INTERNATIONAL JOURNAL OF
ENERGY AND ENVIRONMENT

Volume 8, Issue 1, 2017 pp.83-96
Journal homepage: www.IJEE.IEEFoundation.org

Water implications in Mediterranean irrigation networks: Problems and solutions

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Received 28 Sep. 2016; Received in revised form 25 Nov. 2016; Accepted 4 Dec. 2016; Available online 1 Jan. 2017

Abstract
Agriculture is a significant user of water and energy in Mediterranean coasts of Europe, such as Spanish Mediterranean regions. Water implications of such irrigations are well known but there are many problems that must be taken into account when designing each phase of the irrigation system, not only in the construction phase but in the exploitation, control and maintenance of all the elements in the network. All the possible problems in each part of the irrigation system will be analyzed in the following paper, proposing several solutions to avoid these problems or mitigate its consequences. These solutions go from the simple maintenance of pipes and valeus to the implementation of more sophisticated systems, such as SCADA, or management strategies, such as benchmarking.

Keywords: Irrigation systems; Mediterranean region.

1. Introduction
The Mediterranean irrigation presents several singularities, due to the economic conditions, the energy demands, the wide variety of customs in each group of irrigators, topography, and definitely, its specific weather conditions, typical of a semi-arid zone; where the water shortage is the major constraint to agricultural production in areas with a Mediterranean climate [1].
The irrigation systems are designed so that they can fulfil certain requirements, without forgetting the economic issues (subsidies, low-medium costs). The main requirement is that water must reach each irrigator with the pressure and flow demanded. To reach this goal, water pressure systems must be implanted with a correct design.
These hydraulic infrastructures are formed by several parts whose aim is to capture, store, regulate, treat (if this is necessary), and transport the water from its source to each hydrant or off –takes of every plot, including in the design of each element the importance of complying the requirements mentioned before. Therefore, these elements can be structured in:
- Pretreatment (This parts is not always necessary)
- Storage and/or regulation structures
- Distribution
- Regulation
- Control, regulation, protection and manoeuvre elements

- Irrigation in plot
- Exploitation management

The design, calculation, execution and use of the different phases mentioned before, are essential to define the irrigation system's behavior. In this article, we will describe many of the main problems in each phase of the system, analyzing its causes and possible solutions.

2. Specific problems

Figure 1 shows the main problems concerning each phase of an irrigation network are shown.

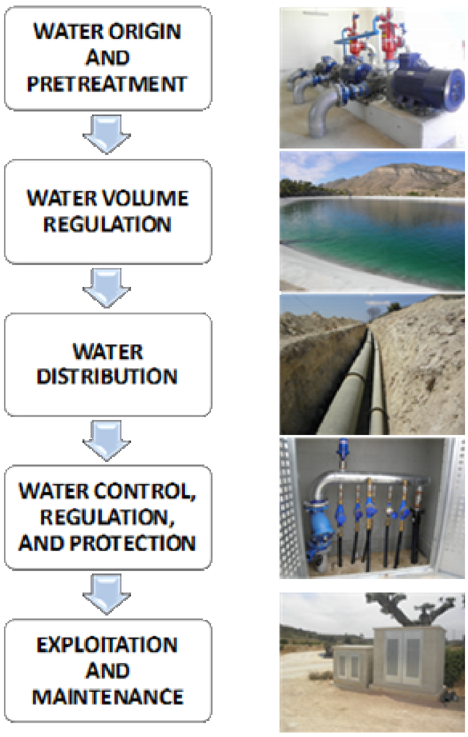

Figure 1. General problems in irrigation networks.

2.1 Water extraction (origin) and pretreatment

The resource can be captained from different origins, which in the Mediterranean zone are normally: water well, surface water and/or waste water. As the problematic can be different in function of the origin, the main problems according to them are enumerated below. In water wells, descent of levels and marine intrusion are the main problems. The descent of piezometric level causes an increase of consumed energy in order to extract water. When marine intrusion is the problem, the increase of salinity can cause the pollution by salts in the soil, being necessary to leach salts to avoid the contamination of the terrain [2]. In surface water, the main problem is irregularity and availability of the resource, which causes the need of major volume regulations and uncertainty in the planning of crops. This uncertainty can be due to basin plans (e.g. Tajo-Segura Transfer) or to irregular precipitations. At the same time, the main problem of waste water is the existence of contaminant elements (e.g. heavy metals, bacterium) and high conductivity, being necessary tertiary and desalation treatments.

