Sustainable Water Reuse in Portugal

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Abstract: - Portugal, like most of Mediterranean EU member states, regularly experience severe water supply and demand imbalances, particularly in the summer months. Half of Portugal mainland suffers of water deficit. Tourism is a very important economic activity in Portugal and is pushing water demand particularly in regions suffering of water deficit, like the Algarve. Golf courses are an important tourist factor contributing to water demand rising. A number of golf courses are installed in tourist areas and need high amount of water for irrigation. Water reuse is a very important management strategy in situations of water scarcity. Portugal badly needs to include treated wastewater as a dependable water in the nation water resources management. Safe water reuse requires guidelines. This standard presents guidelines on: water quality, irrigation practice, management of environmental impacts, protection of public and animal health and aspects of control and monitoring.

Key words: - Golf course, guidelines, irrigation, reuse, wastewater, water.

1 Introduction

Population growth, urbanisation, and industrial development are the main factors, which continuously increase water demand. Water shortage is a problem occurring in regions where low precipitation and high evaporation are observed simultaneously with increasing water demand. Portugal, like most of Mediterranean EU member states, regularly experience severe water supply and demand imbalances, particularly in the summer months. Half of Portugal mainland suffers of water deficit, because evapotranspiration exceeds surface runoff plus infiltration. Precipitation shows a wide seasonal variation - 66% of annual precipitation may fall in half of the year – and in some regions more than 30% may fall just in one single month. Consequently, a large part of the country shows water deficit along some months in an average year. This situation is aggravated in years of drought, such as it occurred in 2005 that possibly will become more frequent in the future, due to apparent climate change [1]. Tourism is a very important economic activity in Portugal and is pushing water demand particularly in regions suffering of water deficit, like the Algarve. Golf courses are an important tourist factor contributing to water demand rising. A number of golf courses are installed in tourist areas and need high amount of water for irrigation. In Europe, golf is growing at a 7% rate and has been growing at a 9% rate in Portugal since 2001. About half of the existing golf courses are located in the Algarve, a region suffering of water deficit.

The occurrence of water deficit means an obstacle to the social and economic development [2]. The increasing demand for water during the driest period induced by increasing needs of water for tourism and agriculture in that period, combined with the water quality degradation has lead to search for new alternative water sources.

2 Water reuse

2.1 Applications

Water conservation is the hydrological answer to the water deficit problem and water reuse is certainly a very important component of water conservation strategies [3]. Other solutions can be implemented such as water savings (e.g. suppressing the leakage of supply networks, using more efficient irrigation techniques such as drip irrigation and small flush systems), tapping other resources (e.g. desalinating seawater or brackish water) [4]. Reducing demand through pricing is also a possible option but it raises many political difficulties. Water can be reused for one or more beneficial purposes: irrigation for agriculture or landscape purposes, industrial supply, non-potable urban applications (such as street washing, fire protection), groundwater recharge, recreational purposes and direct or undirected water supply. Water reuse can have two important benefits. The most obvious is the provision of an additional dependable water resource. The second is the reduction of environmental impacts by reducing or eliminating wastewater disposal, which results in the preservation of water quality downstream. Therefore, when considered in the framework of an integrated water management strategy at catchments scale, the benefits of wastewater reuse should always be assessed taking into account that it contributes to both enhancing a region's water resource and minimizing its wastewater outflow.

2.2 Treated wastewater in Portugal

The growing number of municipal wastewater treatment plants observed in Portugal delivers about six hundred million m3 of mostly secondary and some tertiary treated wastewater that is discharged in river and coastal waters. In spite of treatment the discharge of treated wastewater still represents a pollutant load to receiving waters and simultaneously the waste of a water resource which could be successfully used for irrigation in agriculture, landscape, golf courses and water reservoirs for fire fighting.

2.3 Portuguese regulations for water reuse

Because water reuse can contribute to the economic development it must be stimulated by central, regional and local authorities, but within the framework of good practices and their monitoring. Portuguese authorities have been developing some regulations in order to create an adequate regulatory framework to enable the implementation of sustainable water reuse in Portugal. The major applications of water reuse in Portugal are agriculture and landscape irrigation, mainly golf course irrigation (Fig. 1). Therefore, priority was provided to water reuse for irrigation and a Portuguese standard on water reuse for irrigation - NP 4434 [6] - was produced by a committee appointed by the Portuguese Quality Institute (IPQ).

Guidelines on water reuse for other applications as well as for irrigation will be published in 2008 by the Portuguese Water Regulator Authority (IRAR).

