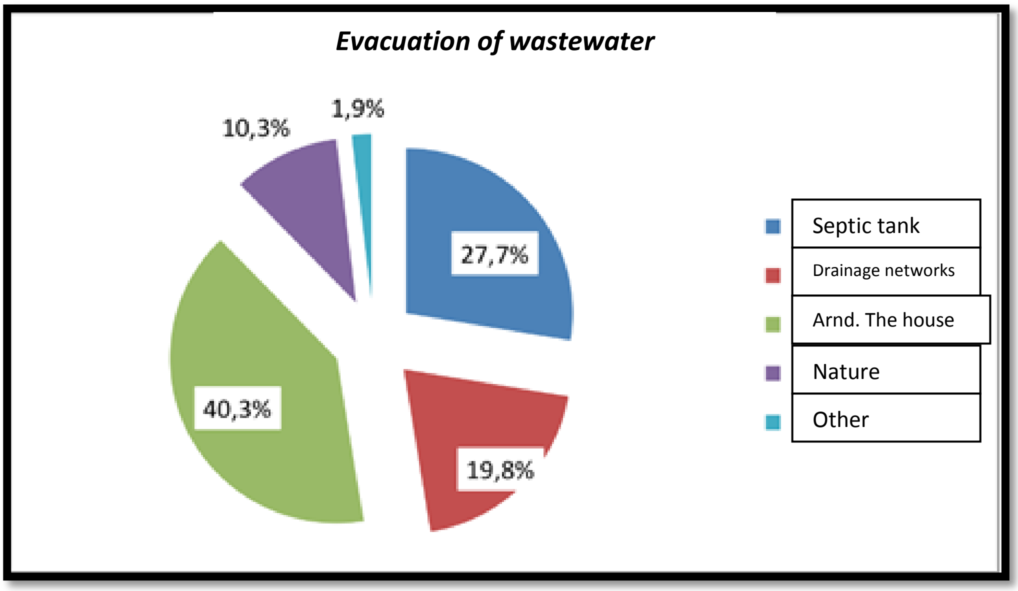


Figure 5.1 – Wastewater evacuation sources

A major factor that limits the connection of households to the sewer system in the city of Praia is the cost of the connection between houses and the sewer system which is estimated at about 30.000 *CVE* per housing. The low income of the population, especially in spontaneous neighborhoods currently occupying about 35% of the residential area of the city, makes about 80% of homes in Praia not linked to network of wastewater collection.

Also it should be noted the absence of legislation or ordinance regulating sanitation and requiring the mentioned connection.

On the other hand, there is no release fee that allows financial support for the operation of the sanitation system.

The sanitation system is characterized by:

- Lack of sewerage network in many neighborhoods/areas in the city. Are only estimated about 45km of pipes (primary and connections) and two wastewater pumping stations (WWPS).
- Low percentage of population with sewage, by the high costs of connection and absent regulations on the matter.
- The network is not separative type so that in times of heavy rains flooding episodes occur in the sewage system and the Wastewater Treatment Plant (WWTP).

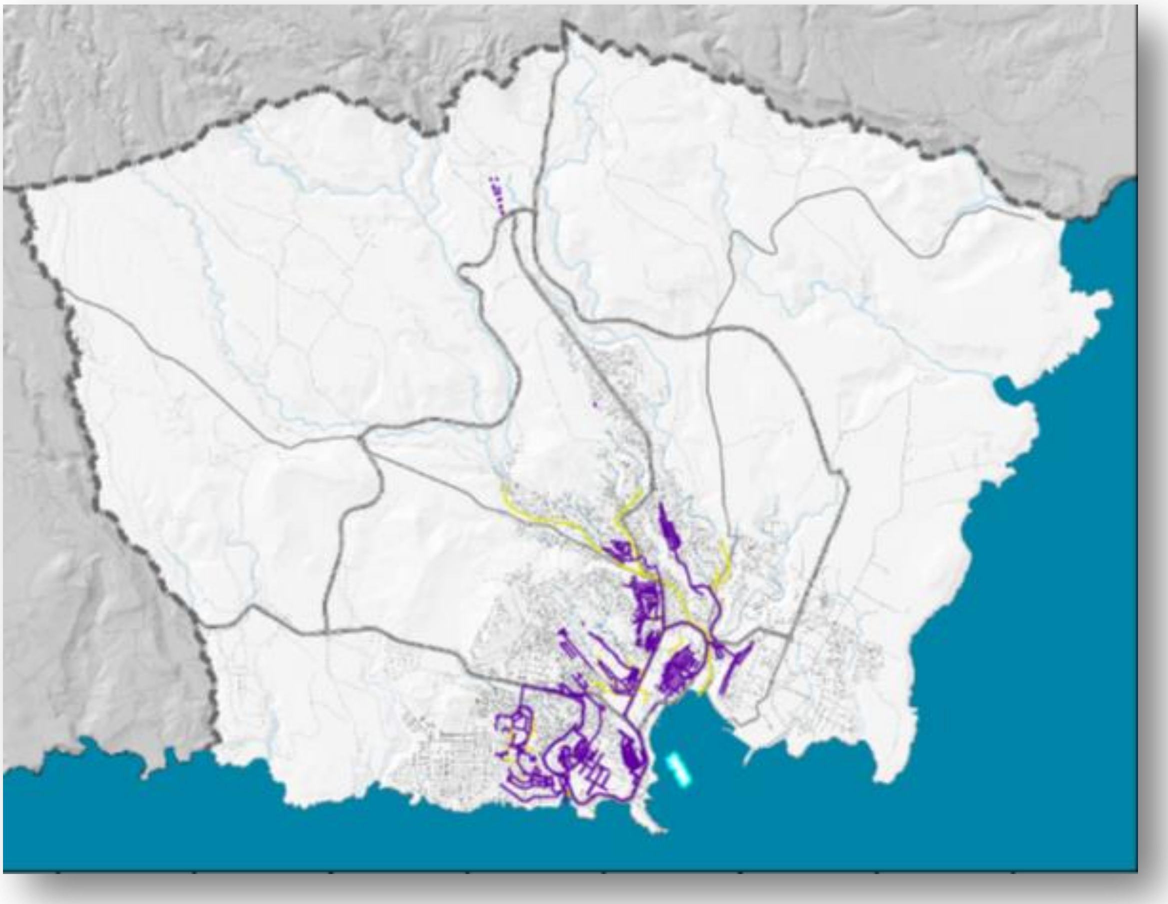


Figure 5.2 - Sewerage (magenta) and rainwater drainage (yellow) by source: Aqualogy Aqua Ambiente, 2012

The city has two waste water pumping stations, which drive the water directly to the WWTP. There is a lack of facilities maintenance and instrumentation, automation and remote control, making the pump manually. As proof of this there is a very thick crust in the well, a sign of poor control of the station.

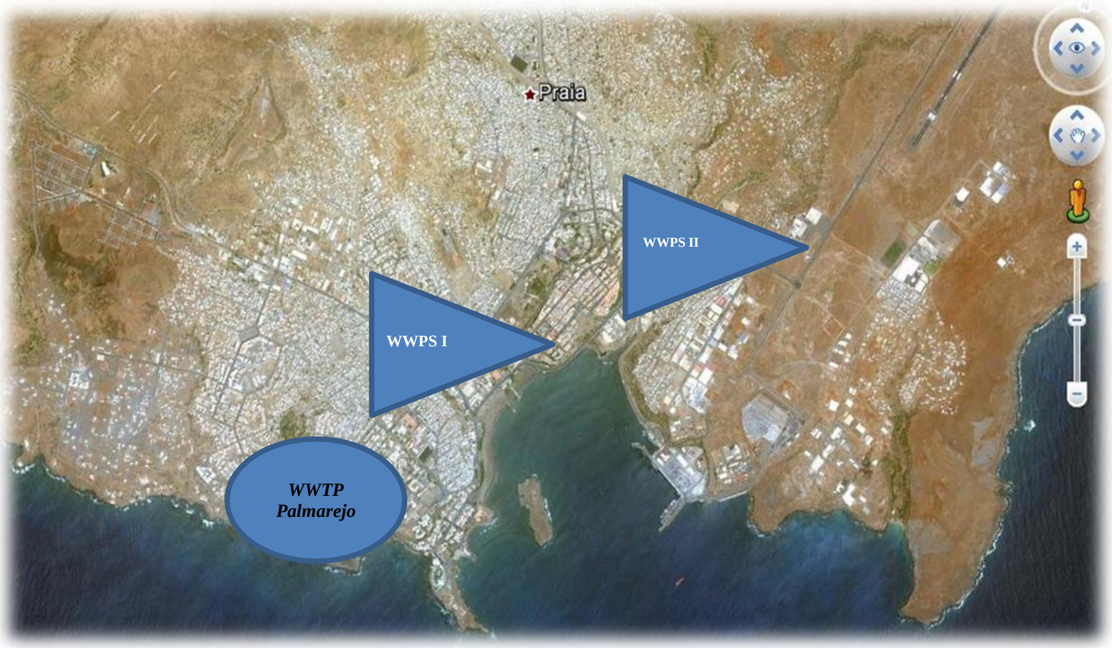


Figure 5.3 – Location of WWTP in Palmarejo and wastewater pumping stations (WWPS); source: Aqualogy Aqua Ambiente

The power cuts are frequent and since the wastewater pumping stations sets are not operational due to frequent thefts, occurs discharges into watercourses. These episodes are frequent.

Pumping wells are accessible from the outside.

Figure 5.4 - Pumping stations “in situ”; source: Aqualogy Aqua Ambiente

The deficient sanitation and uncontrolled discharges of untreated wastewater to the environment cause a negative impact to the environment, and in particular a progressive degradation of the quality of groundwater and surface water, and health risks of the population.

5.2.1 Synthesis of the problem

The main problems of the sewerage network are:

- Lack of sewerage network in many neighborhoods/areas in the city.
- Low percentage of population with sewage, by the high costs of connection and absence of regulations on the matter.
- The existing network is not dimensioned for future connections neighborhoods / areas in the city.
- Poor sewage conditions, leaks.
- Lack of facilities maintenance and instrumentation, automation and control.
- Faulty design of the network (flooding in heavy rain situation, non separative network).

5.3 Wastewater treatment plant

5.3.1 Overview

Located in the area of Palmarejo, WWTP had the first line built in 1997, consisting of a primary treatment, and was upgraded in 2007.

The nominal capacity of the plant is 8.000m^3/day and 14.000m^3/day at its peak, therefore the flow rate is 333m^3/h and the flow tip of 583m^3/h.

Figure 5.5 - WWTP orthophotography; source: Aqualogy Aqua Ambiente

The treated water is discharged to the nearby beach, while there is an outfall 350m long in disuse.

The WWTP counts with five shifts workers for 24 hours and a floor manager.

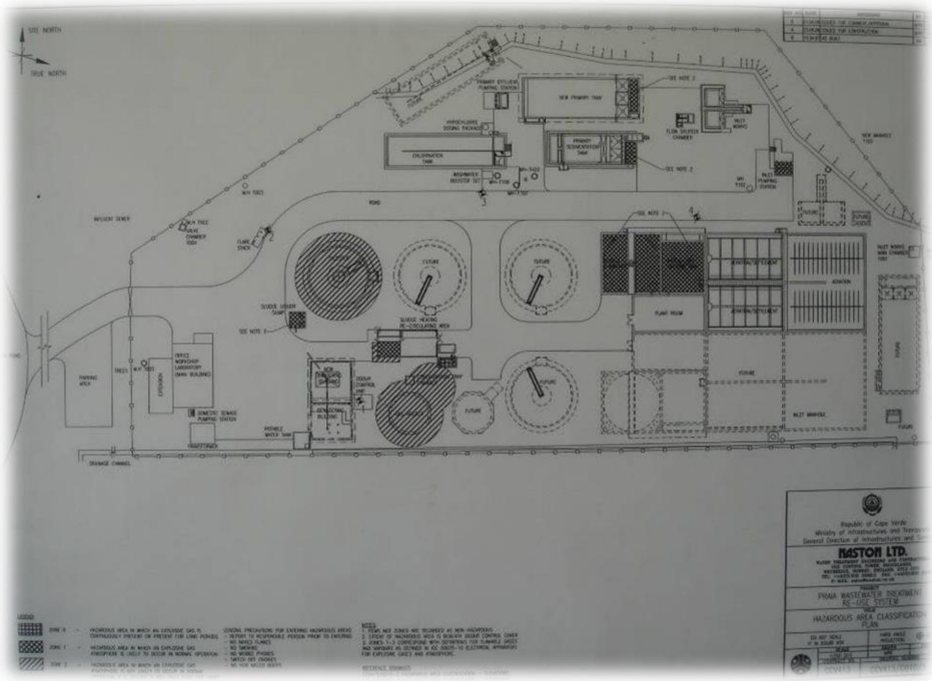


Figure 5.6 - WWTP Implementation Plan by source: Aqualogy Aqua Ambiente

The current treatment line is:

- **Water Line**
  - Pumping head, 2 +1R pumps nominal flow rate of 94-164 l/s;
  - Electromagnetic flow measurement DN 300;
  - Pretreatment, two channels and one other bypass:
    - Thick thinning with 2 manuals bars;
    - Fine thinning with 2 automatic cleaning bars automatic;
    - Grit/degreasing in two aerated channels by a blower with sands extraction using air lift pumps;
  - Primary treatment, 2 rectangular decanters and superficial bottom sweep;
  - Activated sludge biological treatment with extended aeration type nitrification and denitrification;
  - Secondary decantation aerated lamellar (2pcs);
  - UV Disinfection by chlorination channel adding hypochlorite.

- **Sludge line**
  - Mixed agitated sludge tank and impulsion to thickened by 1 +1R screw pumps;

- Gravity sludge thickener with bridge;
- Pumping of thickened sludge by 1 +1 R screw pumps;
- Anaerobic digestion with heating using recirculated sludge;
- Drive to dehydration by screw pumps;
- Conditioning by polyelectrolyte;
- Mechanical dewatering by belt filter;
- Worm drive and dewatered sludge storage;

- **Gas line**
  - Biogas storage;
  - Burning torch;
  - Fuel tank;

5.3.2 Diagnosis of the facilities and its operation

The existing problems are as follows:

- Given the tenuous connection of the population to the sewerage only reaches the treatment plant a rate of 1000 -1500 m^3/day, instead of 8000 - 14000 m^3/day design.
- The connected population is estimated at 26.343hab 2.010 (20% of total), so the residual water supply per capita is about 57 l/inhab.day.
- It is estimated that soon the plant input flow will be about 2.500m^3/day, due to the implementation of improvements to the sewer system.
- General state of poor care and lack of maintenance.
- The pretreatment is in bad shape and it does not observes sand extraction or grease of the desander – degreaser.

Figure 5.7 - Disused Sand Storage by source: Aqualogy Aqua Ambiente

One of two primary decanters out of service and in poor condition:

Figure 5.8 - Primary decanters by source: Aqualogy Aqua Ambiente

Figure 5.9 - State of preservation of Disused Primary Decanter by source: Aqualogy Aqua Ambiente

The primary settler in service has floating fat accumulation on the surface.

Figure 5.10 - Water outflow of the primary decanter by source: Aqualogy Aqua Ambiente

The biological process with nitrification - denitrification requires an automatic operational control, but it is done manually, so the carbonaceous matter degradation and the necessary nitrification-denitrification processes may not occur correctly.

The preservation of the lamellae of the secondary decanters is poor, being some of them misplaced. There is also a layer of algae and floating sludge:

Figure 5.11 - Secondary Decanter by source: Aqualogy Aqua Ambiente

The sludge line is out of service due to a leak in the digester.

Dehydration was never launched.

Figure 5.12 - Band Filters by source: Aqualogy Aqua Ambiente

Initially sludge is extracted from mixed tanks and taken to landfill by truck.

Emerging pathologies in concrete and general poor condition of civil engineering and urbanization.

Figure 5.13 - Pathologies in concrete by source: Aqualogy Aqua Ambiente

The instrumentation and control system is faulty and is not in operation, so that the operation of the plant is manual.

Operating parameters are not optimized (aeration, sludge age, energy consumption, reagent dosing ...).

Lack of operating rooms, workshop and storage conditions:

Figure 5.14 - Storage Area by source: Aqualogy Aqua Ambiente

No analytical tests of the process are performed, although there is a plant laboratory well equipped.

Figure 5.15 - WWTP Laboratory by source: Aqualogy Aqua Ambiente

5.3.3 Problem summary

The main issues presented by the current WWTP are synthesized in consideration to the following contexts:

Influent type:

- Possible seasonality in flow and pollutant load, due to tourism.
- Possible discontinuous contribution of septic tank emptying and overall impact on the influent.
- Type of contributions from septic tanks, with high contents of suspended and dissolved solids, sand, grease and organic nitrogen and ammonia.

Current facilities:

- The WWTP is not sized to the population increase and the expected network connection, both in the context of flow and pollutant loads and the quality of the effluent to obtain.
- The state of existing facilities cannot meet the nutrient removal requirements.
- General deterioration of facilities and equipment, electromechanical, instrumentation, automation, remote and wiring.
- Local deterioration of civil construction, building and urbanization.

- Need to renew its operating equipment due to condition or to adapt to the new plant configuration.
- Existence of completely obsolete equipment such as sludge line.
- Unknown status of buried pipes and of the sludge line, which can present serious congestion issues.
- Not recommended discharge point on the beach.