The presence of a pretreatment phase also depends on the source of water, so it is not always necessary in the irrigation network. Normally, if the water comes from surface water (i.e. rivers, ravines, open flow channels) or if the water is residual, it should be treated.

Raw water may present two principal problems:

1) Inert elements in suspension: Sometimes, depending on the waters' origin, it is necessary to design decanters, filters, desanders or grilles, to stop organic or inorganic contaminants from getting into the network, negatively affecting the functioning of elevation, filtration, control, and regulation devices. In many cases, the accumulation of suspended solids requires the design of mechanic extraction systems, reducing problems derived from clogging and consequently reduction of the total capacity of the tank.

The origin of obstructions may be physical, chemical or biological, depending again on the waters' origin. In deep ground water for example there may be a large quantity of salts that may form incrustations in pipes' walls, whilst in surface water bacteria and algae may be the main problem.

Physical obstructions are caused by solid particles with a mineral origin (mainly sand) or organic particles (plant remains). Limes and clays do not usually cause obstruction, unless they flocculate forming larger aggregates.

At the same time, biological obstructions are caused by the development of the bacteria that, when it combines with mineral particles or algae under certain favorable conditions, aggregates are formed, and this may obstruct the installation.

At last, chemical obstructions are caused by the precipitation of soluble solids. These precipitates are formed due to changes in water temperature, pressure, pH, redox potential, concentration of other elements, and volume of CO_2, O_2 and SH_2 dissolved in water [3].

2) Biotic matter: In this phase of the irrigation system, the main problem is the possible existence of living forms in the water reservoir. In the Spanish Mediterranean zone, one of the most serious problems is the zebra mussel in the Ebro's river basin [4]. This specie is causing major problems in sealing pipes and regulation valves in the coastline zone of Spain (i.e. Cataluña, Valencian Comunity and Murcia).

In the case of residual water, as mentioned above, sometimes tertiary and desalation treatments are necessary. The process needed to transform residual water to clean water is called regeneration and the result of this process is regenerated water. It consists in regenerating the water to its initial conditions, the ones it had before utilizing it. So, when regenerating water, two aspects have to be taken into account: quality levels in the treated effluent should be defined depending on the final use of the water, and the treatment needed to reach these quality as well as the quality level limits should be defined.

In general, the lower the restrictions associated to contact between people, animals or comestibles products and water, the higher the quality level demanded to the regenerated water. Therefore, in case of irrigation networks the quality level demanded is not so restrictive and in the majority of cases the only treatment needed is one to avoid the obstruction of drip emitters. Nevertheless, sometimes crop specifications implies harder treatments.

In regeneration water projects, it has been found out that the distribution to the final user is the most expensive part of the project. Meanwhile the cost of the treatment plant and manouvre and exploitation costs are relatively low in comparison.

On the other hand, desalation treatment is a typical solution in coastal zones. This technology has experienced a considerable boom over the last few years due to the technological progress obtained in the membranes used in the process of reverse osmosis although its use is low due to expensive cost of obtaining the resource.

While regenerated water presents low costs concerning the energetic consumption and the investment of the infrastructures, desalated water presents a higher cost in infrastructures and most importantly, a high energy consumption, which is one of the main problems of this technology [5]. This is shown in Table 1.

Table 1. Investment and energy consumption costs of several elements in the water resources management [5].

Alternative	Investment (€/m^3/year)	Amortization (years)	Consumption (kWh/m^3)
Regeneration (irrigation with no restrictions)	0.26	15-25	0.001-0.73
Regulation (without derivation)	1.9	> 100	-
Regulation (in aquifer)	0.83	25	-
Desalation sea water	3-4	5 (membranes) 25(other)	3.8-4.0

To reduce energy consumption in desalation plants, there are several techniques that could be implemented. For example, the brine of a desalation plant comes out of it with a high pressure, which is an important source of energy that is usually lost when discharging it. To avoid this, there are two methods used to recuperate energy of brines: Pelton turbines or pressure exchangers. At the same time, energy consumption can be also reduced by supplying the plant with renewable energies [6].