Fig. 1 – Water reuse for golf course irrigation

3 Portuguese standard on water reuse for irrigation – NP 4434

Portuguese standard NP 4434 on the use of treated urban wastewater for irrigation was published in December 2005. This standard presents guidelines on: water quality, irrigation practice, management of environmental impacts, protection of public and animal health and aspects of control and monitoring. NP 4434 applies to agricultural irrigation (crops, forest, plant nurseries) and to landscape irrigation (parks, gardens, sport lawns such as golf courses).

3.1 Basis for establishment of Portuguese Guidelines on Water Reuse for irrigation

Although irrigation with wastewater is in itself an effective treatment (a sort of slow-rate land treatment), some treatment must be performed previously for the protection of public health, the prevention of nuisances during storage and prevention of damage to the crops [8,10]. In many circumstances the level of wastewater treatment licensed for discharging the tread wastewater in a receiving water body (usually secondary treatment) is appropriate to enable water reuse for irrigation. However, treated wastewater contains chemical and microbiological components which may induce a potential public health risk. Some chemical compounds dissolved in treated wastewater are nutrient to plants, e.g. nitrate and orthophosphate. However irrigation water can adversely affect plants growth by means of the absorption of phytotoxic substances through roots and leaves. Some elements tend to accumulate within parts of plants, sometimes reaching dangerous levels to animal health.

Microbiological quality of treated wastewater is the principal concern when considering reuse for irrigation. Most countries where water reuse is carried out have produced guidelines on the microbiological quality of reclaimed water for irrigation. The State of California was the pioneer and its wastewater reuse guidelines, first issued in 1918, have been adopted with more or less modifications in several North-American states as well as in other countries. Most of the existing regulations can be considered quite strict, in the sense that they require a high grade water quality, namely concerning the microbiological characteristics, only achievable by means of expensive technology requiring sophisticated operation. Such strict regulations based on a “no risk” philosophy could not be adopted by many countries badly needing to reuse wastewater for irrigation. The only options left in such countries were both undesirable: either no wastewater reuse for irrigation or wastewater reuse without any respect by unbearable regulations, meaning in practice wastewater reuse without any treatment or other sort of restriction, with all the consequent public health risks. Several studies carried out by some international organisations (World Bank, UNEP, UNDP, FAO, IRCWD, and IDRC) identified some contradiction in the requirements of water quality for irrigation and for other uses like bathing and lead to the conclusion that there was no justification for the stringency of most of the existing regulations on wastewater reuse (IRCWD, 1985). The consequence was that specialists were divided in what can be called two “schools”: the less stringent epidemiological evidence school (WHO) and the nil risk school, represented by the US [5]. The committee that produced the NP 4434 (CT 90/SC 3) considered that the guidelines should cover two main areas: (a) the agronomic aspects, related to the maximisation of crop yields and soil and groundwater preservation; and (b) the sanitary aspects, related to public health protection. The document should have the following general characteristics: (a) simplicity, to prevent unnecessary non-encouraging of wastewater reuse; (b) robustness and reliability, to ensure public health protection, good crop production, and to prevent adverse impact in the environment. Finally, the document should be flexible enough to allow for further improvement steps in the light of new scientific and technologic developments and acquired experience.

Guidelines can be defined in great detail or in a broad manner, such as a simple list of chemical and microbiological parameters whose values should range within a certain interval. This simple approach, however, presents a rather serious shortcoming: in most of the southern European countries, where wastewater reuse for irrigation is more necessary, the monitoring of effluent quality from wastewater treatment plants is not completely ensured, due to several factors, including lack of trained staff, available laboratories and financial reasons too. A second simple approach would consist of specifications for minimum treatment level required for certain irrigation purposes. For instance, not less than primary treatment should be authorised in any circumstances; only disinfected effluent would be allowed to irrigate raw eaten vegetables and sport lawns. This methodology is not satisfactory, however, because the operation of treatment plants is frequently unreliable in many areas and the effluent quality is unlike to correspond to the presumed level. A combination of both approaches, consisting of a reduction of the number of parameters to be monitored with some specification concerning the minimum treatment requested for certain irrigation purposes seemed to be a better methodology. The list of parameters for the monitoring of reclaimed wastewater quality for irrigation should include both chemical parameters with major agronomic impact and microbiological parameters affecting public health. However, these impacts depend on the agriculture practices, such as irrigation methods and relevant crops in the region, for example. Therefore, the committee found that the guidelines should be the interception of three factors: specification of limits for some chemical and microbiological quality parameters in combination with treatment specifications and field practices (crops and irrigation methods).