6. Water needs and available resources in irrigation areas

The chapter presented below is intended to define:
Water demands of irrigated areas (urban parks: squares, gardens, roundabouts and medians, and urban gardens).
Regenerated water resources that exist and that are projected from the WWTP in Praia and its availability.

6.1 Work Methodology

In order to begin to perform the technical justification for the study of reuse, and have an understanding of the scope of the project, it is necessary to take into account the scientific documentation referring to the project, technical reports, meeting minutes and studies "in situ" provided by responsible entities involved in the project, as well as documentation and papers, nationally and internationally, in order to support the research questions. Consider also new data that has been provided by the company responsible for this work, including the reports of visits to the WWTP in Praia at pumping stations and INGRH laboratory, as well as reports of meetings with the City County of Praia.
According to the data analyzed, it can be concluded that the responsible agencies aim to prioritize the reuse of treated water for the following uses:

- Production of ornamental plants as an economic activity to improve the situation of families in the city.
- Peri-urban agriculture.
- Animal husbandry, livestock farming.
- Construction industry.

Located and identified on a work map were irrigated areas and priority infrastructures to consider defining the infrastructure of reuse. With this identification, surveyed the irrigated areas of Praia.
In the working map, all those areas were documented photographically and embodied in the working map, as well as the taken route.

6.2 Hydric needs of parks, gardens and urban gardens

So the first point of water needs of the irrigated areas define the water demands of plants on irrigated areas (squares, gardens, roundabouts, medians and urban gardens).
Water is a very important element that influences the processes of growth and development of plants, shrubs and trees, as well as influences the processes of thermal regulation thereof, as it allows them to regulate their temperature adapted to the different climates.

Water consumption and water needs to be held in the irrigated areas depend on the type of plant, shrub or tree and the climate of the area, particularly rainfall, temperature, humidity, solar radiation, and the prevailing wind. Furthermore, the type of soil more or less determines the amount of water that can be stored and which will benefit the plants.

For plants, shrubs and trees irrigated areas optimally evolve, we need to first calculate the water requirements them to then know the amount of water to be applied as well as the adequate watering time.

6.2.1 Calculation method of ET and ET0

To calculate the water needs of plants, shrubs and trees of the irrigated areas, there are several methods that can be found in the FAO bulletin No. 24 (FAO, 2012), now well, has been used *Blanney Criddle* method, presented in the same previous newsletter.

The water needs of plants on irrigated areas are calculated from the estimated maximum evapotranspiration (ET), from the reference evapotranspiration (ET0). Evapotranspiration is the sum of direct evaporation from the soil and transpiration from plants.

The water needs of crops are calculated from the maximum evapotranspiration, ET:

$$\mathbf{ET = Kj \times ET0}$$

With:

ET: The maximum evapotranspiration

Kj: coefficient of gardening. Replaces Kc: crop coefficient depending on the crop and its growth stage. Shall see justification for this coefficient Kc is not the one adopted in this case and have urban gardens.

ET0: reference evapotranspiration, calculated by Blanney-Criddle formula.

For the calculation of reference evapotranspiration, ET0, using one of the abacus found in FAO Bulletin No. 24 and shown in the following figure.

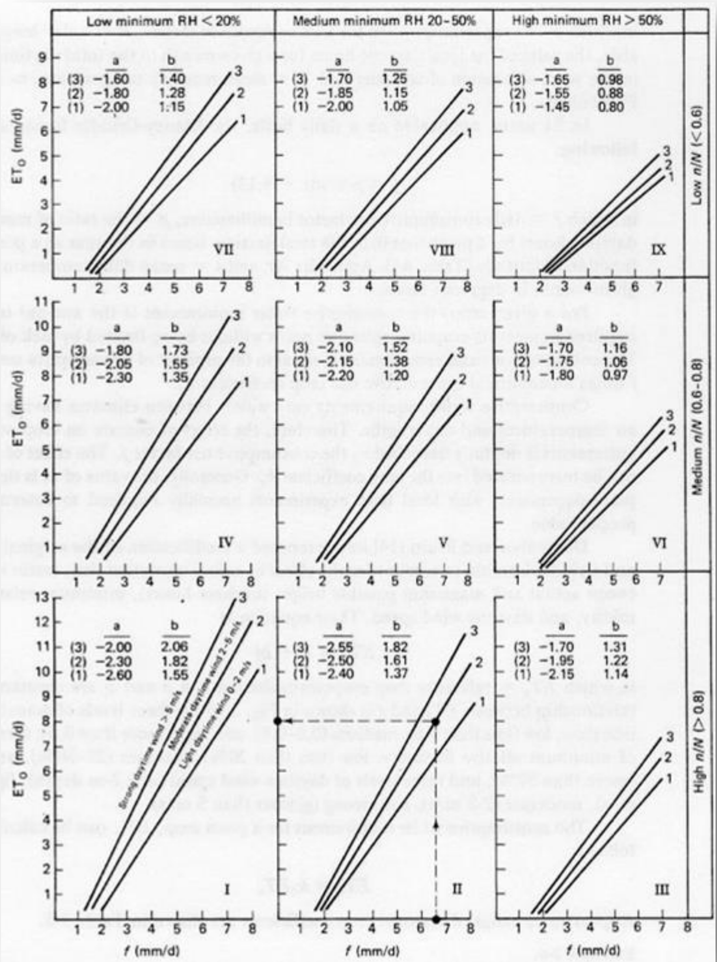


Figure 6.1 - Prediction of ET0 from the factor f Blaney-Criddle, for different conditions of low relative humidity, daily sunshine hours and diurnal winds. Source: FAO Bulletin No. 24

Choose one of the abacus of the figure in terms of the following parameters:

RH min (%): Diurnal minimum humidity;

n / N: Ratio of real hours and maximum hours of sunshine;

U 2: diurnal wind at the height of 2 m;

These three parameters are varying month to month, doesn´t exist a single abacus for the entire year, so choose one or the other, depends on month;

Once chosen the abacus, ***ET0*** can be calculated from the following formula:

$$ET0 = b \times f + a$$

With:

ET0 (mm / day): reference evapotranspiration;

a: Chosen line parameter of abacus;

b: Chosen line slope of abacus;

f: K x p x (0.46 T + 8.13), with:

T (°C): Average Temperature;

p: Percentage of the daily average hours of total annual light.

Geographically, Cape Verde is located between the parallels 14º54' and 15°20' north latitude and between the meridians 23º46' and 23°25' west longitude.

P values for the latitude of Cape Verde (FAO, 2012) (Source. water needs of crops, document 24 p.13) are obtained from a table, which were obtained the following values:

Table 6.1 - Values of p for 15° and 20° latitude

Latitude	September	October	November	December	January	February	March	April	May	June	July	August
15°	0,28	0,27	0,26	0,25	0,26	0,26	0,27	0,28	0,29	0,29	0,29	0,28
20°	0,28	0,26	0,25	0,25	0,25	0,26	0,27	0,28	0,29	0,30	0,30	0,29

6.3 Climate data

The climatic data used are primarily those of the Municipal Master Plan. Other data that have guided have been obtained from the following items:

- *Modelação Espacial da Precipitação Ilha de Santiago, Cabo Verde, com o Geostatistical Analyst, de Silva, J., Monteiro, P., Negreiros, J., Aguilar, F, Aguilar, M.*

- Integrated analysis of eastern part of Santiago Island, Cape Verde (Africa).

6.3.1 Pluviometry

According to the PDM, in the city of Praia, rainfall varies greatly from year to year from the point of view, many of its distribution in time and space, and the overall amount. Rainfall usually as heavy rainfall, even in certain localities, the total annual rainfall occurs in two or three isolated storms. According to the graph of PDM, the annual average pluviometry is about 200 mm/year.

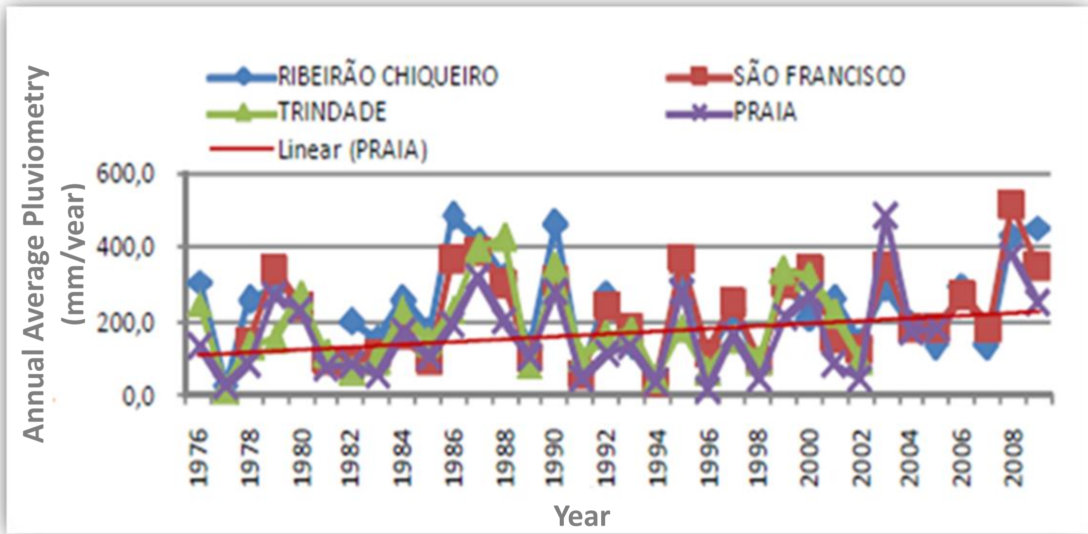


Figure 6.2 - Chart - Pluviometric data: 1976-2008. Source: PDM

Rainfall on the Santiago Island is usually given in a short period of the year, usually from July to October. On the other hand, there are a variety spatial distribution of rainfall on the island due to relief and the wind direction. The highest values occur in the higher altitude areas with strong contrast in relation to low altitude areas.

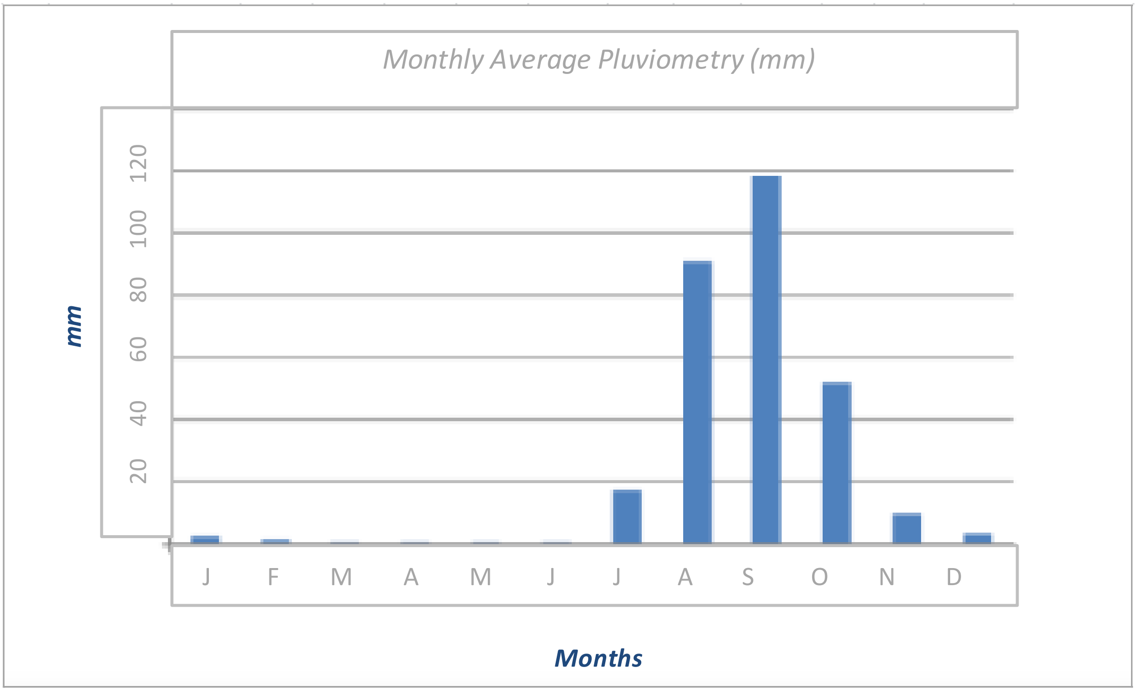


Figure 6.3 - Chart - Monthly average pluviometry. Source: "Modelação Espacial da Precipitação Ilha de Santiago, Cabo Verde, with the Geostatistical Analyst, of Silva, J., Monteiro, P., Negreiros, J., Aguilar, F, Aguilar, M."

6.3.2 Temperature

Higher values of the average temperature for the city of Praia, according PDM, occur in August, September and October.

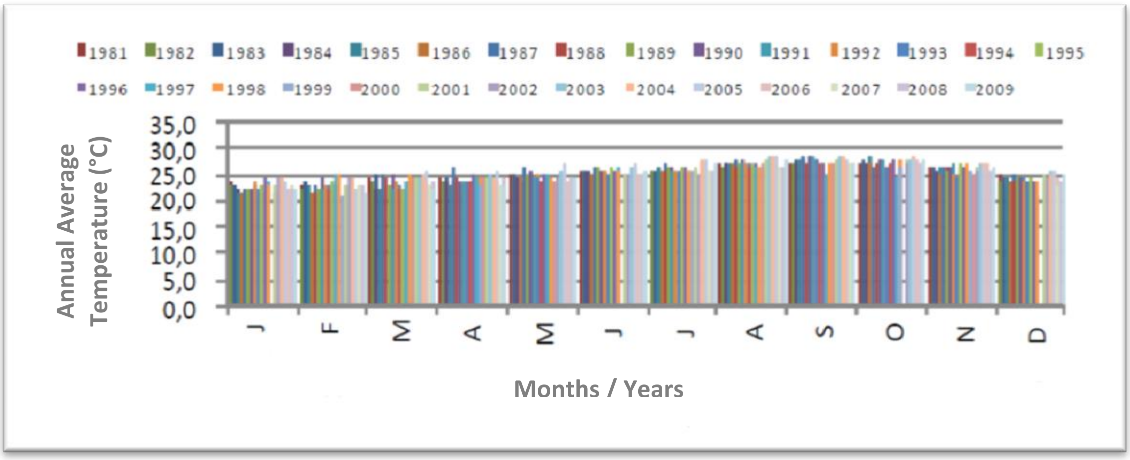


Figure 6.4 - Chart - Monthly mean temperature from 1981 to 2009. Source: PDM

Can get approximately the following values of temperature for Praia (obtained from the graph above) that will serve for the calculation of Blaney-Criddle.

Table 6.2 - Monthly average temperature; source: PDM

Temperature	September	October	November	December	January	February	March	April	May	June	July	August
°C	28	27	26,5	24,8	23	23,8	24,5	24,8	25	26	26,5	27

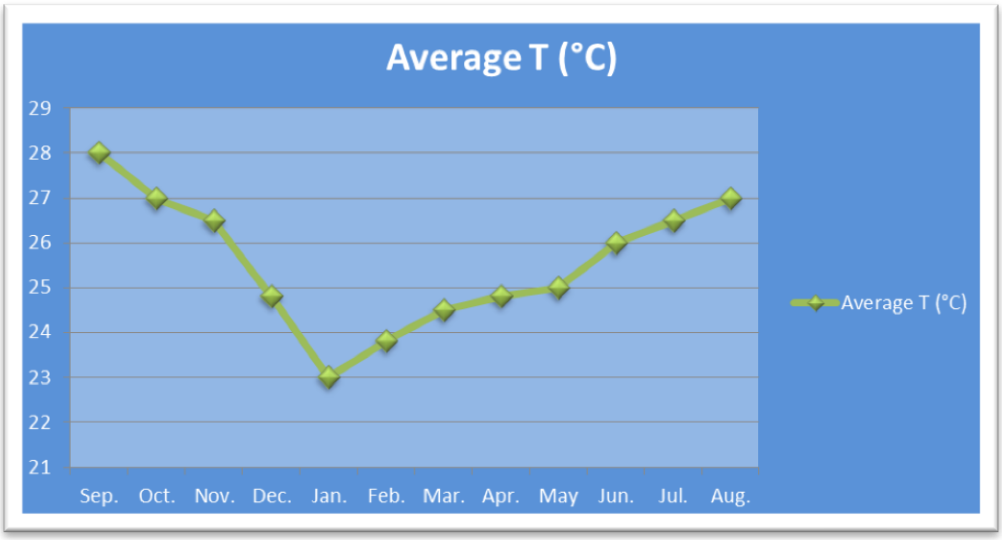


Figure 6.5 - Chart - Monthly mean temperatures. Source: PDM

6.3.3 Wind

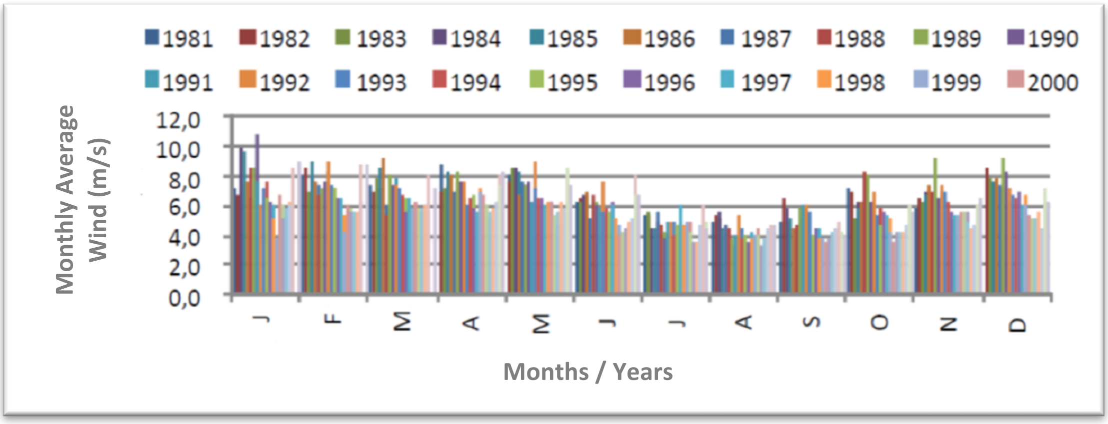


Figure 6.6 - Chart - Monthly average wind from 1981 to 2000. Source: PDM

Looking at the graph, it's possible to find that the speed of 7 m/s from January to May, 5 m/s in June and October, 4.5 m/s in July, August and September, and 6 m/s in November and December. The PDM refers 3 m/s, therefore, can be considered for a wind Blaney-Criddle moderate to strong.