2.2 Water volume regulation
In the majority of existing irrigation systems, water tanks or reservoirs (Figure 2) have been designed and then constructed with the aim of storing and regulating the water extracted from the natural reservoir. These infrastructures are designed generally following two principles: first, the main aim is to design a reservoir with enough capacity to regulate volumes. Once this objective is reached, the second aim is to minimize as much as possible exploitation costs related to flow distribution. The search of these objectives causes a certain confusion in the design of the infrastructures total capacity and in the election of its localization [7].

Figure 2. An example of a water reservoir.

When defining total capacity, normally the criteria followed is to oversize the regulation volume. Despite this does not damage the irrigation system, it results in a high initial cost, hardly amortized. In the geographic zone of Valencia, capacity is related to the availability of the resource: available flow and continuity of the supply, irrigated surface and irrigations needs [8].
Concerning the localization, it is usual to locate these infrastructures in places with sufficient height, to enable a gravity irrigation system. To fulfill pressure and flow requirements, a minimum difference in height is required to ensure the minimum service pressure in the most unfavorable irrigation point, being normally 30 m water column (m w.c.) in drip irrigation. In many cases, this restriction is not respected, resulting in many operational problems due to low pressures in hydrants. In other cases, if the tanks' localization requires sensible environmental zones, it would be more reasonable to locate the tank in a lower level, foreseeing the installation of a pump station to guarantee the systems' requirements. Definitively, this decision depends on many and different factors such as: people involved, customs, public administration, environmental impact, and economic situation [9]. At the same time, environmental issues represent a very important factor in the design of nowadays infrastructures, where project developers aim to make them "energy efficient" and "sustainable".

2.3 Distribution network
When designing the distribution network, many aspects must be taken into account to allow a good operation of it and to avoid negative consequences. First, the operation management, which can be schedule or on-demand. Once the type of operation is defined, the design of the networks' pipes can be performed, being determined by the calculation of the circulating flows in each line. If irrigation network operates by schedules, the circulating flow is determined according to opened number of irrigation points downstream in the most unfavorable schedule. When the irrigation network operates by demand, different methods can be used. For the study case of branched networks in which terminals are hydrants and where an excess flow valve is installed, the method described as the most effective in the calculation

of circulating flows is the Clément's Method [10, 11] which depends on some irrigation parameters (continuous unitary flow, degree of freedom, and guarantee supply) that should be correctly defined to achieve realistic results.

Either way, the flow in each plot off-takes is defined by the type of crop, the total surface, irrigation needs of crops and technical solutions planned for each plot (i.e. number of dropper for each plant, flow per emission device for a crop, number of plants per hectare). So, each irrigation project must calculate the diverse parameters that affect the networks' operation, avoiding future possible problems. The ultimate goal should be covering the water needs with maximum efficiency and uniformity, which requires a period of communication between irrigators and project designers before achieving a final design, and where the organization of irrigation methods, particular for each zone and customs, must be defined for the present and future, avoiding a premature obsolescence of the system. In order to achieve this other methods based on robust database [3] or computational neural networks [12], among others, can be used.

When designing the network, materials and protection devices must be carefully chosen, to avoid problems linked to breakage or collapse of the pipes, basically due to transitory phenomena originated by the operation of valves or by the variation of the functioning point of pumps [13]. Nevertheless, to avoid this problem not only the design must be correctly defined, but the operation of the network. At other times, the collapse of pipes is due to bad performance of the pipe's material or due to a bad execution. Cavestany [14] analyzed the collapse of pipes in irrigation networks in function of the material, concluding that pipes with polyester reinforced with glass fiber present a high break index by kilometer, if this material is compared with other types of material (i.e. PEAD, PVC, iron ductile). Some images of pipe installation are shown in Figure 3.

Figure 3. Construction of pipe ditches.