3.2 Quality criteria of treated urban wastewater for irrigation

The Portuguese decree nº 236/98 states in its Annex XVI the chemical quality criteria for irrigation water as MRV (maximum recommended value), which were adopted in NP 4434 and are presented in Tables 1 and 2. Concerning microbiological quality of irrigation water the Decree nº 236/98 [7] indicates that the water should contain no more than 103 faecal coliforms /100 mL and less than 1 helmynth egg/L.

Table 1 – Standards on salinity of irrigation water.

Parameter		Unit	MRL
Salinity	EC TDS	dS/m 25° C mg/L	1 640
R_{Na}		-	8
TSS		mg/L	60
pH		Sorensen	6.5 – 8.4

The rational for NP 4434 is based upon the principle that the required microbiological characteristics of irrigation water should be established taking into consideration the use of the irrigated plant (e.g. for food to be eaten raw by humans and animals, forest, industrial crop, sport lawns, etc.) together with the type of irrigation method.

Although every irrigation method was found acceptable for treated urban wastewater exception for overflow, NP 4434 recommends that preference is given to irrigation methods that limit contact between irrigation water and the plant, especially with the edible parts of the plant, and reduce the risk of runoff and spray generation and transportation by the wind.

Table 2 – Standard on chemical quality of water for irrigation

Element or ion	MRV (mg/L)	MPV (mg/L)
Aluminium (Al)	5.0	20
Arsenic (As)	0.10	10
Barium (Ba)	1.0	*
Beryllium (Be)	0.5	1.0
Boron (B)	0.3	3.75
Cadmium (Cd)	0.01	0.05
Lead (Pb)	5.0	20
Chloride (Cl^-)	70	-
Cobalt (Co)	0.05	10
Copper (Cu)	0.20	5.0
Chromium (Cr)	0.10	20
Tin (Sn)	2.0	*
Iron (Fe)	5.0	*
Fluoride (F)	1.0	15
Lithium (Li)	2.5	5.8
Manganese (Mn)	0.20	10
Molybdenum (Mo)	0.005	0.05
Nickel (Ni)	0.5	2.0
Nitrate (NO_3^-)	50	*
Selenium (Se)	0.02	0.05
Sulphate (SO_4^{2-})	575	*
Vanadium (V)	0.10	1.0
Zinc (Zn)	2.0	10.0

3.3 Site characterisation

In order to prevent adverse environmental impact the following characteristics of the irrigation site were given consideration in NP 4434: chemical properties, especially the soil heavy metal content; topography;

hydrogeological vulnerability; distance to dwellings.

3.3.1 Soil chemistry

Some soil chemical characteristics are important mainly from the fertility point of view: pH, salinity, cation exchange capacity, nutrients, organic matter, and percentage of exchangeable sodium. Usual agricultural techniques are appropriate to manage these characteristics. Therefore, only some soils with high heavy metal content may be excluded from irrigation with treated urban wastewater [10]. In NP 4434 soils that present heavy metal content greater than allowed to soils for sludge disposal are not acceptable for irrigation with treated urban effluents.

3.3.2 Topography

The irrigation site should not present more than 20% slope to prevent soil erosion and runoff and subsequent risk of surface water contamination. Some irrigation methods require soil slope as low as 3%, as recommended in NP 4434.

3.3.3 Hydrogeologic vulnerability

Water reuse for irrigation should not be carried out over soil classified as hydrologic vulnerable such as very permeable soil or karstic rock. The water table should always be deeper than 1 to 4 metre during irrigation, depending on the type of irrigation method: drip irrigation can be used when the water table is 1 m, but furrow irrigation requires that the water table is around 4 m.

3.3.4 Distance to dwellings

In NP 4434 distance from irrigated site to dwellings depends on the irrigation method and the wastewater treatment. No distance is required for drip irrigation. A distance of 100 m should be observed around sources for drinking water. In any other situations NP 4434 recommends that distance ranges between: 10 m to 50 m where the effluent contains less than 200 FC/100 mL; 20 m to 80 m where the effluent contains less than 1000 FC/100 mL; 30 to 100 FC/100 mL for effluent containing more than 1000 FC/100 mL.

3.4 Classes of crops to be irrigated with treated urban wastewater

In NP 4434 crops are classified in 4 classes according to the level of risk of microbiological contamination generated by irrigation with treated urban wastewater: Class A - vegetables to be eaten raw. Class B - public parks and gardens, sport lawns, forest with public easy access. Class C - vegetables to be cooked, forage crops, vineyards, orchards. Class D - cereals (except rice), vegetables for industrial process prior to consumption, crops for textile industry, crops for oil extraction, forest and lawns located in places of difficult or controlled public access. Vegetables whose edible parts are in close contact with the irrigated soil are not included in Class A. Irrigation of such crops with treated wastewater is not permitted in NP 4434. Crops of class A can only be drip irrigated. The irrigation of other classes of crops with treated urban wastewater depends on the treatment level according to Table 3.