6.3.4 Diurnal minimum humidity

According to the PDM mean relative humidity of air has high values especially during the night, due to the proximity of the sea, may fall sharply when influenced by eastern quadrant winds during the dry season.

RHmin consider minimum humidity of 40%, which means according to Blaney-Criddle an average humidity.

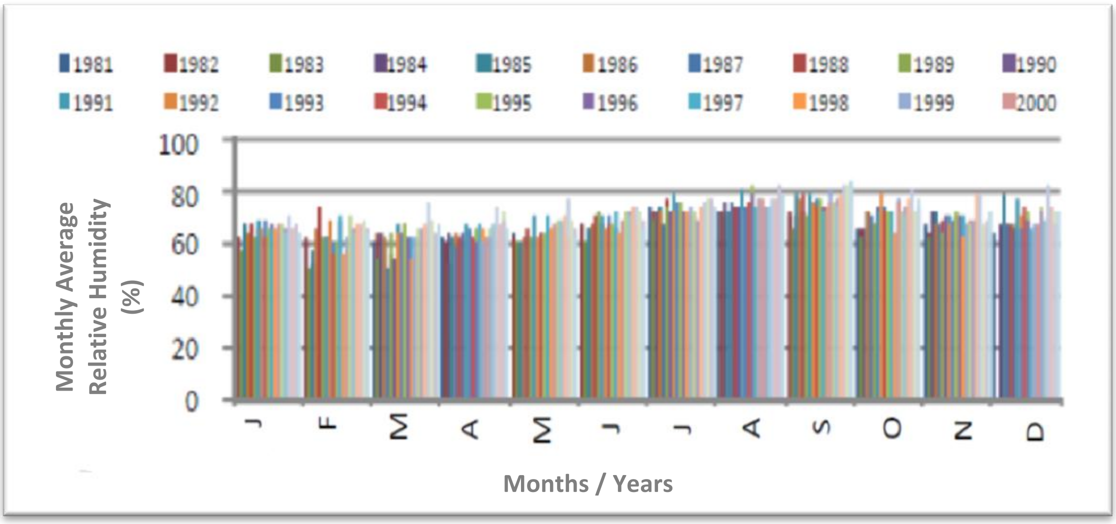


Figure 6.7 - Chart - Monthly average relative humidity from 1976 to 2008. Source: PDM

6.3.5 Radiation

According to the PDM, sunstroke is generally high due to the low cloud cover throughout the dry period. From March to June insolation is much higher reaching daily extreme values of 11 hours.

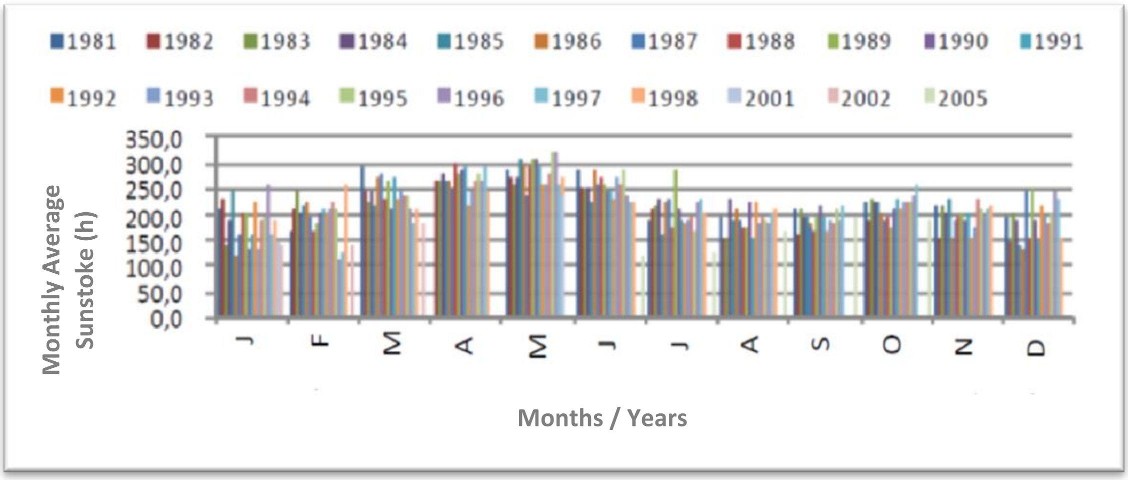


Figure 6.8 - Chart - 1976-2008 monthly average insolation. Source: PDM

Looking at the graph, the maximum insolation months are from March to June has an average of 250 hours per month, which means that get to *n* (number of real hours daily) / *N* (maximum daily number of hours) is 0.8 hours per month. Therefore, can be considered for Blaney Criddle medium-high radiation rate.

6.4 ET0 Calculation

In the following table, based on the calculation methodology described above, yields the following results.

Table 6.3 - ET0 calculation values

Month	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
Days / Month	30	31	30	31	31	28,25	31	30	31	30	31	31
Average T (°C)	28	27	26,5	24,8	23	23,8	24,5	24,8	25	26	26,5	27
p (%) Latitude: 15°	0,28	0,27	0,26	0,25	0,26	0,26	0,27	0,28	0,29	0,29	0,29	0,28
f (ETo)	5,88	5,55	5,28	4,88	4,86	4,96	5,24	5,47	5,69	5,83	5,89	5,75
a (ETo)	-2,15	-2,10	-2,10	-2,10	-2,10	-2,10	-2,55	-2,55	-2,55	-2,15	-2,15	-2,15
b (ETo)	1,38	1,52	1,52	1,52	1,52	1,52	1,823	1,823	1,823	1,38	1,38	1,38
ETo (mm/day)	**5,97**	**6,33**	**5,93**	**5,32**	**5,29**	**5,44**	**7,00**	**7,42**	**7,83**	**5,89**	**5,98**	**5,79**

6.5 Coefficients Kc and Kj

Relative changes in vegetation cover and plant stages vary the value of **Kc**. Kc describes the variations in the amount of water consumed by the plants as they grow.

In agricultural crops this coefficient varies since planting to harvest. Three values of the coefficients in the case of crops are needed to define the evolution of the culture coefficient growth cycle:

- The initial crop coefficient (**Kcini**) for the period of exercise.

- The crop coefficient means (**Kcmid**), which corresponds to the period of their growth and development.

- The final growing coefficient (**Kcend**) which corresponds to the period of ripening.

The values of crop coefficients used are extracted from *FAO reports 24 and 56 and part of PAGI "programa para la mejora de la gestión del riego"* - program to improve irrigation management. These reports contain tabulated values of **Kc** for each crop.

Furthermore, these values are crop coefficient for each crop in each zone.

Now, due to the present case, in which irrigates a high percentage of parks, gardens, squares, roundabouts and road tabs, concerning urban gardens, plus there is a large variation of species in a place, is not possible to put a crop coefficient value for all as each species has a different value of **Kc**. The variation of the density, the existence of microclimates, the association between trees, shrubs and plants, among other things, affect the value of evapotranspiration. Also in a park or garden, most plantations require a maintenance dose, not production. And, in opposite case, urban gardens requires production but timely in a specific month of the year.

Therefore, in gardening, **Kc** factor that adjusts the water required by plants is called gardening coefficient is abbreviated to **Kj**. And it is this factor that it's used to calculate evapotranspiration.

Gardening coefficient takes into account the heterogeneity of garden using three coefficients, and is expressed as follows:

Kj= Ke x Kd x Km

With,

Ke: the species in the garden;

Kd: the density of plantation;

Km: the microclimate.

By assigning numerical values to each of these coefficients is obtained the garden coefficient **Kj**.

Table 6.4 - Values of the coefficient Kj

Vegetation types	Species Coefficient, Ke			Density Coefficient, Kd			Microclimate Coefficient, Km		
	High	Medium	Low	High	Medium	Low	High	Medium	Low
Trees	0.9	0.5	0.2	1.3	1.0	0.5	1.4	1.0	0.5
Shrubbery	0.7	0.5	0.2	1.1	1.0	0.5	1.3	1.0	0.5
Groundcovers	0.7	0.5	0.2	1.1	1.0	0.5	1.2	1.0	0.5
Mixed Plants	0.9	0.5	0.2	1.1	1.1	0.6	1.4	1.0	0.5
Grass	0.8	0.7	0.6	1.0	1.0	0.6	1.2	1.0	0.8

Praia green areas, consist of parks, gardens, squares, roundabouts and road tabs that extend and are distributed by most neighborhoods

In these areas, trees that can be found: American Acacia (Prosopis juliflora) (American acacia) Neem tree (Azadirachta indica), palm (phoenix Atlantic), almond, date palm tree (phoenix dactylifera)

Besides shrubs and herbaceous species are the most common in these spaces.

Below, at the Annex II, it is possible to see some Praia green areas, according to a photographic trace obtained *"in situ"* (Aqualogy Aqua Ambiente, 2012).

Returning to the calculations and known the species of green areas, had been considered **Kj** values between 0.60 and 0.75 depending on season of the year.

6.6 ET coefficient calculation

In the following table, based on the calculation methodology described above, it's obtained the results of the reference evapotranspiration (**ET0**), the gardening coefficient **Kj** and maximum evapotranspiration (**ET**) for each month.

Table 6.5 - ET coefficient calculation

Month	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
ETo (mm/day)	5,97	6,33	5,93	5,32	5,29	5,44	7,00	7,42	7,83	5,89	5,98	5,79
Kc value	0,75	0,70	0,70	0,60	0,60	0,60	0,60	0,60	0,60	0,75	0,75	0,75
ET (mm/day)	4,48	4,43	4,15	3,19	3,18	3,26	4,20	4,45	4,70	4,42	4,49	4,34

These results can be expressed in graph form, as below.

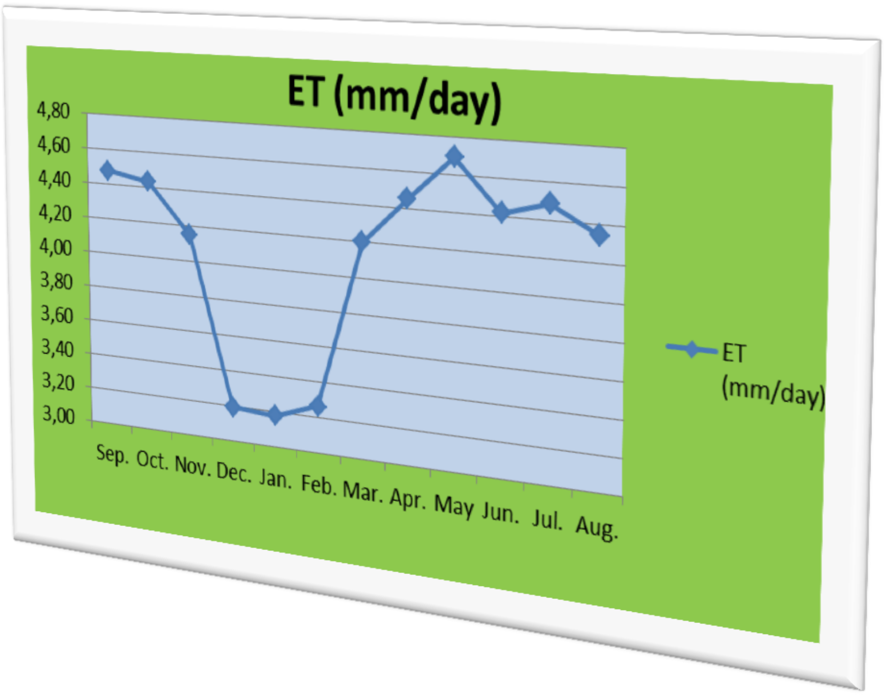


Figure 6.9 - Chart - ET distribution for each month

6.7 Hydric Needs

After calculating the maximum evapotranspiration (**ET**) for each month of the year and the monthly average rainfall known, are calculated net irrigation needs.

Rainfall of some months could cover part of the irrigation water needs and in other months, but May not cover the entire needs of irrigation water. Therefore, depending on the month, some might have surface runoff, and other would be retained in the soil of the root zone (FAO, 2012). *Irrigation Techniques Manual for pressurized lines - Chapter 6 of the FAO*.

Therefore calculate net irrigation needs as follows:

- **Net irrigation needs = ET x Kr - effective rainfall**

  if ET > effective rainfall

- **Net irrigation needs = 0**

  if ET < effective rainfall

With,

Cs= coefficient for evapotranspiration under drip irrigation.

Because intake located in the vicinity of the plant, in drip irrigation water requirement is different from other irrigation methods. The water supply is equal to the daily needs of the plant, so that virtually all the water supplied is transpired by plants, shrubs and trees. Consequently, it is necessary to multiply the **ET** by a reduction coefficient **Kr** for crop evapotranspiration under drip irrigation. This coefficient depends on the coverage **Kr** soil for growing in the vertical projection C (FAO, 2012).

After calculating the monthly net irrigation needs, to calculate gross irrigation needs is according this relation:

Gross Irrigation Needs = Net Irrigation Needs / Ea

With,

Ea: efficiency of the irrigation system, which includes both the application efficiency of the irrigation system as wash fraction or extra amount of water leaching of salts depending on the salinity of the irrigation water and the threshold tolerance to salinity of the plants, shrubs and trees.

The following table shows the results of the water needs of plants, shrubs and trees in the irrigated areas of the municipality of Praia for each month of the year.

As shown in the table below, marked in orange is the month of greatest need or demand for water and it corresponds of the month of June, with a total peak demand **1.043,95 m^3/ha.month**.

Therefore, the water needs of June will be those that determine the design of the irrigation system.

Also, in table can also be observed grayed cells that is the net needs all year, estimated at **8.137,26 m^3/ha** and the gross needs throughout the year, which is estimated at **9.090,41 m^3/ha.**

Table 6.6 - Hydric needs calculation

WATER NEEDS	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	TOTAL
ET (mm/day)	4,48	4,43	4,15	3,19	3,18	3,26	4,20	4,45	4,70	4,86	4,49	4,34	
ET (mm/month)	134,29	137,44	124,54	99,03	98,47	91,39	130,18	133,61	145,60	145,78	139,08	134,63	
Rainfall (mm/day)	2,17	0,97	0,40	0,19	0,48	0,29	0,19	0,13	0,03	0,03	0,48	1,61	
Rainfall (mm/month)	65,00	30,00	12,00	6,00	15,00	8,00	6,00	4,00	1,00	1,00	15,00	50,00	
Effective Rainfall (mm/day)	1,73	0,77	0,32	0,15	0,39	0,23	0,15	0,11	0,03	0,03	0,39	1,29	
Kr	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	
Net Needs = ET x Kr-Effective Rainfall	1,18	2,11	2,38	1,92	1,68	1,89	2,57	2,79	3,03	3,13	2,53	1,53	
Efficiency of the irrigation system, Ea	0,8	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	
Gross Needs = Net Needs / Ea (mm/day)	1,47	2,34	2,64	2,14	1,86	2,10	2,86	3,10	3,36	3,48	2,81	1,70	
Net Needs (m^3/ha·month)	352,86	653,37	713,51	595,72	520,07	530,01	798,16	836,49	938,38	939,56	784,04	475,09	8.137,26
Gross Needs (m^3/ha·month)	441,07	725,97	792,79	661,92	577,85	588,90	886,85	929,43	1042,64	1043,95	871,15	527,88	9.090,41

6.8 Work phases, zones and irrigation hydric needs

After calculating the water needs in the previous section, in which is known the needs in terms of water by hectare, was made an inventory of the irrigated areas to be irrigated (parks, gardens, squares, roundabouts, road tabs and urban gardens).

This inventory has been made based on technical documentation of Canaragua, the ITC and Aqualogy Aqua Ambiente and minutes of meetings held with the City County of Praia, MAHOT, Electra, ANMCV and FUCAEX.

Therefore, and also by available mapping and cartography from Praia, pictures taken and Google earth search, there has been a measurements inventory with irrigable areas.

Once the inventory done, the irrigated areas are grouped in phases (in order to have a unified approach will have the word *PHASE* and a digit), and in turn these phases are formed by sub-phases (which have the word *PHASE* and two digits, the first which corresponds to the dependent phase).