Generally, irrigation water presents several impurities that should be treated to avoid problems in the installation. These impurities can obstruct irrigators' issuers, so water must be filtrated to avoid these obstructions. There are two filtration levels. The first level corresponds with the general station of filtration, which is located inside the main pipe. After this first level of filtration, the second one corresponds to the filters installed in the head of the irrigation network in each irrigation points. There are many types of filters (Figure 4 shows one of them), depending on the problem that is being treated [3]:

- Hydrocyclone separator: it is not a filter; it is a sand separator. It is used to extract particles of higher density than water and it is installed before the pumping station, to protect pumps from the sand.

- Sand filters: they are also installed before pumping station and they are used to eliminate organic impurities such as algae, apart from small mineral particles.
- Ring filters: its effect is intermediate between sand and mesh filters, and they have become popular in the last years due to its ease to automatize its cleaning utilizing water pressure jets.
- Mesh filters: they perform a retention of particles in the surface of the filter, so they get very quickly clogged. For this reason, they are used to filter inorganic particles of not very dirty waters. Usually they are installed in irrigation head after injection of fertilizer. They do not work well when there is algae or organic matter as they become clogged very quickly.

The main problems in filters are: they become clogged very quickly, the complexity of its cleaning, low availability of spare parts for the filter elements and lack of regular cleaning. At the same time, another typical problem is an inadequate design of the filtration system due to ignorance of chemical and physical conditions in the influent, necessary degree of filtration, maximum and minimum flows, or final water flows requirements [15]. Other problem presented in the filters is the precipitate of different elements in your filtering elements (i.e. ring, mesh), being necessary the injection of chemical substance (e.g. peroxide for organic materia) to clean this element during the operate time.

Figure 4. Installation of filters to avoid the networks' obstruction.

When communitarian fertirrigation is carried out, the injection equipment of fertilizers has the function of mixing the fertilizer with the irrigation water. Good management of the fertilization system allows accurate distribution of fertilizer to the crop, avoiding additional works to the farmers and increasing savings in the exploitation costs. However, the communitarian fertirrigation is favorable if the irrigated area is similar in terms on: type of crop, age of crop, characteristics of soil, among others. As the previously cited terms are difficult to achieve in irrigation networks, sometimes these systems do not reach the expected prospects.

The causes of the problems in fertirrigation systems are linked to: absence of automatization (i.e. if the automatization installed in a collective fertigation system is not correctly designed, operations can't be optimized); poor design due to ignorance of certain initial data such as the requirements of the irrigable area, irrigation shifts, availability of fertilizer, their solubility and the availability of equipment (commercial or specific); and collective fertirrigation where the design of an injection, equipment and control systems have an inadequate capacity or an incorrect automation of the parameters which define the fertirrigation. These problems joint to the diversity of crops explain the inexistence of many installations, being the fertirrigation performed by the farmer in each irrigation point.

Finally, the flow distribution finishes in the hydrants (Figure 5) which are located in each plot if they are single-user. When hydrants are multiuser, the distribution finishes with the existing pipes which connect the hydrant with each plot. The adoption of multiuser hydrants or single-user, is a factor that it does not only define the network, but the possibility of automatize it. Hydrants ('single' or 'multi') contain the following elements: filtration (strainers), maneuver (cut valve), measurement (water meter box), and sometimes, control (pressure regulation valve) and pressure measurement (manometer). An example of a pressure regulation valve is shown in Figure 6 in the form of an air suction valve. If these elements are taken into account, the design with hydrants multiusers is more advantageous because in a same place, different control and measurement elements are installed, facilitating its reading, reparation and maintenance activities. Also, the multiuser hydrant allows the installation of remote-control, cheaper than single-user. However, in the Valencian Comunity (Spain), a high percentage of irrigation systems do not include regulation and control equipment in the general network but are individually installed in the sheds of the farmers as they are essential to ensure an efficient use of the available resources [7]. Besides, in on-demand networks the reading of water meter box is not automatic, being the opening of taps manual and decided by the farmer, due to aleatory character of the system.

Figure 5. An example of a hydrant.

Figure 6. Air suction valve.

The problems associated with hydrants are focused on: obstruction of filters, bad operation of measurement and regulation (if it exists) elements, and leakages in manifold. All problems can be detected when the operator visits the hydrant and is able to repair it. For this reason, the remote-lecture in water meter box is not generalized in these networks, as the operator not only checks the correct operation of the installed component in the hydrant but is able to take the reading. However, irrigation networks should include remote telemetry which allows technicians to know the state of each one of the variables which define the network (i.e. final supply, valves, pumping systems, among others) and to predict the system's performance. So, this allows a good operation of the system, the readjusting of demands, and the optimization of the energetic resource. Definitively, it involves a correct management of water resources.