3.5 Control of environmental impact and public health risk

The safe water reuse for irrigation requires not only appropriate wastewater treatment, crop selection according to water quality and irrigation method, good site evaluation, as mentioned in previous items, but also measures aiming at reducing to a minimum the risks of contamination of groundwater and surface water, the contact of people and animals with the irrigation water, the transportation of droplets by wind, the inhalation of aerosols. The NP 4434 establishes some procedures to minimize such risks, concerning the irrigation installation and the irrigation site. NP 4434 presents guidance on signalling the irrigation installation layout of piping, time schedule of irrigation sessions, protection equipment for irrigation operators, animal access to irrigation field, wind speed for spray irrigation. Procedures for field drainage and protection with a tree curtain are also described.

3.6 Monitoring

The use of treated wastewater for irrigation brings water to the soil-plant biosystem but nutrients and other substances that may be beneficial and hazardous, depending on plant needs and soil buffer capacity. Therefore, the sustainable long term of water reuse for irrigation requires monitoring the amount of applied nutrients and heavy metals. NP 4434 includes a table where the irrigation operator records the volume of treated wastewater applied during every irrigation session and based upon the water analysis calculates the amount of nutrients (N, P_2O_5 and K_2O) and heavy metals (Cd, Cu, Cr, Pb, Hg, Ni and Zn).

Usually nutrients applied to the biosystem soil-plant together with treated urban wastewater do not match completely the needs of crops and the addition of artificial fertilisers is necessary. The Portuguese standard NP 4434 presents a table with a fertilisation programme, which guides the irrigation operator to calculate the amount of fertilisers to be added in order to complement the fertilisation carried by the treated wastewater. The table is based on a balance between crop needs, soil chemical analysis and the estimated nutrient amounts to be applied together with the estimated irrigation volumes. Guidance on the frequency of soil analysis is included. The real amount of applied fertilisers both the irrigation water and the complementary artificial fertilisers is recorded by the irrigation operator in another table. Monitoring of the impact of the use of treated urban wastewater for irrigation on groundwater quality is important and NP 4434 provides a table to record the results of analysis of samples of groundwater taken from piezometers. Monitoring details are given in the standard.

4 Conclusions

The need for European Union (EU) regulations on water reuse has been emphasised by several authors. This paper presents the newly published NP 4434 and the Technical Guide currently under preparation, which certainly can contribute to the discussion for EU regulations. NP 4434 is an important tool in Portugal for a more efficient water resources management by means of using an alternative water resource: it guides on the use of treated urban wastewater agricultural irrigation (crops, forest, plant nurseries) and landscape irrigation (parks, gardens, sport lawns such as golf courses). It is the first regulation in the country that presents not only quality criteria for treated urban wastewater for irrigation but also provides guidance on other important aspects to ensure safe practice, e.g. for selection of irrigation equipment and methods, guidelines for environmental protection and includes environmental impact monitoring in areas irrigated with treated urban wastewater.

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Table 3 – Microbiological quality of treated urban wastewater for irrigation

Classes	Type of crop	Faecal coliforms (NMP or cfu/100 mL)	Helminth eggs (egg/L)	APPROPRIATE TREATMENT	NOTES
A	Vegetables to be eaten raw	100	1	Secondary⇒Filtration⇒Disinfection or Terciary⇒ Filtration⇒Disinfection	UV Disinfection (self cleaning lamps) or O_3 preferable to chlorination.
B	Public parks and gardens, sport lawns, forest with public easy access	200	1	Secondary⇒Filtration⇒Disinfection or Terciary⇒ Filtration⇒Disinfection	UV Disinfection (self cleaning lamps) o O_3 preferable too chlorination. Irrigatio must avoid contact with people
C	Vegetables to be cooked, forage crops, vineyards, orchards	10^3	1	Secondary⇒Filtration⇒Disinfection or or Terciary⇒ Filtration⇒Disinfection or Waste stabilisation ponds (System with ≥3 ponds and $t_R \geq 25$ d)	UV Disinfection (self cleaning lamps) or O_3 preferable to chlorinaton. Irrigation of vinyards and orchards must avoid contact with fruit. Fruit fallen on the soil should not be collected.
D	Cereals (except rice), vegetables for industrial process, crops for textile industry, crops for oil extraction, forest and lawns located in places of difficult or controlled public access	10^4	1	Secondary ⇒ Maturation ponds ($t_R \geq 10$ d) or Secondary ⇒Filtration⇒Disinfection	UV Disinfection (self cleaning lamps) or O_3 preferable to chlorinaton. Irrigation must avoid contact with people