- PHASE 1. Includes SUBPHASE 1.1, SUBPHASE 1.2, SUBPHASE 1.3, SUBPHASE 1.4 and SUBPHASE 1.5;
- PHASE 2. Includes SUBPHASE 2.1 and SUBPHASE 2.2;
- PHASE 3. Includes SUBPHASE 3.1 and SUBPHASE 3.2.

The main criteria to define these phases had been the priority of execution. The ***PHASE 1*** has high priority to be the city center, ***PHASE 2*** has medium priority actions to be the proximity to the airport and finally ***PHASE 3*** has low priority actions because it corresponds to future urban extensions. In addition, to define the sub phase's criteria was areas with a similar level to optimize resources and energy.

To get an estimate of the water needs (flow) of all plants, shrubs and trees in the parks, gardens, squares and roundabouts of Praia, was made an estimate of the flow will be needed to irrigate all the irrigable areas of Praia, corresponding to ***92.46 hectares***.

Therefore, is multiplied by the total known area that will irrigate.

Table 6.7 – Gross needs and flows to irrigation process

WATER NEEDS	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
Irrigation Area (ha)	92,46	92,46	92,46	92,46	92,46	92,46	92,46	92,46	92,46	92,46	92,46	92,46
Gross Needs (m^3/month)	40781,63	67123,00	73301,09	61200,79	53428,30	54449,40	81998,03	85935,23	96402,91	96523,79	80546,98	48807,82
Gross Needs (mm/day)	135,94	216,53	244,34	197,42	172,35	194,46	264,51	286,45	310,98	321,75	259,83	157,44
Hours of irrigation per day (h/day)	8,00	8,00	8,00	8,00	8,00	8,00	8,00	8,00	8,00	8,00	8,00	8,00
Days of irrigation per month (day/month)	30,00	31,00	30,00	31,00	31,00	28,00	31,00	30,00	31,00	30,00	31,00	31,00
Needed Gross Flow (l/s)	15,73	25,06	28,28	22,85	19,95	22,51	30,61	33,15	35,99	37,24	30,07	18,22
Needed Gross Flow for irrigation (l/s)	47,20	75,18	84,84	68,55	59,84	67,52	91,84	99,46	107,98	111,72	90,22	54,67

Table 6.8 - Summary table of the phases and the design flow a) by source: Aqualogy Aqua Ambiente

Phase	Sub-phase	Design Flow (m^3/day)
1	1.1	142,36
	1.2	596,65
	1.3	22,25
	1.4	86,94
	1.5	100,89
	1	**949,09**
2	2.1	959,57
	2.2	842,93
	2	**1.802,50**
3	**3**	**2.074,55**
	TOTAL	**4.826,14**

6.9 Available resources

The water used to irrigate the irrigable areas shall proceed from the WWTP of Praia. Purified water is therefore to be applied to tertiary treatment to obtain a given quality to be reused for irrigation, becoming reclaimed water.

The nominal capacity of the WWTP is ***8.000 m^3/day***, although currently only treated about ***1.500 m^3/day***, for lack of connection of the population to the sewerage network.

As seen above, the water needs of all phases of implementation of the irrigation network are ***3.217,46 m^3/day***, however, with a design flow adopted (subsequently adding previous value one and a half) of ***4.826,14 m^3/day***. This is the sum of ***949,09 m^3/day*** for Phase 1, ***1.802,50 m^3/day*** for Phase 2 and **2.074,55** ***m^3/day*** for Phase 3.

During Phase 1, with the flow currently treated by the WWTP, the demand is covered, as it is anticipated that Phase 1 ensure the proper functioning of existing sanitation system for a flow of ***2.500 m^3/day*** (outside the scope of this study) and implement the necessary improvements to the WWTP to ensure the quality of the treated effluent.

During Phase 2, is expected to expand tertiary treatment to cover the demands of irrigation, so demand will also be covered.

Finally, during Phase 3 is expected to expand tertiary treatment to attend the demands of irrigation, so demand will also be covered.

Therefore, provide reclaimed water for irrigation in all phases.

7. Irrigation, transportation and primary networks

The chapter presented below is intended to define new actions and infrastructure to execute for reuse reclaimed water in the WWTP, always according required quality criteria, to meet the demand of the irrigated areas.

7.1 Proposed actions

Once defined the water needs and know the demands of irrigation water, it should raise a number of infrastructures to reach and supply the irrigated areas.

This infrastructure must be able to distribute the treated water from the treatment plant to the consumer points: parks, squares, gardens, roundabouts, road tabs and urban gardens.

Are generated to cover the largest possible percentage of the water needs considering a number of criteria of rationality that are:

- Dimension of demand.
- Distance to the resource (the WWTP and irrigation distribution wells).
- Height difference between resource (WWTP distribution and irrigation wells) and demand (irrigation points).
- Network proximity to the demand points.

These infrastructures are:

- ***Transport network piping***. The pipelines are impulsiom pipes that carry the water from the WWTP to different irrigation distribution tanks and carry water from an irrigation tank to another.
- ***Storage tanks and irrigation distribution***. These deposits will be executed so that stored water is driven from the WWTP or driven from another irrigation reservoir.

Both pipelines transport network as storage tanks and irrigation distribution are distributed according to the phases in Praia defined below.

- ***Primary network piping***. The primary network pipes are pipes grouped areas irrigated within a phase and described herein.

Thus, the proposed actions are in line to meet the water demands of irrigation areas, considering the following:

- Transportation or impulsion pipelines of the WWTP to irrigation distribution tanks.

- Primary pipes, which will go directly connected to the distribution irrigation tanks, and from which flow the secondary pipelines.
- Secondary pipes, will group tertiary pipes.
- Tertiary pipes, which shall become to the sides.
- Drip lateral pipes.

7.2 Implementation phases of actions

The proposed actions can be divided in phases. In each of these phases requires a given flow rate and it had been estimated above.

Table 7.1 - Summary table of the phases and the design flow a) by source: Aqualogy Aqua Ambiente

Phase	Sub-phase	Design Flow (m^3/day)
1	1.1	142,36
	1.2	596,65
	1.3	22,25
	1.4	86,94
	1.5	100,89
	1	**949,09**
2	2.1	959,57
	2.2	842,93
	2	**1.802,50**
3	**3**	**2.074,55**
	TOTAL	**4.826,14**

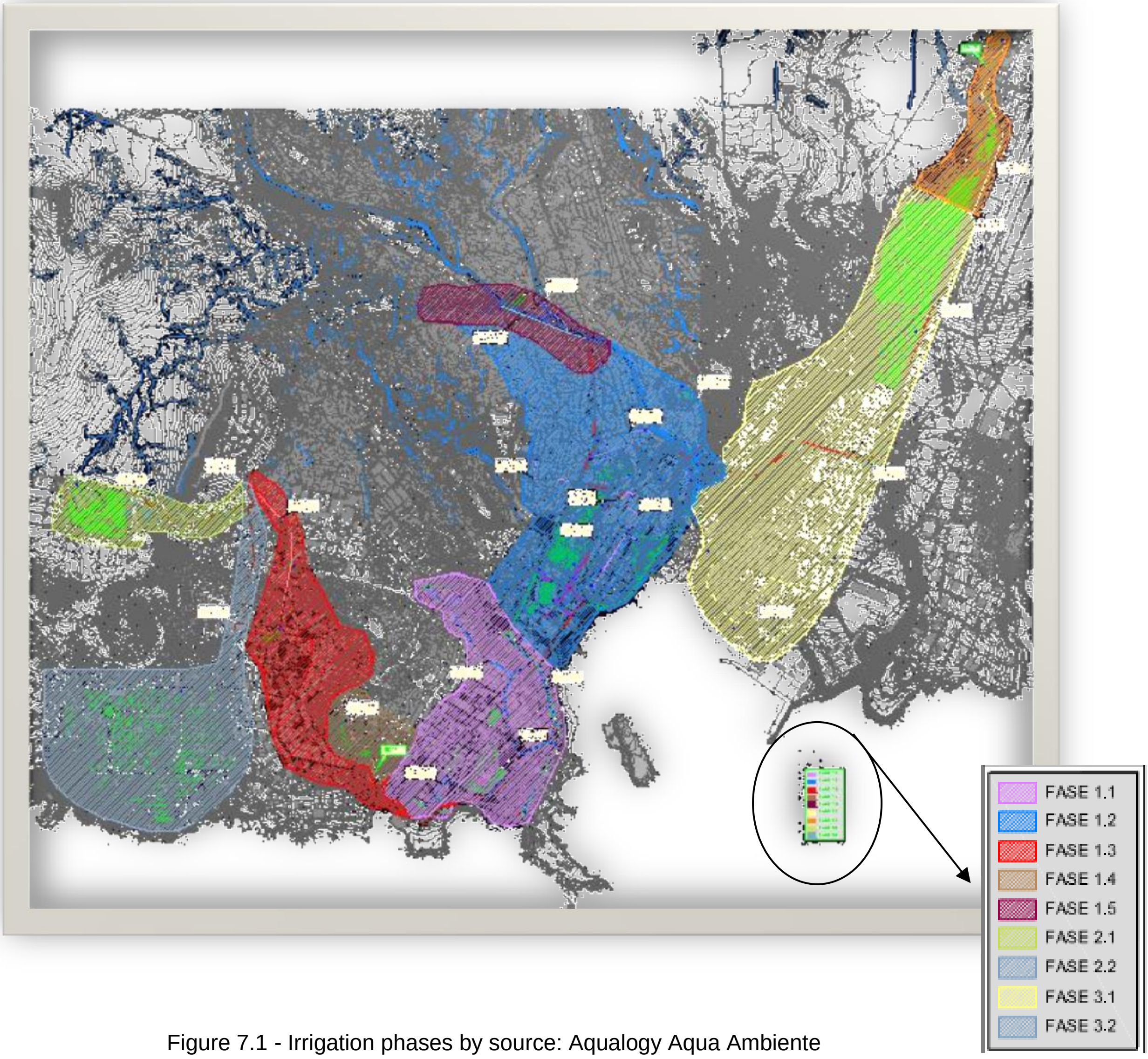


Figure 7.1 - Irrigation phases by source: Aqualogy Aqua Ambiente

7.2.1 Phase 1

High priority actions, it includes actions to improve existing sanitation infrastructure to enable reuse project, as well as new infrastructure necessary to irrigate the green areas of the city center (Parliament and Plateau) and all urban gardens.

- ***SUBPHASE 1.1.*** Irrigation areas near the parliament. By transport pipe carries water from the WWTP to irrigation tank 1. From this reservoir water the following three sectors.

    - *Sector 1* - Northern irrigation areas.
    - *Sector 2* - Irrigated areas of road tabs and roundabouts.
    - *Sector 3* - Irrigation areas of parliament and João Paulo I park.

Figure 7.2 - Phase 1.1 by source: Aqualogy Aqua Ambiente

- ***SUBPHASE 1.2.*** Irrigation areas near Plateau. By transport pipe, carries water from the WWTP to irrigation tank 2. From this tank are irrigated four sectors corresponding to this phase.

    - *Sector 1* - Irrigation zone of 5 de Julho Park, road tabs and roundabouts on the north of this phase.
    - *Sector 2* - Irrigated areas of the city county square (Albuquerque park) and the Presidential Palace.
    - *Sector 3* - Garden irrigation zones between 5 de Julho Park and the national library, plus around the national library, a football field, road tabs and roundabouts on the south of this phase.
    - *Sector 4* - Urban garden in the northeast of the phase.

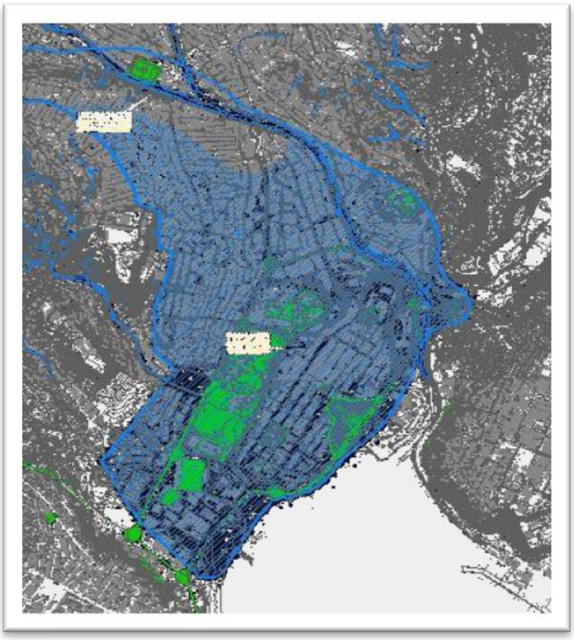


Figure 7.3 - Phase 1.2 by source: Aqualogy Aqua Ambiente

- ***SUBPHASE 1.3.*** Irrigation zones of Palmarejo Square and avenue roundabout that goes to university at the height of the square above. By conveying pipe, takes the water to the irrigation tank 3. Since there, are irrigated the previous áreas, belonging to Sector 1 of this phase.

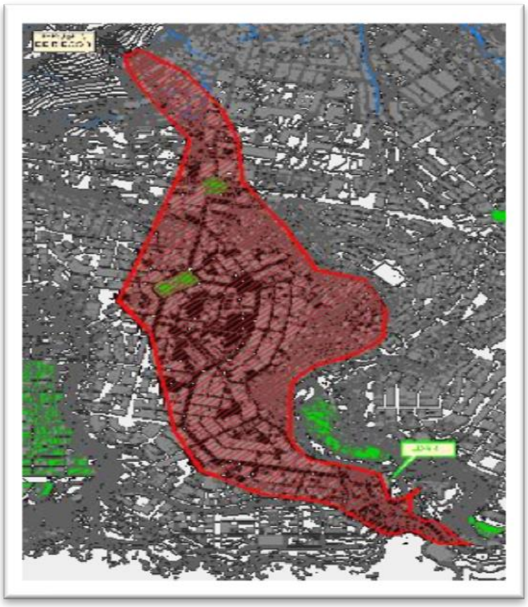


Figure 7.4 - Phase 1.3 by source: Aqualogy Aqua Ambiente

- ***SUBPHASE 1.4.*** The urban garden is located in the vicinity of the WWTP. Will boost directly through a primary network pipeline from the WWTP to the urban garden belonging to Sector 1 of this phase.

Figure 7.5 - Phase 1.4 by source: Aqualogy Aqua Ambiente

- ***SUBPHASE 1.5.*** Irrigation areas at northwest of the city, which includes a soccer field, a playground, a roundabout and an urban garden. By transport pipe carries water from the tank 2 to the irrigation tank 5. From this tank irrigates aforementioned areas belonging to Sector 1 of this phase.

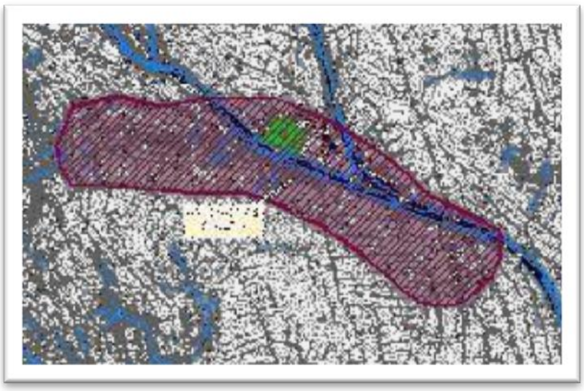


Figure 7.6 - Phase 1.5 by source: Aqualogy Aqua Ambiente

7.2.2 Phase 2

Medium priority actions aimed at enabling the irrigation of green areas near the airport and nearby urban parks. By transport pipe carries water from the WWTP to irrigation tank 4.

- ***SUBPHASE 2.1.*** Irrigation areas of southern on phase 2. Irrigated areas are near the port and the southern half of the garden that exists in front of the airport runway and the southern half of the medians and roundabouts. From the irrigation tank 5 the refereed areas are irrigated, belonging to Sector 1 of this phase.

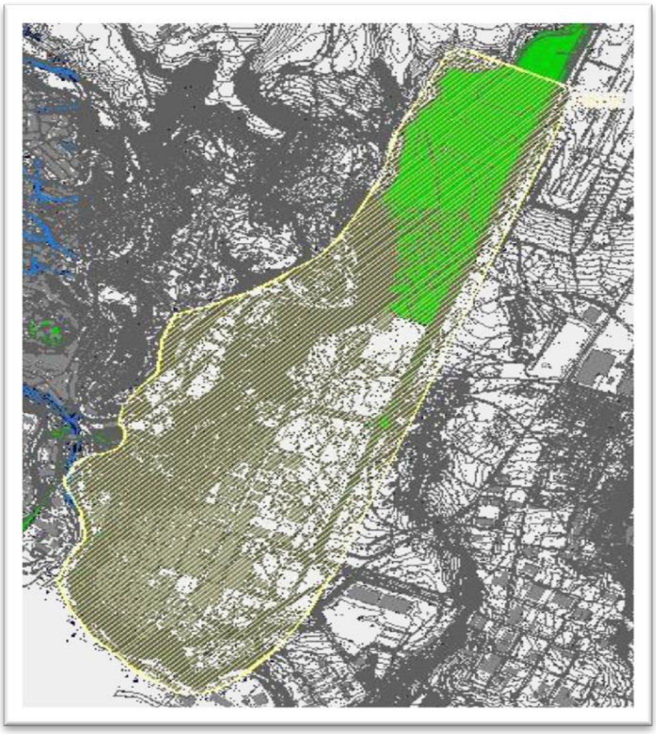


Figure 7.7 - Phase 2.1 by source: Aqualogy Aqua Ambiente

- ***SUBPHASE 2.2.*** Irrigation areas of northern on phase 2. Irrigated areas are close to the airport: park at the airport that is located in the main entrance, the northern half of the garden that exists in front of the airport runway, the northern half of the road tabs and roundabouts. From the five Irrigation tank said areas are irrigated, belonging to Sector 1 of this phase.