Under an energetic and environmental point of view due to the deflection of water resources caused by climate change, energy consumption has increased to allow a better distribution from the tanks to the hydrants [16]. On this basis, the Kyoto Protocol on Climate Change and the Water Framework Directive define two objectives respectively: achieve a good environmental status in surface water and groundwater (meaning that water consumption and contamination must decrease) and reduce CO_2 emissions, improve energy efficiency and increase the use of renewable energies. To accommodate itself to this new situation, Spanish irrigation must achieve a better hydrological efficiency, increasing guarantee supply in drought seasons and reduce energy consumption by operating the pumps at their best efficient point or by replacing pressure systems with gravity systems. At the same time, in the particular case of Spain, energy consumption has increased due to the modernization of the irrigation networks: most of the networks have passed from being a gravity network to be a pressure system (localized irrigation or sprinkler irrigation), and consumed energy has increased in 627% since 1950 [17].

2.4 Control, regulation, protection and manoeuvre elements

Regarding to flow distribution, the drip irrigation network is characterized by distributing the necessary flow and pressure to farmers. The required flow is equal to the product of irrigation endowment and irrigation surface. When the network is measured, the designer establishes the upper limit of irrigation surface. If the plots' surface is greater than the irrigation surface established, it must be divided in sectors. Therefore, the flow is regulated indirectly by the irrigation endowment in each plot. Other times, when the network discharge is in open channel or reservoir, flow control valves are installed. The function of these valves is to avoid the collapse of the hydraulic infrastructure and to regulate the circulating flow in the network.

However, the regulation of pressure is always necessary in plots, as it must remain between 25 and 30 m w.c. Pressure can be regulated in: plots, hydrants, or networks' branch [18]. It is more difficult to regulate it in branches because the flow is very variable in this point. If we take into account this variability and the fact that in the majority of cases, there is a poor maintenance of the valves' regulation pilot, these conditions turn into exploitation problems.

Besides, networks include several types of valves (Figure 7), being the most numerous the cut valves which are located in main lines, branches, hydrants, and irrigation points. Other types of valves can be found: pressure reduction valves, excess flow valves, pressure relief valves, and pressure sustaining valves. The most identified problems in valves are: valve inoperability, inexistence of a hermetic seal, mechanical damage or theft of valve parts, or plugging of the pilot. These problems are usually solved by carrying out a proper maintenance, which must be performed with a greater frequency than in drinking systems as the water quality is worst in the irrigation network.

Figure 7. Valves are utilized to control, regulate and protect the network.

The case of pressure relief and excess flow valve is different because the difficulty is to fix the tar value (flow or pressure) in the valve. In pressure relief, low tar value can cause opening of the valve without it being necessary. In excess flow valves, which are installed to avoid loss of water when breakages occur, if the tar value is high, low breakages can happen, not being detected by the valve. The previously cited problems (inoperability, mechanical damage, plugging of the pilot) are shared by these valves too.

The selection, location and design of regulation elements require solid knowledge of the characteristics, performance conditions and limitations of these elements. A frequent error in the design phase, and during execution, is the no definition of the technical characteristics of these elements. This vagueness in the design can generate incorrect operation in the systems because not all hydraulic valves are the same, they differ in characteristics, performance and therefore, in price. One of the main reasons of valve problems is the inadequate selection and sizing of the equipment. In the case of pressure reduction valves, not only the definition of the circulating flows and regulatory pressures is decisive for the selection of the valve. On many occasions, trying to reduce costs, hydraulic valves are installed, that although they are suitable for operating functions (opening and closing) are not suitable for control functions (i.e. reduction or maintenance of pressure, flow limitation, among others). This implies that the valve should reduce pressure below certain predetermined values, under either the peak demand or the minimum demand, and should not affect the behavior of pipes and elements downstream.