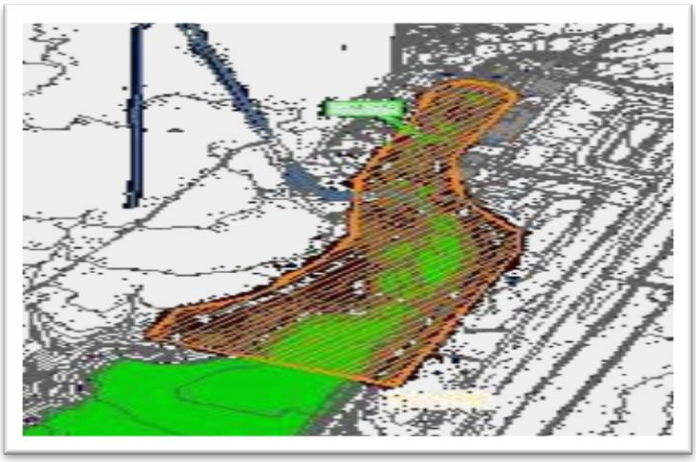


Figure 7.8 - Phase 2.2 by source: Aqualogy Aqua Ambiente

7.2.3 Phase 3

Activities of low priority, aimed at providing irrigation service to areas of future urban growth. By transport pipe carries water from the WWTP to irrigation tank 3, which will be expanded (about to be implemented in the sub phase 1.3)

- ***SUB PHASE 3.1.*** Irrigation areas in the south on the phase 3. They are the irrigated areas of the gardens of the southwestern city's future development. From Irrigation tank 3, are irrigated the above areas.

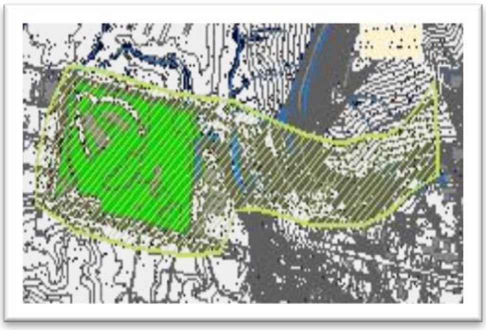


Figure 7.9 - Phase 3.1 by source: Aqualogy Aqua Ambiente

- ***SUB PHASE 3.2.*** Irrigation areas in the south of the phase 3. They are the irrigated areas in the vicinity of the University Jean Piaget. From Irrigation tank 3 are irrigated the above areas.

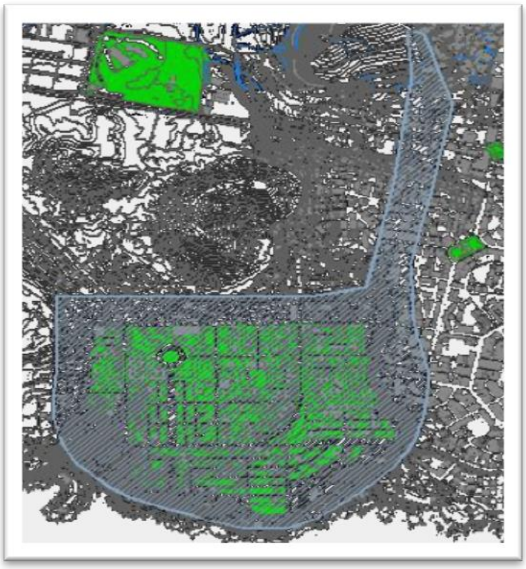


Figure 7.10 - Phase 3.2 by source: Aqualogy Aqua Ambiente

Since the demand is for the irrigation of parks and gardens, and irrigation water is reclaimed water from a wastewater treatment plant, the irrigation system to be used is drip irrigation. This is based on the continuous supply of water onto the soil surface (surface irrigation) using pressure pipes and emitters, so that only a portion is wetted the ground, the closest to the floor.

Therefore, because to use reclaimed wastewater to the treatment plant and drip irrigation is the most suitable for sanitary, drip irrigation type was chosen surface drip irrigation drip.

Water output by the droppers is produced with very little pressure through holes, usually very small size, wetting a volume of soil that is called wet bulb.

In the irrigated areas the water should be applied in small amounts and with high frequency, that is, give a large number of irrigation, in which water intake is reduced in each. Thereby attempting to maintain the water content in the soil at nearly constant levels and avoids large fluctuations in moisture.

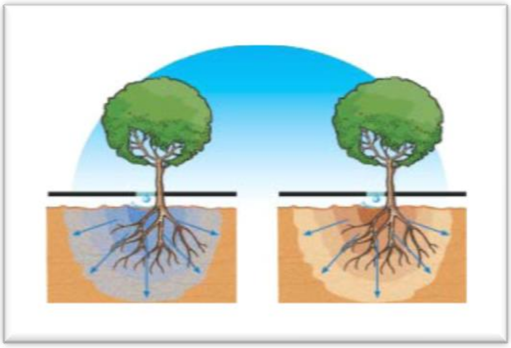


Figure 7.11 - Distribution of water in the left figure and the salts inside the wet bulb right figure. Source: *Manual de Riego de Jardines de la Consejería de Agricultura y Pesca de la Junta de Andalucía.*

Pressurized water flows through the pipeline network tertiary and secondary side of the system, from the head, to reach the drip, which loses pressure and speed out drop wise. In these cases, both laterals as drippers are located on the surface of a garden watering, and the water seeps into the ground and distributed following the shape described above wet bulb.

Figure 7.12 – Dropper by source: Aqualogy Aqua Ambiente

7.3 Phases diagram and sectors

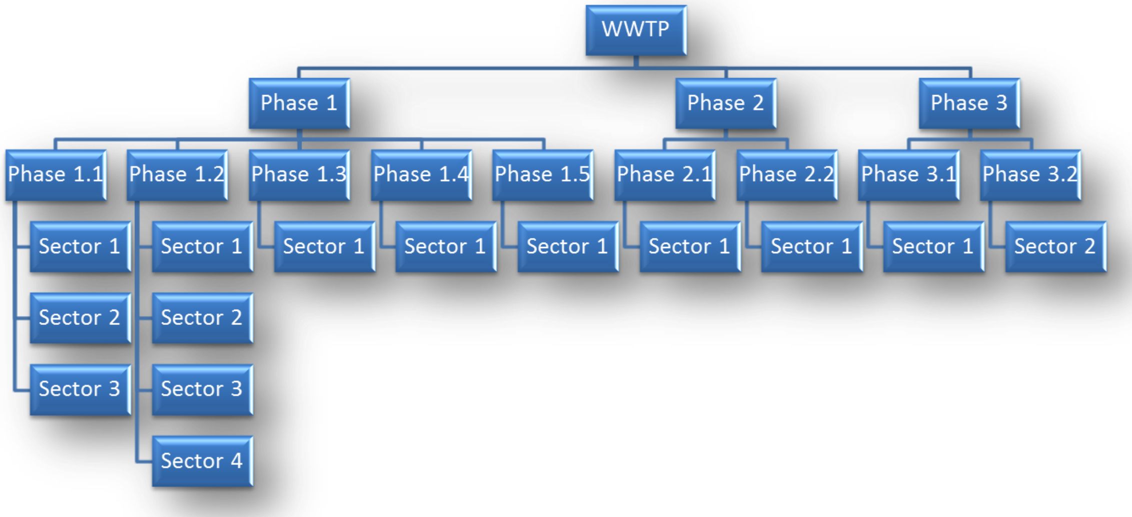


Figure 7.13 - Diagram – Phases and sectors

8. Determination of water quality reclaimed

The chapter presented below is intended to define the quality requirements for reclaimed water to irrigate plants contained in irrigated areas (urban parks: squares, gardens, roundabouts and medians, and urban gardens).

8.1 Irrigation water quality

The reuse of wastewater for irrigation properly treated is an important alternative that allows the reuse of these waters.

To determine the quality of reclaimed water for irrigation should take into account the following aspects:

- Public and health criteria;
- Qualities, according uses, for reclaimed wastewater;
- Agronomic criteria.

The risk on the health of both people and as plants, which can be caused by the irrigation of public areas with treated wastewater depend on the extent of human exposure and the used system. In this sense, drip irrigation systems are best suited to use treated wastewater.

On the one hand, plants do not come into direct contact with the water and also to keep the area wet bulb always wet, plants have available water, which decreases the occurrence of problems of salinity on the other hand, is the continuously safest method from the point of view of management, as neither the person in charge of irrigation and the irrigated area users have risks of contact with water.

Sprinkler irrigation systems, however, are those that involve greater risks, upon direct contact between water and plants, and an increased risk of exposure of the person in charge of irrigation.

Moreover, according to the uses to which it is addressed the reuse, and that in the present study refers to irrigation of parks, gardens, squares, roundabouts and mainly urban garde2ns, the possibility of water intakes for ornamental plants, and the possibility of water intake concrete will be different the required water qualities. For irrigation of crops that are consumed raw, the criteria are more stringent than for irrigation of irrigable areas.

Finally, referring to agronomic criteria, the salts in the soil or the use of a salt rich water to be controlled, a fundamental objective before implantation of an irrigation system. There are numerous aspects to be determined according to water quality as those related to the choice of irrigation or cultivation to establish the components of the irrigation system or the type of treatment that is necessary to perform water irrigate with it.

The World Health Organization (WHO) in its four volumes *"WHO Guidelines for the safe use of wastewater, excreta and greywater"* establishes a set of guidelines for reclaimed water quality as their intended uses, which are involved in the three criteria to determine water quality: health, according to the uses and agronomic.

It should be noted that in Cape Verde there is no specific regulation of water quality criteria for irrigation reuse, since it is not regulated. Therefore, based on the foregoing, it was chosen two sources to identify quality criteria for irrigation reclaimed water schemes in Praia:

- Spanish Normative ***Real Decreto 1620/2007 de 7 de diciembre - BOE núm. 294, Sábado 8 diciembre 2007***, establishing the legal framework for the reuse of treated water.

- WHO Guidelines - ***"WHO Guidelines for the safe use of wastewater, excreta and greywater".***

Quality criteria for water reuse as its uses according to Spanish law *RD 1620/2007* of reuse of reclaimed water, in *Annex I* quote the maximum allowable values (MAV) and which are shown in the following table:

Table 8.1 - Anexx I.A. Quality criteria for water reuse according to their uses (irrigation of urban green areas)

Maximum Admisible Value				
	URBAN	*AGRICULTURE*		*INDUSTRIAL*
USE	URBAN GREEN ZONE IRRIGATION (PARKS, SPORTS FIELDS AND SIMILAR)	APPLICATION WATER SYSTEM ON CROPS THAT ALLOWS DIRECT CONTACT OF REGENERATED WATER WITH THE EDIBLE PARTS FOR HUMAN CONSUMPTION	ORNAMENTAL CROPS	OTHER INDUSTRIAL USES
Intestinal nematodes	1egg/10l	1egg/10l	1egg/10l	No fixed limit
Escherichia Coli	200UFC/100ml	100 UFC/100ml	10.000 UFC/100ml	10.000 UFC/100ml
Suspended solids	20mg/l	20mg/l	35mg/l	35mg/l
Turbidity	10UNT	10UNT	No fixed limit	15UNT
Legionella spp.	1000UFC/l	1000UFC/l	100UFC/l	100UFC/l
Other criteria		It is mandatory to carry out the detection of pathogens: Presence / Absence (Salmonella)		

So, here are the criteria established by the WHO ***"Guidelines for the safe use of wastewater, excreta and greywater"*** comparatively with ***RD1620/2007***.

It can be seen that the criteria laid down by WHO, are not as stringent as those laid down in RD 1620/2007.

Microbiological parameters

WHO establishes several categories of use as options A through H, as shown in the following table. Category A is the least restrictive, with maximum E. coli 1000CF/100ml and includes sports fields and public parks. As can be seen, is much less restrictive than the RD 1620/2007, that the most restrictive (urban irrigation) sets a limit of 200UFC/100ml of Escherichia coli.

Table 8.2 - Checking and monitoring of E.Coli for different degrees of wastewater treatment (A to H). Source: WHO.

Table 2.5 Verification monitoring[a] (*E. coli* numbers per 100 ml of treated wastewater) for the various levels of wastewater treatment in Options A–G presented in Figure 2.1

Type of irrigation	Option (Figure 2.1)	Required pathogen reduction by treatment (log units)	Verification monitoring level (*E. coli* per 100 ml)	Notes
Unrestricted	A	4	$\leq 10^3$	Root crops
	B	3	$\leq 10^4$	Leaf crops
	C	2	$\leq 10^5$	Drip irrigation of high-growing crops
	D	4	$\leq 10^3$	Drip irrigation of low-growing crops
	E	6 or 7	$\leq 10^1$ or $\leq 10^0$	Verification level depends on the requirements of the local regulatory agency[b]
Restricted	F	3	$\leq 10^4$	Labour-intensive agriculture (protective of adults and children under 15 years of age)
	G	2	$\leq 10^5$	Highly mechanized agriculture
	H	0.5	$\leq 10^6$	Pathogen removal in a septic tank

[a] "Verification monitoring" refers to what has previously been referred to as "effluent standards" or "effluent guideline" levels.

[b] For example, for secondary treatment, filtration and disinfection: five-day biochemical oxygen demand (BOD_5), <10 mg/l; turbidity, <2 nephelometric turbidity units (NTU); chlorine residual, 1 mg/l; pH, 6–9; and faecal coliforms, not detectable in 100 ml (State of California, 2001).

As for nematode eggs in all crops and irrigation, except for one, the high growth of crops where there is not recommendation, WHO recommends the maximum 1 egg per liter, as shown in the two tables below, being less restrictive than the RD 1620/2007.

Table 8.3 - Sanitary objectives for wastewater use in agriculture. Source: WHO.

Table 3.3 Health-based targets for wastewater use in agriculture

Exposure scenario	Health-based target (DALY per person per year)	Log_{10} pathogen reduction needed[a]	Number of helminth eggs per litre
Unrestricted irrigation	$\leq 10^{-6}$ [a]		
Lettuce		6	≤ 1[b,c]
Onion		7	≤ 1[b,c]
Restricted irrigation	$\leq 10^{-6}$ [a]		
Highly mechanized		3	≤ 1[b,c]
Labour intensive		4	≤ 1[b,c]
Localized (drip) irrigation	$\leq 10^{-6}$ [a]		
High-growing crops		2	No recommendation[d]
Low-growing crops		4	≤ 1[c]

[a] Rotavirus reduction. The health-based target can be achieved, for unrestricted and localized irrigation, by a 6–7 log unit pathogen reduction (obtained by a combination of wastewater treatment and other health protection measures); for restricted irrigation, it is achieved by a 2–3 log unit pathogen reduction.

[b] When children under 15 are exposed, additional health protection measures should be used (e.g. treatment to ≤0.1 egg per litre, protective equipment such as gloves or shoes/boots or chemotherapy).

[c] An arithmetic mean should be determined throughout the irrigation season. The mean value of ≤1 egg per litre should be obtained for at least 90% of samples in order to allow for the occasional high-value sample (i.e. with >10 eggs per litre). With some wastewater treatment processes (e.g. waste stabilization ponds), the hydraulic retention time can be used as a surrogate to assure compliance with ≤1 egg per litre.

[d] No crops to be picked up from the soil.

Table 8.4 - Sanitary objectives for wastewater use in agriculture. Source: WHO.

Table 2.4 Health-based targets and helminth reduction targets for treated wastewater use in agriculture

Type of irrigation	Health-based target for viral, bacterial and protozoan pathogens	Microbial reduction target for helminth eggs
Unrestricted	$\leq 10^{-6}$ DALY per person per year[a]	≤1 per litre (arithmetic mean)[b,c]
Restricted	$\leq 10^{-6}$ DALY per person per year[a]	≤1 per litre (arithmetic mean)[b,c]
Localized (e.g. drip irrigation)	$\leq 10^{-6}$ DALY per person per year[a]	(a) Low-growing crops:[d] ≤1 per litre (arithmetic mean) (b) High-growing crops:[d,e] No recommendation

[a] The health-based target can be achieved, for unrestricted and localized irrigation, by a 6–7 log unit pathogen reduction (obtained by a combination of wastewater treatment and other health protection measures); for restricted irrigation, it is achieved by a 2–3 log unit pathogen reduction.

[b] When children under 15 years of age are exposed, additional health protection measures should be used.

[c] An arithmetic mean should be determined throughout the irrigation season. The mean value of ≤1 egg per litre should be obtained for at least 90% of samples in order to allow for the occasional high-value sample (i.e. with >10 eggs per litre). With some wastewater treatment processes (e.g. waste stabilization ponds), the hydraulic retention time can be used as a surrogate to assure compliance with ≤1 egg per litre.

[d] High-growing crops include fruit trees, olives, etc.

[e] No crops to be picked up from the soil.

Physicochemical parameters

The WHO recommends for use restriction degree low to moderate a range of suspended solids, about 50 to 100 mg/l, being less restrictive than RD 1620/2007 as shown in the following table. In terms of the turbidity, the table above recommended maximum value 2 UNT.

In terms of conductivity, in the ranges recommended by the WHO, the values are between 0.7 and 3 dS/m, and the range recommended by WHO for total nitrogen is between 5 and 30 mg/l, as can be seen in the following table.

Table 8.5 - Recommendations quality for water reuse as restrictiveness of use and irrigation mode (sprinkler irrigation, surface irrigation, drip irrigation). Source: WHO.

Table A1.1 Water quality for irrigation

Parameter		Units	Degree of restriction on use		
			None	Slight to moderate	Severe
Salinity EC_w[a]		dS/m	<0.7	0.7–3.0	>3.0
TDS		mg/l	<450	450–2000	>2000
TSS		mg/l	<50	50–100	>100
SAR[b]	0–3	meq/l	>0.7 EC_w	0.7–0.2 EC_w	<0.2 EC_w
SAR	3–6	meq/l	>1.2 EC_w	1.2–0.3 EC_w	<0.3 EC_w
SAR	6–12	meq/l	>1.9 EC_w	1.9–0.5 EC_w	<0.5 EC_w
SAR	12–20	meq/l	>2.9 EC_w	2.9–1.3 EC_w	<1.3 EC_w
SAR	20–40	meq/l	>5.0 EC_w	5.0–2.9 EC_w	<2.9 EC_w
Sodium (Na^+)	Sprinkler irrigation	meq/l	<3	>3	
Sodium (Na^+)	Surface irrigation	meq/l	<3	3–9	>9
Chloride (Cl^-)	Sprinkler irrigation	meq/l	<3	>3	
Chloride (Cl^-)	Surface irrigation	meq/l	<4	4–10	>10
Chlorine (Cl_2)	Total residual	mg/l	<1	1–5	>5
Bicarbonate (HCO_3^-)		mg/l	<90	90–500	>500
Boron (B)		mg/l	<0.7	0.7–3.0	>3.0
Hydrogen sulfide (H_2S)		mg/l	<0.5	0.5–2.0	> 2.0
Iron (Fe)	Drip irrigation	mg/l	<0.1	0.1–1.5	>1.5
Manganese (Mn)	Drip irrigation	mg/l	<0.1	0.1–1.5	>1.5
Total nitrogen (TN)		mg/l	<5	5–30	>30
pH			Normal range 6.5–8		
Trace elements (see Table A1.2)					

TDS, total dissolved solids; TSS, total suspended solids
Sources: Ayers & Westcot (1985); Pescod (1992); Asano & Levine (1998).
[a] EC_w means electrical conductivity in deciSiemens per metre at 25 °C.
[b] SAR means sodium adsorption ratio ($[meq/l]^{1/2}$); see section A1.5.

Table 8.6 - Recommended maximum concentrations of elements for crop irrigation.

Source: WHO.

Table A1.2 Threshold levels of trace elements for crop production

Element		Recommended maximum concentration[a] (mg/l)	Remarks
Al	Aluminium	5.0	Can cause non-productivity in acid soils (pH <5.5), but more alkaline soils at pH >7.0 will precipitate the ion and eliminate any toxicity.
As	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.
Be	Beryllium	0.10	Toxicity to plants varies widely, ranging from 5 mg/l for kale to 0.5 mg/l for bush beans.
Cd	Cadmium	0.01	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans.
Co	Cobalt	0.05	Toxic to tomato plants at 0.1 mg/l in nutrient solution. Tends to be inactivated by neutral and alkaline soils.
Cr	Chromium	0.10	Not generally recognized as an essential growth element. Conservative limits recommended due to lack of knowledge on its toxicity to plants.
Cu[b]	Copper	0.20	Toxic to a number of plants at 0.1–1.0 mg/l in nutrient solutions.
F	Fluoride	1.0	Inactivated by neutral and alkaline soils.
Fe[b]	Iron	5.0	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum. Overhead sprinkling may result in unsightly deposits on plants, equipment and buildings.
Li	Lithium	2.5	Tolerated by most crops up to 5 mg/l; mobile in soil. Toxic to citrus at low concentrations (<0.075 mg/l). Acts similarly to boron.
Mn[b]	Manganese	0.20	Toxic to a number of crops at a few-tenths to a few mg/l, but usually only in acid soils.
Mo	Molybdenum	0.01	Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum.
Ni	Nickel	0.20	Toxic to a number of plants at 0.5–1.0 mg/l; reduced toxicity at neutral or alkaline pH.
Pd	Lead	5.0	Can inhibit plant cell growth at very high concentrations.
Se	Selenium	0.02	Toxic to plants at concentrations as low as 0.025 mg/l, and toxic to livestock if forage is grown in soils with relatively high levels of added selenium. Essential element to animals, but in very low concentrations.
V	Vanadium	0.10	Toxic to many plants at relatively low concentrations.
Zn[b]	Zinc	2.0	Toxic to many plants at widely varying concentrations; reduced toxicity at pH >6.0 and in fine textured or organic soils.

Source: Adapted from Ayers & Westcot (1985); Pescod (1992).

[a] The maximum concentration is based on a water application rate that is consistent with good irrigation practices (5000–10 000 m^3/ha per year). If the water application rate greatly exceeds this, the maximum concentrations should be adjusted downward accordingly. No adjustment should be made for application rates less than 10 000 m^3/ha per year. The values given are for water used on a continuous basis at one site.

[b] Synergistic action of Cu and Zn and antagonistic action of Fe and Mn have been reported in certain plants species' absorption and tolerance of metals after wastewater irrigation. If the irrigation water contains high concentrations of Cu and Zn, Cu concentrations in the tissue may increase greatly. In plants irrigated with water containing a high concentration of Mn, Mn uptake in the plants may increase, and, consequently, the concentration of Fe in the plant tissue may be reduced considerably. Generally, metal concentrations in plant tissue increase with concentrations in the irrigation water. Concentrations in the roots are usually higher than in the leaves (Drakatos, Kalavrouziotis & Drakatos, 2000; Drakatos et al., 2002; Kalavrouziotis & Drakotos, 2002).

The following table summarizes the requirements of Real Decreto 1620/2007 and WHO guidelines and criteria finally adopted on the water quality for irrigation in Praia.

To maximize ease of operation and optimize the necessary infrastructure, it is proposed a single criterion of quality for water reuse, to be applied in all possible applications.

Table 8.7 - Quality of reclaimed water in Praia.

PARAMETERS	MAXIMUM ALLOWABLE VALUE FOR MORE LIMITED USES (AGRICULTURAL)	RECOMMENDED MAXIMUM VALUE	MAXIMUM ADOPTED VALUE
	RD 1620/2007	WHO	
Intestinal nematodes	1egg/10l	1egg/1l	**1egg/10l**
Escherichia Coli	100UFC/100ml	1000UFC/100ml	**100UFC/100ml**
Suspended solids	20mg/l	50-100mg/l	**35 mg/l**
Turbidity	10 UNT	-	**10 UNT**
Legionella spp.	1000UFC/l	-	**1.000 UFC/l**
Conductivity	-	between 0,7 and 3 dS/m,	**between 0,7 and 3 dS/m**
Total nitrogen	-	between 50 and 30 mg/l	**between 50 and 30 mg/l**
Other criteria	**It is mandatory to carry out the detection of pathogens: Presence / Absence (Salmonella)**		

The use that determines the maximum adopted water quality will require the one that is more demanding with the maximum values (quality single criterion). This means that have to use the quality required in the use of agricultural irrigation (for urban gardens) to require the same in the reclaimed water at the point of delivery.

Notably, anyway, that for industrial use (use for making concrete) and to the use of ornamental plants most specific demands of legionella that has been adopted. It is proposed that when the value of Legionella in the reclaimed water exceeds 100 CFU / l applies even higher doses of hypochlorite in the tanks and in the WWTP irrigation as make sure to use for ornamental plants and the manufacture of concrete.

8.2 Frequency of sampling and analysis

Shall be conducted sampling and analysis of reclaimed water to ensure the water quality criteria. Monitoring shall take place at the outlet of the regeneration plant, and all delivery points in the irrigated areas and urban gardens. Also propose sampling and analysis in irrigation tanks.

The frequency of testing will be modified in the following cases:

1. After 1 year of control may submit a reasoned request to reduce the frequency of analysis up to 50%, for those parameters that are not likely their presence in the waters.

2. If the number of samples with a concentration lower than the maximum values adopted in the above table is lower than 90% of the control samples during a quarter (or fraction thereof, where lower operating periods) will double the sampling frequency for the following period.

3. If the result of a control exceeds at least one of the parameters of maximum deviation ranges set forth below, frequency control parameter exceeds the range of deflection will be doubled for the remainder of the period and the next.

4. The minimum frequency analysis according to RD 1620/2007 are specified in the following table:

Table 8.8 - Frequency analysis. Source: Decreto Real 1620/2007

USE	Intestinal nematodes	Escherichia Coli	Suspended solids	Turbidity	NT and PT	Other contaminants	Other criteria
URBAN	Biweekly	2 times per week	Weekly	2 times per week	----	The public agency responsible for the sanitation of the town assess the frequency of analysis on the basis of the discharge permit and reclamation treatment.	Monthly
AGRICULTURAL	Biweekly	Weekly	Weekly	Weekly	----		Biweekly
INDUSTRIAL	----	Weekly	Weekly	Weekly	----		Monthly

Now, it proposes the following analysis minimum frequencies for Praia and specified in the following table:

Table 8.9 - Frequency of analysis in Praia

USE	Intestinal nematodes	Escherichia Coli	Legionella	Suspended solids	Turbidity	NT and PT	Other contaminants	Other criteria
URBAN AGRICULTURAL INDUSTRIAL	Deposits - monthly; Delivery points - quarterly	Fortnightly in deposits and delivery points	Deposits - monthly; Delivery points - quarterly	Deposits - monthly; Delivery points - quarterly	Deposits - monthly; Delivery points - quarterly	Deposits - monthly; Delivery points - quarterly	The public agency responsible for the sanitation of the town assess the frequency of analysis on the basis of the discharge permit and reclamation treatment.	Biannual

It should be noted that in the WHO document "WHO Guidelines for the safe use of wastewater, excreta and grey water", does not specify precisely the periodicity and frequency of analysis, these will be referred to according to its intended use water regenerated.

The reclaimed water quality is assessed by analyzing samples taken systematically at all points of delivery of the same and with the minimum frequencies mentioned above.

This control should be rigorously applied because products are going to water for human consumption in peri-urban agriculture (urban gardens) with health risks that could be generated.

8.3 Conformity criteria

The quality of reclaimed water is considered to be appropriate to the requirements herein if in the analytical tests of a quarter, or fraction thereof if the period of holding is less, meets simultaneously:

1. The 90% of the samples have lower results than the maximum values adopted for all parameters specified above.

2. The samples taken exceed the maximum value specified above do not exceed the maximum deviation limits set out in the table below the maximum deviation limit parameter.

3. For the rest of the substances must ensure compliance with Environmental Quality Standards at the point of delivery of reclaimed water as law enforcement itself.

In the following table, are shown the parameter limit of maximum deviation, being the maximum deviation the difference between the measured value and the AMV.

Table 8.10 - Maximum deviation for the maximum value adopted in Praia

PARAMETER	*Limit parameter of maximum deviation*
Intestinal nematodes	100% of AMV
Escherichia Coli	1 log unit
Legionella	1 log unit
Taenia saginata	100% of AMV
Taenia solium	100% of AMV
Suspended solids	50% of AMV
Turbidity	100% of AMV
Nitrates	50% of AMV
Total nitrogen	50% of AMV
Total phosphorus	50% of AMV

8.4 Management measures against violations

Suspension of the reclaimed water supply shall be in cases that do not meet the criteria under 1 and 3 above.

If a control parameter exceeds a maximum deviation limits in the table above, will proceed with a second control at 24 hours. If this situation persists, supply shall be suspended.

The supply will resume when they have taken appropriate steps with regard to the treatment so that the issue does not happen again, and have found that the reclaimed water meets the maximum values adopted for four successive days' checks.

In previous non-compliance will apply frequency modification under control of the minimum frequency trials in Praia.

8.5 Samples analysis

Are proposed as a reference or guide the following methods or analytical techniques, everything and those alternative methods may be used provided they are validated and give results comparable to those obtained by the reference.

Table 8.11 - Method of analysis of the samples (microbiological)

MICROBIOLOGICAL PARAMETER	***Limit parameter of maximum deviation***
Intestinal nematodes	Method Bailenger modified by Bouhoum & Schwartzbrod. "Analysis of wastewater for use in agriculture", Ayres & Mara WHO (1996)
Escherichia Coli	Bacterial Count Glucuronidase, positive Escherichia coli
Legionella	ISO 11731 Part 1: 1998 Water Quality. Detection and enumeration of Legionella.
Taenia saginata	-
Taenia solium	-

Table 8.12 - Method of analysis of samples (parameters contaminants)

CONTAMINANTS	***Analytical methods and reference techniques***
Suspended solids	Gravimetry with glass fiber filter
Turbidity	Nephelometry
Nitrates	Molecular absorption spectroscopy
	Ion Chromatography
Total nitrogen	Total Kjeldahl nitrogen, nitrate and nitrite
	Autoanalyzer
Total phosphorus	Molecular absorption spectroscopy
	Plasma spectrophotometry
Dangerous Substances	Chromatography
	Spectroscopy

8.6 Global Regulatory Reuse

As reference, are proposed global policies that are cited in Annex I, to develop a quality normative for reclaimed water and uses, and also a municipal water quality normative for Praia.

9. Regulation and good practice using

The irrigated areas irrigation may be done with reclaimed wastewater from Praia's itself WWTP that, not being potable, have sufficient quality for this purpose, thus avoiding using water intended to be used for public consumption. But this reuse may involve a health risk if not followed a series of preventive measures and health guarantees.

This water must meet microbiological and physic-chemical quality requirements that are specified in the Annex I of water quality and get an authorization or concession for use. Minimum health criteria are possible to avoid the potential risks of exposure to biological and chemical agents they may contain.

Table 9.1 - Quality criteria for water reuse according to their uses (irrigation of urban green areas)

Maximum Admisible Value				
USE	*URBAN*	*AGRICULTURE*		*INDUSTRIAL*
	URBAN GREEN ZONE IRRIGATION (PARKS, SPORTS FIELDS AND SIMILAR)	APPLICATION WATER SYSTEM ON CROPS THAT ALLOWS DIRECT CONTACT OF REGENERATED WATER WITH THE EDIBLE PARTS FOR HUMAN CONSUMPTION	ORNAMENTAL CROPS	OTHER INDUSTRIAL USES
Intestinal nematodes	1egg/10l	1egg/10l	1egg/10l	No fixed limit
Escherichia Coli	200UFC/100ml	100 UFC/100ml	10.000 UFC/100ml	10.000 UFC/100ml
Suspended solids	20mg/l	20mg/l	35mg/l	35mg/l
Turbidity	10UNT	10UNT	No fixed limit	15UNT
Legionella spp.	1000UFC/l	1000UFC/l	100UFC/l	100UFC/l
Other criteria		It is mandatory to carry out the detection of pathogens: Presence / Absence (Salmonella)		

The purpose of this suggestion, the document of *Best Practices Manual* is made available to the citizens of Praia, users of urban gardens, maintenance and city county workers, information and patterns of behavior to adopt according sanitary and environmental type necessary to avoid potential risks mentioned above.

The manual of good practice is a manual that should be a tool for all actors involved in the reuse of water (from the managers and operators of the same and users):

- Expressly prohibits the reuse of treated water for human consumption as well as for bathing and cooking.
- Ensures that the reclaimed water is used with minimal risk or with acceptable risks from two points of view: health first, and secondly environmental.

- Allows to user and operator reuse the water undoubtedly without negative legal and health consequences.
- Allow it to enhance the positive environmental impacts of reuse.

9.1 Good practice in the network and sewerage system

The municipality should be responsible for self-control and collect and record in a book:

- Discharges to the sewer.
- The sewerage network and collectors.
- The malfunction announcements
- Inspection.

9.2 Good practice in purification, depuration and regeneration

The municipality or agency in charge of water purification and regeneration should be responsible for control, collect and record in a book:

- Purification (primary and secondary treatment);
- Regeneration (tertiary treatment);
- System reliability by self-control;
- Malfunction notices;
- Flow measurement;
- The quality of the effluent and affluent;
- System inspection.

Maintenance should be planned so that depuration avoid reducing the quality of the effluent and to proceed in accordance with the system of regeneration, through preventive maintenance when there is no reuse, or providing storage periods or by giving notice to the regeneration process not to use the effluent during maintenance or breakdowns.

The treated and reclaimed wastewater must meet quality criteria according municipal technical normative for reclaimed water use established by the local agency.

It should be noted that the treatments prior to the regeneration process may affect its poor functioning. Its malfunction usually affects both disinfection and water quality.

The health authority or water manager must signal the ultraviolet disinfection areas with preventive posters.

It should verify that the facilities and equipment are kept clean during the regeneration operation of the equipment. Must check visually the effluent at the outlet of the regeneration plant. Also be performed microbiological and physicochemical analysis.

Avoid overconfidence, without objective data to prove it. The cleaning and disinfection activities should be recorded.

Flag, delimit and restrict work areas, reducing exposure times.

9.3 Good practices in reuse: storage, use and distribution

The agency responsible for the storage of reclaimed water in irrigation tanks and distribution, maintenance of the distribution and use of water should be responsible for managing, controlling, and collect and record in a book:

- Malfunction notices.
- Measurement of flow rates and pressures in the delivery points (droppers), thereof its shutter.
- The quality of water in reservoirs and delivery points.
- System inspection.