Regarding automation, this must provide solutions to the real needs of the irrigable area. This equipment should be robust, reliable, adaptable and must include the possibility of integrating standard use equipment and software. In many occasions, automation equipments are under-utilized because the water managers do not count with the necessary training. This is the main reason for which the automation has not been installed in the majority of irrigation network. The automation is taking importance in the last years in pumped systems due to an increase of the price of electric energy. In this irrigation networks, the automatic start and stop of pumps by automata systems is very important to optimize the programmed pumped times, reducing the exploitation cost.

The manometers are the elements responsible for measuring water pressure in the irrigation network. They are extremely useful elements for controlling the installation as they let us know if the network is working at the right pressure and if there is any breakage. For example, by placing them properly in the filtering equipment, the plugging produced by suspended solids will allow us to see if they need to be cleaned. This element can be used to measure the transient pressures occurring in the network. In real networks, transient pressures of 80 m w.c. above the static pressure of the system have been registered. Regarding to pressure, incorrect operation of the pressure reduction valve introduces overpressures in the system, and these can reach values above 100 m w.c. These values have been monitored by authors of this research in real cases study.

The elements used to protect the installations are:

- In networks which distribution is by gravity, the protection is performed by pressure rating although sometimes pressure relief valves can be used to reduce overpressures. However, the pressures considered in the design of the network is the sum of the static pressure and a minimum of 40 m w.c. of overpressure.
- In networks which distribution is by pumped systems, the protection can be performed by pressure tanks, chimneys, or pressure ratings. The main problem of the pressure tanks is the decrease of the inflation pressure due to the lack of maintenance. When the protection is done by a chimney the main problem is the visual impact caused during its construction. Finally, when the pressure rating is the protections' method, a possible problem is the collapse of pipes by pressures below the atmospheric pressure.

Finally, control volume is necessary in the network in order to take decisions about its operation. The knowledge of the consumed volume in each irrigation point, provided the circulating flow along with the time in main line, is very important because this allows the development of hydraulic and energy audits in the network. The main problem of many networks is that all measurement elements are not installed. In some cases, only water meter boxes in each plot are installed and sometimes these are old, presenting high measurement errors. The majority of the networks do not have flowmeters installed in the main line to allow the recording of the injected flows. Not having them results in not knowing the networks' volumetric performance and so, water managers cannot account water losses such as: leakage, non-registered, evaporation in the reservoir, among others. If these volumes are known, water manager can take decisions to try to improve the hydraulic and energy performance of the network.

2.5 Exploitation and maintenance

The problems in the exploitation in irrigation networks are focused on two different parts: hydraulic and economic cost. The main hydraulic problems in irrigation system can be due to:

- Insufficient pressure in irrigation head in hour of maximum demand due to an incorrect design of the network. This mistaken design is motivated by: low irrigation endowment selected, low open probability, change of crop with greater irrigation needs, and/or by an incorrect application of the design method. This problem has a difficult solution: establishing irrigation schedules in period of maximum needs to mitigate the restriction. However, this solution restrains the farmers' control over the irrigation times.
- Reduction of the inside diameter of the pipe by precipitate of calcium carbonate. This precipitate is formed in period of low demand (velocity flow is lower or null) when water contains dissolved calcium and magnesium salts. In some cases, the reduction of diameter is very important, plugging the conduct completely. Currently, the perfect solution has not been found, because the currently used electromagnetic systems eliminate the precipitate but cause obstruction in the irrigation head.
- Obstruction of the filters of the irrigation head due to precipitated particle lime. When the precipitate of calcium carbonate has occurred and the flow in the pipe increases, the particles are detached,

causing the obstruction in the particular irrigation head. This problem can endure for a long period of time, if the number of irrigation points in operation is low. A possible solution is to put drainage points for the extraction of these particles before the start of the irrigation season.
- Other times, the lack of maintenance in valves can cause operational problems such as leakiness. In the case of cut valves this happens when they are incorrectly maneuvered and in the case of regulating valves (i.e. reduction, sustaining valve, excess flow valves) when they are incorrectly operated or the pilot is not cleaned.
- Related to air valves, lack maintenance or annulment of the same by the operation personnel, can cause overpressure by formation of air pockets.