Due to agricultural and urban activities (urban irrigation irrigated) certain disinfectants used in irrigation tanks (which are storage tanks and distribution). In several different points of the distribution can be managed to improve the quality of the reclaimed water. In the same tanks eutrophication checks must be done, so as to supply water to be made suitable extraction processes.

It should verify that the facilities and equipment are kept clean during the operation of the equipment. It should be inspected visually losses in distribution network. Also be performed microbiological and physicochemical analysis.

In addition, the reclaimed water is transported from the WWTP to irrigation tank or from an irrigation tank to another or directly to the sectors in the case of long distances, residence times in canal systems or pipes that are of hours. Therefore, the transport system is as a reactor in which reactions can occur favored by biofilms formed on the walls of the channel or carrier pipe. This biofilm must be properly maintained and that failure to comply may alter water quality, reduced transport capacity or leakage problems appear in the pipes.

The control of biofilm that may arise should be controlled through manholes and vent systems at specific points in the network.

Ensure that the pipes are closed so there is no contact between the water and any user, operator or general population.

The layout of the pipes should be such as to ensure that there is no possibility of connection to the urban water supply network.

The municipality should signal associated infrastructure reclaimed water by the color violet, must dial covers manholes, tanks and associated infrastructure so as to facilitate the public, user and maintenance worker, identification and maintenance.

Figure 9.1 - Manhole covers of reclaimed water; source: Aqualogy Aqua Ambiente

Figure 9.2 - Reclaimed water pipe in a trench; source: Aqualogy Aqua Ambiente

There must be a good situation analysis to identify and prioritize potential problems against insect pests or rodents by passive techniques that create physical barriers that prevent access. Also with good hygiene practices can avoid these problems.

The Municipality must continuously control the chlorination system and detect leaks by the visual checks or by the flow meters installed on the network.

The Municipality should perform remote control system as well as all functional operating equipment (pumps, valves, and meters).

Flag delimit and restrict work areas, reducing exposure times of maintenance workers.

9.4 Good practices in the application of water to irrigate

Once applied reclaimed water in irrigated areas and urban gardens, according its reuse, water, substances and organisms are dispersed in the environment. These can occasionally be dangerous for people and watered the plants themselves.

9.4.1 General and information

Should have a proper monitoring of the application of water, mainly in urban gardens where irrigation products obtained are for human consumption (for food). Must have a health check of reclaimed water use, especially in those areas of application where children and elderly live.

The population must have full knowledge of the use of reclaimed water (on the remainder of irrigated green areas). They must be informed of the type of water to use for watering and the risks they may entail.

Users must have knowingly accepted the use of reclaimed water (concerning urban gardens). They must be informed of the type of water used, and the risks they may entail. In addition, users must have an authorization / allowance for reclaimed water irrigation and irrigation methods training and gathering with reclaimed water to avoid health problems.

It is recommended that workers, before they are allowed to work on wastewater reuse, aware of the possibility of disease transmission reclaimed wastewater and the precautions to be taken in this regard. Everyone who is related to the reuse must maintain a high level of caution as there is always the possibility of equipment failure or human error. They must have done a training course to learn how to manipulate water, aspects of risk prevention, preparedness in case of malfunction and communication and alarm systems.

In no one case, wastewater reuse won't be used outside the areas for which they are authorized.

9.4.2 Design and Implementation

The municipality should signal associated infrastructure to reclaimed water by the color violet, must mark manholes tops, hydrants and associated infrastructure so as to facilitate the public, user and maintenance worker identification and maintenance.

Figure 9.3 - Covers of reclaimed water; source: Aqualogy Aqua Ambiente

Figure 9.4 - Reclaimed water pipe in the irrigation area; source: Aqualogy Aqua Ambiente

Must be expressly prohibited reuse of treated water for human consumption as well as for bathing, cooking and washing clothes. The population, users and maintenance workers should be informed that it can't be used for these applications.

The City should update network maps of water (water supply and reused).

The reclaimed water pipes must be adequately separated from potable water pipes to prevent leakage or loss that may enter through cracks in water pipes. If it's near, special protections should be arranged.

The entire system of sewage pipes has different color from piping system water for public consumption. If two water systems must be installed so that it is impossible a return of treated wastewater to the water system for public consumption.

The design of the secondary distribution network should limit the most severe changes of direction as well as the stalemate, as they are conflict points for water quality.

The network must have mechanisms to close the network in phases and sectors, to isolate areas behind anomalous situations

9.4.3 Signals

In addition, the municipality must signal areas that are irrigated with reclaimed water to prevent thefts and prevent health problems. The population, users and maintenance workers should be informed by signaling the area. Signs should be placed in visible places, the letters should be large enough to be read from a distance with the following information: "*REGENERATED*

WATER NOT FOR HUMAN CONSUMPTION" or "*RECLAIMED WASTEWATER, DO NOT DRINK*" or "*DANGER, NO DRINKING WATER*". Should also be signs such as "*REGENERATED WATER NOT FOR HUMAN CONSUMPTION*, DON'T SWIM".

Figure 9.5 - Prohibition signs by source: Aqualogy Aqua Ambiente

Figure 9.6 - Information signs source: Aqualogy Aqua Ambiente

All valves, and / or droppers should be adequately marked to warn that the water is not potable or safe for drinking or bathing, they must only to be used by authorized personnel.

Vehicles carrying water for concrete must be marked by signs and corresponding symbols, preferably in the driver's door and the rear of the tank. Should be noted that the water is not suitable for human consumption.

9.5 Irrigation system: rational, efficient and thrifty use of water

Localized irrigation systems are the most appropriate to use treated wastewater. On the one hand, plants do not come into direct contact with the water and also to keep the area wet bulb always wet, plants have available water continuously, which decreases the occurrence of problems of salinity. On the other hand, is the safest method from the point of view of management, as neither the person responsible for irrigation neither the users of the irrigated area have risks of contact with water.

In no case wastewater will be reuse outside the areas for which it is authorized.

It should be inspected visually and make a verification that the uses and users are the authorized, and to make a watered plant control and irrigation water appearance. Also be performed microbiological and physicochemical analysis.

The municipality must ensure adequate water quality at the point of delivery for use.

The irrigation system in the plots will be located by drip, preferably buried, as they are the most efficient and recommended irrigation systems. It is a system to avoid water-plant contact and the contact person-plant, because it is a system practically closed that doesn´t generates aerosols. Irrigation should be applied so as not to form aerosols.

It is necessary to install very good filtering systems to avoid internal shutters, and use products to prevent entry of rootlets by emitters. Another option is the use of self-compensating emitters and anti-suction, i.e., droppers ensuring a flow within a given pressure range and which carry a device that prevents the entry of particles into the interior, and which largely avoids shutters of the drippers and get a good irrigation.

Figure 9.7 - Integrated drippers, punctured, interlining. Source: “Manual de riego de jardines de la Junta de Andalucía”.

Make a good maintenance program and a good drip emitter's selection, considering some factors such as the minimum diameter of passage, design or type of emitter to install. For example, emitters of low flow (less than 16 l / hour) at increased risk of shutter by having a smaller water passage diameter. As the minimum diameter, the shutter sensitivity of the emitters will be, according the *Manual de riego de jardines de la Junta de Andalucía*:

Table 9.2 - Shutter sensitivity. Source: Manual de riego de jardines de la Junta de Andalucía.

Minimum Diameter (mm)	*Obturation sensivity*
ϕ_{min}	
$\phi < 0{,}7$	**High**
$0{,}7 \leq \phi \leq 1{,}5$	**Medium**
$\phi > 1{,}5$	**Low**

Biological shutters are produced by the accumulation of algae, bacteria and plant remains in the irrigation network, which usually happens when the irrigation water remains stagnant in pools, ponds or tanks before being used for irrigation. Biological shutter risk is greater when irrigation is done with treated wastewater. In both cases as a preventive measure should chlorinate water with sodium hypochlorite, taking special care when watered crops are sensitive to chlorine.

In drip irrigation facilities, it is important to perform a pipe cleaning and after completion of the installation work of the system and before start watering, leaving the ends of all pipes open during the estimated time to clean any plastic waste and debris generated within the network during installation. Regardless of irrigation method used, a good maintenance of the facility goes through a check of all components, since the filters to irrigation emitters, through valves, sensors, automation, electrical cables, and so on.

Valves, hydrants and drippers must be the kind that can only be manipulated, operated and used by authorized personnel.

It is recommended to use driving action procedures and pipe connection *'mouth'* different from those that are used to water supply. Avoid outdoor faucets facilities of reclaimed water with other non-potable water.

Use low pressure drip systems, with large holes to occur and produce big water droplets and prevent the formation of aerosols.

In all irrigation systems with reclaimed water, when there are long periods of non-use pipes must be emptied.

Whenever possible, avoid the channels and the conduction pipes at outdoor irrigation systems.

Seek to maintain safe recommended distances in the application of reclaimed water, as can be seen in the following table:

Table 9.3 - Recommended systems. Source: Manual de Buenas Prácticas de uso de Aguas Regeneradas (2011) de la Asociación Española de Abastecimientos de Agua y Saneamiento.

Instalación	Método de aplicación	Distancia en m.	Observación
Pozos de captación comunitarios de aguas potables	Cualquiera	50	Si no hay protección se debe doblar la distancia
Pozos privados para abastecimiento	Cualquiera	30	Si no hay protección se debe doblar la distancia
Sumideros	Todos excepto localizado	50 (localizado 25 m)	Conectados con acuíferos o aguas subterráneas
Aguas superficiales (ríos, lagos)	Todos	30	Detectar escorrentía
Zonas próximas a Viviendas o patios de viviendas	Aspersión o microaspersión	50	Excepto si hay cortavientos
Vías de comunicación	Aspersión o microaspersión	15	Excepto si hay cortavientos
Límite de propiedad	Cualquiera	10	Excepto si hay cortavientos y no hay escorrentía

The maintenance managers must have technical project documentation relating to the irrigation system with the plan of completion of the work (*As-built*) where all components are identified to facilitate quick location in case of breakdowns or malfunction.

Must perform shutter and pressure controls of the drippers, by inspecting and cleaning them. Shutter of the emitters, due to the presence of suspended solids in the recycled water, is a drawback is resolved with the cleaning and maintenance.

The Municipality should avoid crop waterlogging of urban gardens and plants, shrubs and trees of the irrigated areas using drip irrigation. Should be minimized, as much as possible, the contact with the population.

Prevent surface runoff protrude from the intended area to irrigate, usually vegetated surface (garden area, irrigated plot). Can minimize puddling or runoff if watered properly and the emitters are placed suitably so that the water will not stop impervious surfaces such as roads or streets.

Avoid wet the people and, if necessary, establish buffer measures with screens or obstacles that limit the spreading.

Avoid making irrigation and maintenance in the hottest hours of the day and on windy days.

In any public access irrigated area irrigated with water, supply points must be equipped with locking devices and protection against vandalism. For protection of the emitters, some protection systems used are as follows:

- Devices on the basis of the emitters to prevent removal.
- Protectors of the regulatory mechanisms of the nozzles to prevent accidental or intentional mismatch of these.
- Stainless steel elevators that provide resistance to the emitters, against possible shocks.
- Use of collars in the body of the emitters.
- Use protective covers with locking screw.
- Systems enable the installation of the transmitters under the ground level, at shallow depth (1.5 cm).
- Screws for fixing the protection cover to the body of the emitter.

Buried the items of irrigation systems, as in the case of integral pipe used for located underground irrigation also provides some protection against vandalism, since not be visible, decreases the risk of suffering malicious damage.

To protect water taps, regulators, valves, meters, and so on, recessed manholes are often used. Small vessels are manufactured in plastic materials such as polypropylene, polyethylene and PVC. These manholes have protection mechanisms such as locks or security screws, which allow setting the cap to the manhole, preventing theft or mishandling of the items they contain inside. Among the existing models, highlighting the circular and rectangular manholes.

To keep control of the water consumed with the irrigations is very useful to measure the volume of water actually applied. This is achieved by installing water meters at strategic locations in the network.

Avoid material and water thefts, of the reclaimed water network.

The municipality must make the remote control system as well as all operating equipment (gate valves, hydraulic valves, filters, and water meters).

It is convenient to group the plants (create hydro zoning) according requirements of the water or similar water needs to facilitate the irrigation system economy, both as garden plants as urban gardens.

Watering is more effective if done first thing in the morning or evening, the insolation is less and reduce evaporation losses and automated. Furthermore, there is no influx of population during the evening. Schedule irrigation, so that have enough time so that it can dry before the population has access to irrigated areas.

Use native plants for the garden, which are adapted to the local climate and require much less water to survive.

In the gardens with localized drip irrigation systems, water should be applied in small amounts and with high frequency, that is, give a large number of irrigation, in which water intake is reduced in each of it. Thereby, attempting to maintain the water content in the soil at nearly constant levels and avoids large fluctuations in moisture. Thus, water in the soil will be permanently in optimal conditions to be extracted by the plant, but at a reduced volume, so that the soil will occupy a more important role as a physical support for the plants and water storage.

In the case of tree-gardens, the water application of high frequency can create problems anchoring root system to the soil, drought or outages (failures in the network, works in an area near the garden, etc.). Therefore, in these cases it will be more interesting to apply lower irrigation frequencies and higher endowments in order to increase the volume of the wet bulb and root depth.

In drip irrigation systems, water affects and influences only a portion of the ground, the closest to the roots, so that prior to the selection of the number, flow rate and disposition of emitters, should establish a minimum soil volume wet by them, to allow proper development of plants and anchoring to the floor, because this volume is very small to the roots.

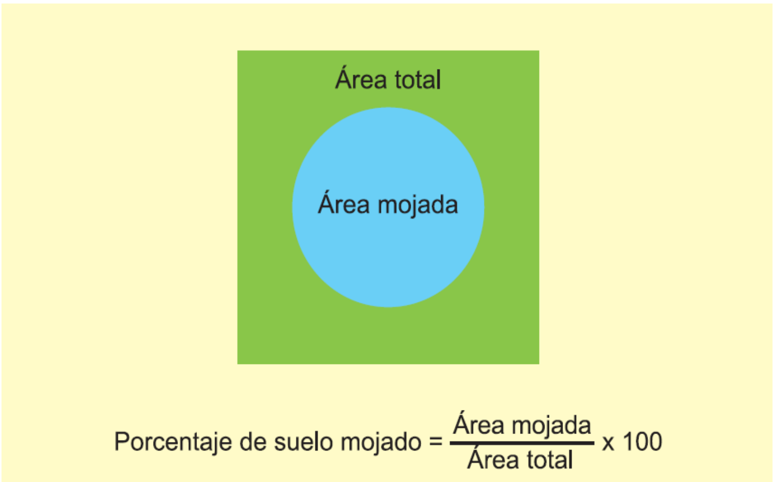


Figure 9.8 - Wet area. Source: Manual de riego de jardines de la Junta de Andalucía.

A surface irrigation system is that employing issuers pipelines, installed on the soil surface, creating a continuous strip of moistened soil. The pipes issuers used dripping pipes and pipe exuding. In the case of employing drip irrigation emitters, can also achieve a continuous web of moisture playing with the distance of the emitters in the lateral pipe. This practice is customary in watering hedges.

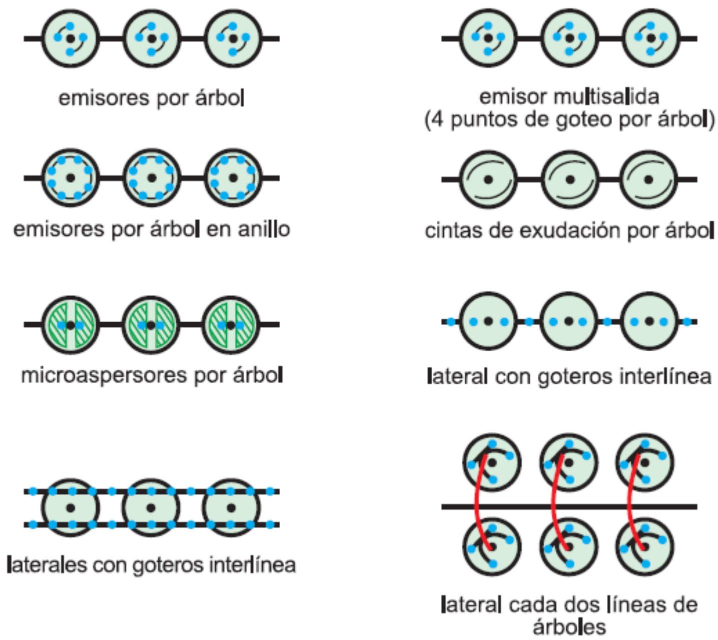


Figure 9.9 - Frequent provisions of the trees irrigation emitters. Source: Manual de riego de jardines de la Junta de Andalucía.

About the irrigation process, it is essential:

- Checking the time and watering frequency.
- Must conduct regular uniformity assessment process of irrigation. The process of evaluating a drip irrigation system includes the study of the uniformity with which they are applying irrigation water. A low uniformity would lead to a poor distribution of water with garden areas receiving excess nutrients and water, which would be to deficit areas, resulting primarily in an unacceptable landscape aesthetic. To evaluate the uniformity of the irrigation of a sector by choosing a certain number of uniformly distributed emitters that depend on the size of the installation, the number of branches and the length thereof.
- Controlling leakage or malfunction of the irrigation system.
- Controlling odors from water applied.

- Avoid accidental discharges.
- Fix and repair immediately breaks. Carry out maintenance and periodic inspection of leaks and breaks.
- Periodically, and at least once every six months, the entire system will be reviewed.
- The user should not have access to the connection or modify the internal distribution system.

9.6 Risk prevention, health and safety

The population, users and maintenance workers should wash with clean water immediately if contact with the reclaimed water. In case of contact with eyes, must be seen a doctor.

Wash hands after handling any element of the irrigation network. There must be first aid kits in areas of use, so that any small wound can be treated quickly to prevent infection.

It is recommended that all workers who come into contact with reclaimed wastewater during your work day to change clothes and wash well after finishing work and before leaving the area of use.

Do not bring food to these areas, not eat, drink or smoke while watering.

Everyone who comes into contact with reclaimed wastewater must have followed a training course that explains the health risks of reuse.

For maintenance workers, have gloves, clothing and footwear specific for irrigation.

Give to maintenance workers exposed, training in occupational risk prevention and appropriate immunizations and medical examinations at least every year.

Undertake studies and training related to the use of reclaimed water.

Not be allowed, in any case, the population, users and maintenance workers with bare feet during irrigation.

9.7 Risks and sanitation prevention

The following, are all possible risks and is performed the execution of a risk analysis and determine control measures for all phases of good sanitation practices.

Table 9.4 - Table of risks, persons exposed to risks and considerations to take into account for prevention. Source: WHO Guidelines for the safe use of wastewater, excreta and greywater

Table 5.1 Major exposure points for the reuse of excreta and greywater

Risk activity[a]	Major exposure route	Groups at risk	Risk management considerations
Emptying the collection chamber/vessel (1–4)	Contact	Entrepreneurs Residents Local communities	Provision of protective clothing and suitable equipment for persons involved Training Facility should optimize on-site treatment Design of facility and selection of technology to facilitate safe emptying Avoid spillage
Transportation (1–5)	Contact Secondary spread through equipment	Entrepreneurs Local communities	Avoid spillage Equipment not used for other purposes without proper disinfection/cleaning
Off-site secondary treatment facility (1–3) Ponds (5)	Contact (all) Vectors	Workers Nearby communities	Ensure treatment efficiency Protective clothing Facility should be fenced off Ensure no access for children Consider and minimize vector propagation Exclude recreational activity and consider vectors (5)
Application (1–3, 5)	Contact Inhalation	Entrepreneurs Farmers Local communities	Use "close to the ground application," work the material into the soil directly and cover Reduced access should be ensured if quality is not guaranteed; in such cases, applications to parks, football fields or where the public have access should be avoided Protective clothing for workers Minimum one month between application and harvest
Crops Harvest Processing Sale (1–5)	Consumption Handling	Consumers Workers Vendors	Crops eaten raw pose the most risk; industrial crops, biofuels or crops eaten only after cooking pose less risk Adequate protective clothing (gloves, shoes) Provide safe water in markets for washing and refreshing vegetables
Consumption (1–5)	Consumption	Consumers	Practising good personal, domestic and food hygiene Cooking food thoroughly

[a] (1) Dry collection; (2) Faecal sludge; (3) Wet systems; (4) Urine; (5) Greywater.

10. Results and discussion

According to the methodology used in the analysis and the proposed study, taking into account the sustainable development of the city of Praia, which is intended to carry the full irrigation with reclaimed water of the city, must note the following:

Network of drinking water supply

- Production of drinking water for the network is insufficient to supply the current and future needs;
- The network doesn't cover the entire territory, which is usually supplied by tanks, boreholes and water sources;
- The network is undersized, in poor condition and has considerable losses that reach close to 50%;
- There is a great imbalance between water availability among the population. The consumption of the population connected to the network is 10 times greater than domestic consumption fueled by tanks. However, the consumption of drinking water is low: 70 l / inhab.day network water and 6 l / inhab.day water tanks;
- Lack responsible for monitoring the quality of drinking water production: quantity and quality;
- High cost of drinking water, 2.5 € / m^3 for domestic use and 5.3 € / m^3 for tourist use.

Sanitation network

- Lack of the sewerage network in many city neighborhoods;
- Low binding percentage of the population to the sewerage network, both for the high cost of connection to the sewerage system and the lack of regulations;
- The existing network is not scaled for future connections of city neighborhoods;
- State conservation very poor and there are many leaks / loss of residual water;
- Lack of maintenance facilities and instrumentation, automation and control;
- Deficiencies in the design of the network (checkup many floods due to heavy rains since it is a non-separative network).

WWTP (Palmarejo)

- Built in 1997 and scaled with only primary treatment, had an enlargement in 2007, has a nominal capacity of 8.000 m^3/day and a tip of 14.000 m^3/day;
- However, the estimated flow that reaches the treatment plant is 1.500 m^3/day due to weak binding of the population to the sewerage network;
- With the implementation of the proposed improvements in the sanitation system is intended to achieve an estimated 2.500 m^3/day;

- Currently, the water leaving the treatment plant is discharged into emitter submarine is located on the beach and none of this water is harnessed;
- Possible seasonality in the flow and pollutant load due to tourism;
- Possible discontinuous emptying of septic tanks which impact the global affluent;
- Typology of the inflows from septic tanks, with high contents of dissolved and suspended solids, sand, grease, organic nitrogen and ammonia;
- The WWTP is not designed for the increased population and not binding to the sanitation network provided both in flow and pollutant loads and the water quality to be obtained;
- The condition of the existing facility does not meet the requirements for removal of nutrients;
- Do not recommended the discharge point on the beach;
- Lack of knowledge of buried pipes and possible obstructions;
- General deterioration of facilities: civil works, buildings, land development, electromechanical equipment, electrical installations, remote management;
- The pretreatment has deficiencies and is in disuse;
- One of the primary decanters is out of service and in poor condition;
- Biological treatment requires an automatic operational control as it is currently done manually;
- The conservation status of the lamellae of the secondary decanters is deficient;
- The sludge line is out of service;
- No analysis is performed throughout the treatment process.

Summary table of the phases and the design flow a) by source: Aqualogy Aqua Ambiente

Phase	Sub-phase	Design Flow (m^3/day)
1	1.1	142,36
	1.2	596,65
	1.3	22,25
	1.4	86,94
	1.5	100,89
	1	**949,09**
2	2.1	959,57
	2.2	842,93
	2	**1.802,50**
3	**3**	**2.074,55**
	TOTAL	**4.826,14**

Measurement of water needs:

Calculation of the water needs of plants by method Blanney Criddle (FAO)

WATER NEEDS	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	TOTAL
ET (mm/day)	4,48	4,43	4,15	3,19	3,18	3,26	4,20	4,45	4,70	4,86	4,49	4,34	
ET (mm/month)	134,29	137,44	124,54	99,03	98,47	91,39	130,18	133,61	145,60	145,78	139,08	134,63	
Rainfall (mm/day)	2,17	0,97	0,40	0,19	0,48	0,29	0,19	0,13	0,03	0,03	0,48	1,61	
Rainfall (mm/month)	65,00	30,00	12,00	6,00	15,00	8,00	6,00	4,00	1,00	1,00	15,00	50,00	
Effective Rainfall (mm/day)	1,73	0,77	0,32	0,15	0,39	0,23	0,15	0,11	0,03	0,03	0,39	1,29	
Kr	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	
Net Needs = ET x Kr- Effective Rainfall	1,18	2,11	2,38	1,92	1,68	1,89	2,57	2,79	3,03	3,13	2,53	1,53	
Efficiency of the irrigation system, Ea	0,8	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	
Gross Needs = Net Needs / Ea (mm/day)	1,47	2,34	2,64	2,14	1,86	2,10	2,86	3,10	3,36	3,48	2,81	1,70	
Net Needs (m³/ha·month)	352,86	653,37	713,51	595,72	520,07	530,01	798,16	836,49	938,38	939,56	784,04	475,09	8.137,26
Gross Needs (m³/ha·month)	441,07	725,97	792,79	661,92	577,85	588,90	886,85	929,43	1042,64	1043,95	871,15	527,88	9.090,41

WATER NEEDS	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
Irrigation Area (ha)	92,46	92,46	92,46	92,46	92,46	92,46	92,46	92,46	92,46	92,46	92,46	92,46
Gross Needs (m³/month)	40781,63	67123,00	73301,09	61200,79	53428,30	54449,40	81998,03	85935,23	96402,91	96523,79	80546,98	48807,82
Gross Needs (mm/day)	135,94	216,53	244,34	197,42	172,35	194,46	264,51	286,45	310,98	321,75	259,83	157,44
Hours of irrigation per day (h/day)	8,00	8,00	8,00	8,00	8,00	8,00	8,00	8,00	8,00	8,00	8,00	8,00
Days of irrigation per month (day/month)	30,00	31,00	30,00	31,00	31,00	28,00	31,00	30,00	31,00	30,00	31,00	31,00
Needed Gross Flow (l/s)	15,73	25,06	28,28	22,85	19,95	22,51	30,61	33,15	35,99	37,24	30,07	18,22
Needed Gross Flow for irrigation (l/s)	47,20	75,18	84,84	68,55	59,84	67,52	91,84	99,46	107,98	111,72	90,22	54,67

SWOT analysis:

S

Existing potential;

Prioritizing the political level of the water sector;

The water in the center of the cooperation policy;

The introduction and massification of modern irrigation technologies;

Currently, a 547.500 m³ / year of treated water that is poured into the sea;

W

Some negligence in the recovery of surface waters;

The lack of technical skills in the water superficial;

The large energy dependence and its intrinsic relationship with the high cost of treated water;

Some institutional uncertainty on the issue of wastewater treatment;

Anthropogenic actions that compromise the operation sustainable management of water resources;

O

Increased agricultural and industrial production;

Fight against poverty;

Decreasing pressure on groundwater and surface water resources;

Job creation;

The programs of medium and long-term recovery of waste water;

Massification of micro irrigation;

Better use of available water resources;

T

Lack of hydrological data;

Absence of specific know-how;

Large financial resources;

Psychological and cultural resistance;

11. Conclusions

The high cost of drinking water, lack of current availability of adequate resources to supply quality and environmental goals of the City Council necessitate the reuse of treated water.

Given the objectives of expanding the supply network to the entire population, to expand the production capacity of water and given the expected urban growth, it is estimated that not only increase the population served but endowments (l / inhab.day) of water increase, therefore a significant increase in flow and pollutant loads to the sewer system are expected.

All this justifies the need for an expansion of treatment capacity and the type of process and to undertake profound improvements in all contexts.

Skinny network coverage of sanitation and poor condition of the WWTP, along with forecasts of population growth and the strategic areas of PDM, make necessary a series of actions aimed at:

- Expand the network to expand sanitation services to the population (Phase 3 Sanitation Project of the European Union provides a connection only 30% of households to the network).
- Design of the sewerage hydraulic capacity to meet current and future needs, considering the increases in line with the forecasts of growth.
- Make a separate system of sewage and rainwater, as far as possible.
- Perform actions to reduce impacts on episodes of intense rainfall.
- Implement policies for connecting the entire population that has sewage (outside the scope of this project).

In view of the diagnosis made, actions to be implemented in the WWTP are:

- Improve the treatment process to ensure at all times the quality requirements at the outlet of the WWTP (after tertiary treatment).
- Commissioning optimal operation of existing facilities of the WWTP, as required by the process.
- The solution must be sustainable over a long period of time, especially during the irrigation period of the irrigated areas and urban gardens.
- Implement a new tertiary treatment. The tertiary treatment must always ensure the quality of reclaimed water.
- Perform analytical control of water at the outlet of tertiary treatment, to guarantee its quality.
- Implement a system of regulation and distribution of water regenerated for reuse.
- Implement system automation and control system of the regeneration and reuse.

The current state of maintenance and operation of the WWTP hinders the operation of future tertiary treatment.

This master plan reuse is linked to the connection to the sewerage system to cover the maximum treatment capacity of the WWTP.

The realization of the connection to the sewerage system must be coordinated with the development stages of the study and the planned investment.

Reuse can be a factor for economic improvement over access to water for the community.

Due to the experience developed in similar situations, the establishment of a tariff system for the reorganization debugs and reuse might bear the economic costs that relate to the planned investment and operation of the facility.

The proposed reuses technologies are fully developed in the study are reliable and guaranteed the quality of the effluent according to the intended use.

The use of reclaimed water needs a legal framework to ensure the health control.

Should perform the training of good practice to the user. It's very important that users realize that the recycled water is a safety feature, quality and budget.

To ensure the determination of water quality, the quality parameters should be determined by its use and maximum values are also required according to their use. Suggest the sources listed in Annex I to determine the parameters adopted quality as well as the control system frequency analysis:

Maximum Admisible Value				
USE	URBAN	AGRICULTURE		INDUSTRIAL
	URBAN GREEN ZONE IRRIGATION (PARKS, SPORTS FIELDS AND SMILAR)	APPLICATION WATER SYSTEM ON CROPS THAT ALLOWS DIRECT CONTACT OF REGENERATED WATER WITH THE EDIBLE PARTS FOR HUMAN CONSUMPTION	ORNAMENTAL CROPS	OTHER INDUSTRIAL USES
Intestinal nematodes	1egg/10l	1egg/10l	1egg/10l	No fixed limit
Escherichia Coli	200UFC/100ml	100 UFC/100ml	10.000 UFC/100ml	10.000 UFC/100ml
Suspended solids	20mg/l	20mg/l	35mg/l	35mg/l
Turbidity	10UNT	10UNT	No fixed limit	15UNT
Legionella spp.	1000UFC/l	1000UFC/l	100UFC/l	100UFC/l
Other criteria		It is mandatory to carry out the detection of pathogens: Presence / Absence (Salmonella)		

USE	Intestinal nematodes	Escherichia Coli	Suspended solids	Turbidity	NT and PT	Other contaminants	Other criteria
URBAN	Biweekly	2 times per week	Weekly	2 times per week	----	The public agency responsible for the sanitation of the town assess the frequency of analysis on the basis of the discharge permit and reclamation treatment.	Monthly
AGRICULTURAL	Biweekly	Weekly	Weekly	Weekly	----		Biweekly
INDUSTRIAL	----	Weekly	Weekly	Weekly	----		Monthly

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Annexes

Annex I – Regenerated water quality normative and uses

In depth and selective analysis of the existing literature, oriented to the objective, and with a high level of critical spirit, should be noted that in Cape Verde there is no specific regulation of water quality criteria for irrigation reuse. Therefore, the sources to determine the quality criteria to reuse water in irrigation schemes in Praia are:

<ins>WORLD HEALTH ORGANIZATION</ins>

- **WHO Guidelines for the safe use of wastewater, excreta and greywater.**

<ins>SPAIN</ins>

- **Real Decreto 1620/2007 de 7 de diciembre, BOE núm. 294, Sábado 8 diciembre 2007 (by establishing the legal framework for the reuse of treated water).**
- **MMAMRM (2010): Ministerio de Medio Ambiente y Medio Rural y Marino. Guía para la aplicación del R.D. 1620/2007 por el que se establece el Régimen Jurídico de la Reutilización de las Aguas Residuales, Madrid.**

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<ins>PORTUGAL</ins>

- **Instituto Português da Qualidade (IPQ, 2005). NP 4434 Norma Portuguesa sobre reutilização de águas residuais urbanas tratadas na rega. Caparica, Portugal.**

<ins>FRANCE</ins>

- **Journal Officiel de la République Française (2010). Arrêté du 2 août 2010 relatif à l'utilisation d'eaux issues du traitement d'épuration dees eaux résiduaires urbaines pour l'irrigation de cultures ou espaces verts. J.O. du 31 août 2010. Texte 32 sur 157, France.**

<ins>UNITED STATES</ins>

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- **US EPA (2004). Guidelines for Water Reuse, EPA 625/R-04/108, EPA, Washington DC, USA.**

AUSTRALIA

- **NRMMC-EPHC (2006). Australian Guidelines for Water Recycling: Managing Health and Environmental Risks. Natural Resource Management Ministerial Council and the Environment Protection and Heritage Council.**

GREECE

- **Greek Common Ministerial Decision (CMD, no 145116 (354B)/08.03.11) (2011). Measures, Limits and Procedures for Reuse of Treated Wastewater. Ministry of Environment, Energy and Climate Change, Athens, Greece (in Greek).**

Annex II – Photographic trace *(“in situ”)*

Figure 6.9 - Neem tree (Azadirachta indica)

Figure 6.10 - Cactácea (Echinocactus grusonii), aloe vera (Aloe barbadensis), Drago (Dracaena draco)

Figure 6.11 - Palm tree (Trachycarpus fortunei), bougainvillea (Bougainvillea spp.) and bush

Figure 6.12 - Neem tree (Azadirachta indica), Cactaceae (Mauhueniopsis), aloe vera (Aloe barbadensis)

Figure 6.13 - Aloe vera (Aloe barbadensis), Palm trees (Phoenix atlántica)

Figure 6.14 - Palm tree (Phoenix atlántica) and bush

Figure 6.15 - Pita (Agave lurida), Higuera chumba (Opuntia ficus-indica), Cactaceae (Mauhueniopsis)

Figure 6.16 - Cactaceae (Echinoccactus grusonii) and Cactaceae (Myrtillocactus)

Figure 6.17 - Palm tree (Trachycarpus fortunei), drago (Dracaena draco), Cactaceae (Carnegiea gigantea) and bush