The economic costs are derived from the idiosyncrasy of the agricultural sector, where the low incomes and advanced age of farmers causes an old-fashioned water management in the majority of the installations. Therefore, although many irrigation communities have modernized their installations, these do not maximize their performance, because in the majority of cases, water managers do not contribute with qualified personnel and strategies required to manage the facilities, reduce the economic costs and increase the hydraulic efficiency. In terms of efficiency in the distribution, to make audit in the networks it is necessary to know the leakages and their localization, therefore water meter boxes should be installed in the network as a first step. The development of an hydraulic audit allows the development of an energy audit. Minimizing energy costs is very important in on-demand irrigation networks, where the network works as a pumped system and so energy expenses are very high in comparison with the other types of irrigation management. The majority of networks share the following problems which generate economic costs:
- The leakages of flow which cause a loss of incomes to irrigation communities.
- As the measurement elements are not installed, leakages cannot be quantified and neither the water volume which is consumed but it is not registered.
- Normally, communities do not carry out maintenance and amortization policies of the infrastructures. This means that they cannot address the renovation of these installations, causing its aging.

For the first and second points, it becomes obvious the need to account leakages. To reduce them, several strategies can be implemented, which are related with the infrastructure maintenance. Among the multiple operation, they can be: to repair or substitute old pipes, installation of systems to achieve an active control of leaks and pressure regulations, maintenance of control elements (e.g. valves, flowmeter, air valves). To achieve an active control of leaks, several systems can be installed such as acoustic methods or SCADA (Supervisory Control and Data Acquisition), which allows a real-time system monitoring and the detection of possible anomalies in the network.

The volume of leakages are closely related with water prices. Water networks which are subsided by the government and have very low water prices, are unable to recover costs from network’s management and investment and so are unable to invest money in reducing water leaks. Spain has not defined a policy for water charges, but with the imminent reduction in funds and the European Water Framework Directive demanding for 2010 recovery mandatory costs, it is clear that the coming years will see a significant water price increase. This will result in a considerable improvement of all water networks. Figure 8 shows the difference in the water price if the total recovery cost are taken account (Denmark, United Kingdom and Germany) and if it is not taken into account, which is the case of Mediterranean regions (Greece, France and Spain).

The reservoirs used to regulate the demand flow in the network lack of maintenance and amortization. The consequence of this is that, currently, rafts which are waterproofed with geomembranes have aged geomembranes, being necessary its replacement as plastic properties no longer carry out their function. The derived problems of this aging are strongly related with the security of these structures, which can compromise the populations’ security as internal erosion may start in the raft, causing breakage thereof and generating a flood downstream. This phenomenon and its consequences, evaluation and delimitation flood area is explained by Sánchez-Romero [20], being the estimated cost to change waterproof membranes in Spain equal to one billion of euros, and this becomes necessary in at least 25000 reservoirs in Spain. This cost is so high because some rafts have more than 30 years old since they were built and have not received the necessary maintenance.

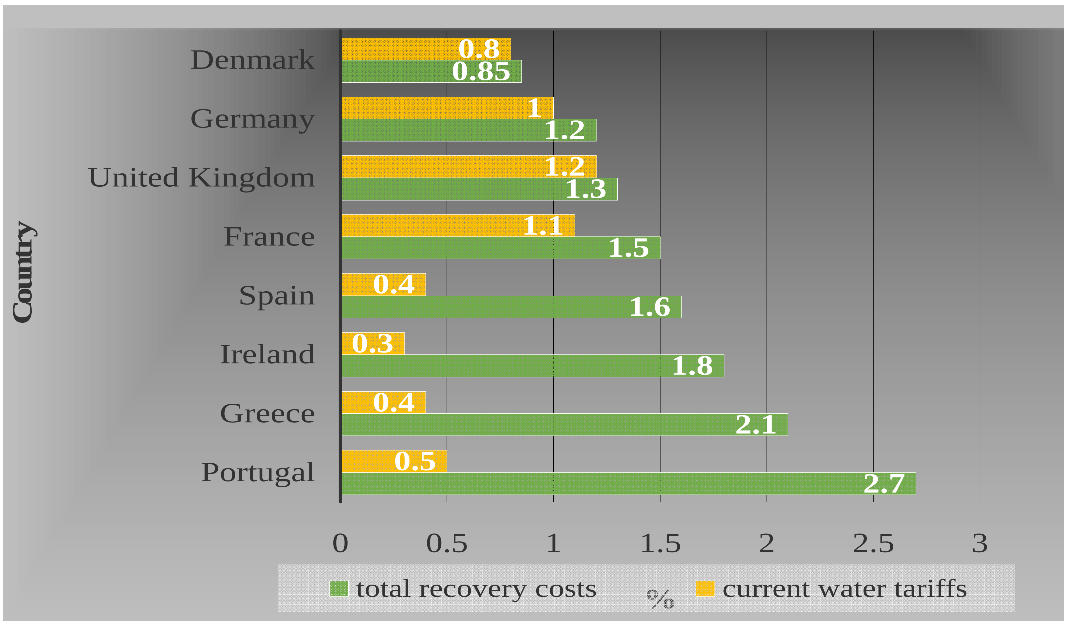

Figure 8. Current water tariffs versus tariffs with total recovery costs, related with the income per capita for each country adapted from [19].

If pipe and element are analyzed, they are in similar conditions to reservoirs, where a lack of maintenance is obvious. In Spain, there are networks which were built in the decade of the 80s and still, water managers have not performed maintenance works, except for the repair of pipe or valve breaks. Only in the case of pumped systems (Figure 9), irrigation communities have begun to replace them due to the need of improving their hydraulic efficiency and so, reducing the electric bill.

Figure 9. Examples of pumps.

Finally, several actions can be planned involving the management of the networks to improve the systems' performance. This final step is called the benchmarking of processes [21], which is defined as the tool or process to improve performance through systematic search and use of pioneering practices.
That is why it is important to emphasize the role of this tool in regulating the water, with the aim of gathering the best practices within the water industry and then adapt them and improve the hydraulic and

energy efficiency of processes continuously. So, it is necessary to have a manager focused on the efficiency of the system and not in the interests of service providers. In Figure 10, the basic concepts of the process of benchmarking are shown.

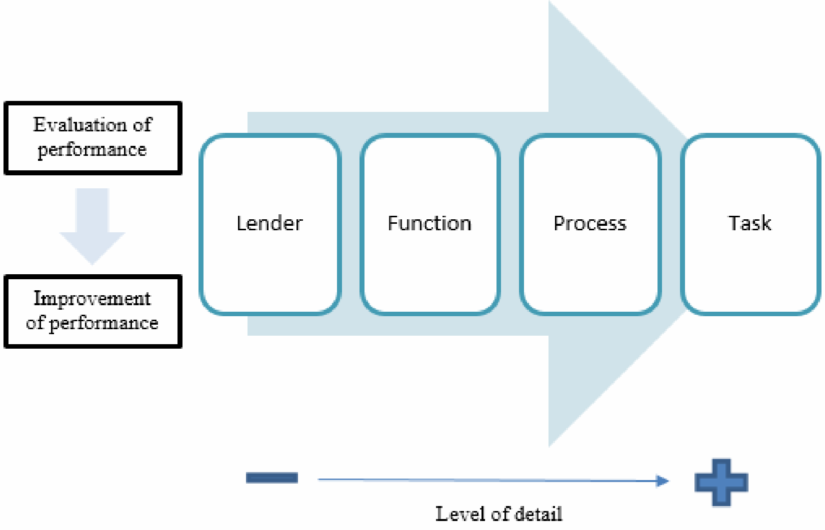

Figure 10. Evaluation and improvement of the performance model (Benchmarking) adapted from [21].

3. Conclusions

An irrigation network is formed by different elements and parts which must operate as a single system to develop the irrigation function for which it was designed. These parts have been enumerated and described in this document, enumerating the main problems that can occur in the exploitation system. Considering the possible solutions for these problems in future designs can contribute to improve the hydraulic and energy efficiency of these networks. The improvement of the efficiency is very important as it will contribute to increase the profitability of farms. Therefore, water managers are obliged to update its installations and therefore, reduce the exploitation costs. If these two objectives are reached, the irrigation networks will be more efficient and sustainable.

Acknowledgements

Authors greatly acknowledge financial support from the “Catedra Aguas de Valencia” in the grant “Modelling Irrigation Activity” for the first author of this contribution.

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