SITE SELECTION FOR AQUIFER RECHARGE WITH TREATED WASTEWATER USING GIS-BASED MULTI-CRITERIA ANALYSIS

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ABSTRACT

Treated wastewater from constructed wetlands (CW) systems in rural areas of the Beira Interior region (Portugal) may be used for aquifer recharge. Approximately 21,500 m^3/year of treated wastewater (reclaimed water) produced in a CW system could be used for aquifer recharge without any additional treatment. The site selected for infiltration is an antrosol with fine sand texture. A rate of 1 m d^{-1} was selected as adequate for infiltration. GIS-based multi-criteria analysis was performed combining 8 thematic maps and economic, environmental and technical criteria to set-up a suitability map for aquifer recharge. An area of 1,280 m^2 was found adequate for treated wastewater infiltration.

KEY WORDS

Constructed wetlands; GIS; infiltration; multi-criteria analysis; suitability map; treated wastewater

INTRODUCTION

The rural areas of the Beira Interior have several golf course projects, SPA resorts with therapeutic treatment and important agricultural activities that represent an economic gain for the region. Those activities need a considerable availability of water. However, in the last decade the region experienced a serious water shortage period that may affect those activities.

Several constructed wetlands systems (CW) for wastewater treatment were built in the last years, since they are considered a low cost technology (Vymazal and Kropfelova (2008) and the final effluent has potential to be reused (Pedrero *et al.* (2010)). According to UNESCO (2009), this kind of solution and selective reuse of reclaimed water will constitute one of the great challenges for the integrated water management in rural areas over the next two decades.

The increasing demand for water in the region, particularly in the arid and semi-arid areas, reveals the significance of the extended groundwater reservoirs formed by aquifers as invaluable water supply sources and water storage formations. Many aquifers of the region are overexploited due to the increase of water demand for agricultural and landscape irrigation. Therefore, aquifer artificial recharge with treated wastewater, either by infiltration or by direct injection, would be an advantageous option.

The main objective of the work was to identify potential sites for treated wastewater infiltration for groundwater recharge using a GIS-based multi-criteria analysis.

MATERIAL AND METHODS

The work involved the characterization of an area located near the CW of Vila Fernando (Portugal) using digital information data (military maps, protected area maps, soil and land use maps, altimetry data and orthophotomaps). A 21 month monitoring campaign (November 2007 to November 2009) was set up in the CW, which included the measurement of the daily flow-rate and the collection of monthly samples of the final effluent to determine pH, temperature, biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total nitrogen (TN), ammonia nitrogen (NH_4-N), nitrate nitrogen (NO_3-N), total phosphorus (TP), total suspended solids (TSS), electric conductivity (EC), sodium (Na), calcium (Ca), potassium (K), chloride (Cl), total coliforms (TC), faecal coliforms (FC), *Escherichia Coli* (E. Coli) and helminthes eggs (HE). Magnesium (Mg), boron (B), cadmium (Cd), chromium (Cr), copper (Co), nickel (Ni), lead (Pb) and zinc (Zn) were also analyzed in the last sampling. All the measurements were analysed according to standard methods.

RESULTS AND DISCUSSION

The results of the monitoring campaign are presented in Table 1.

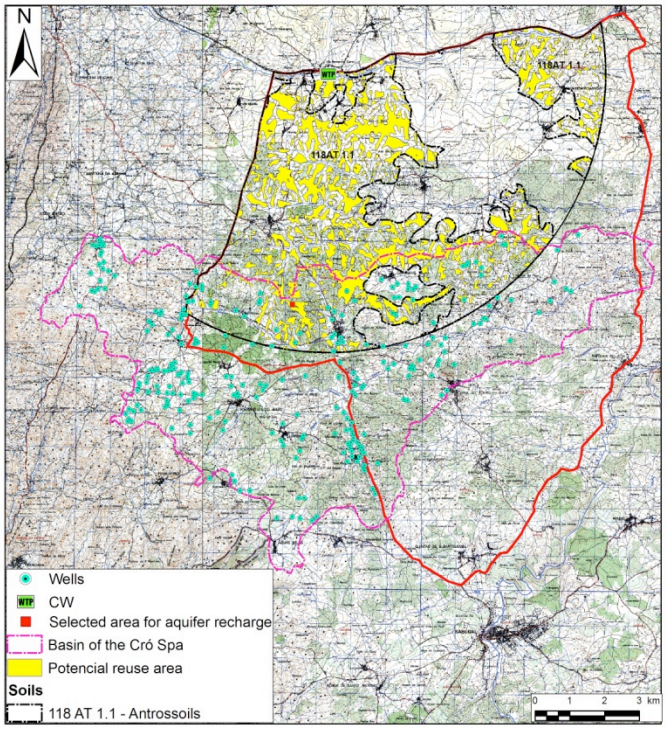
Table 1 – Results of the monitoring campaign (average and confidence interval)

Parameters	Influent [1)]	Effluent (reclaimed water) [1)]
Flow rate ($m^3\ d^{-1}$)	58.9 ± 26.0	-
Temperature (°C)	15.6 - 3.8	15.3 - 3.9
pH	6.2 - 7.3	6.3 - 7.7
EC ($dS\ m^{-1}$)	0.22 ± 0.02	0.22 ± 0.02
BOD_5 ($mg\ L^{-1}$)	105.7 ± 32.1	27.4 ± 7.2
COD ($mg\ L^{-1}$)	265.2 ± 79.8	83.9 ± 13.0
TSS ($mg\ L^{-1}$)	64.0 ± 19.2	27.1 ± 18.3
NH_4-N ($mg\ L^{-1}$)	60.3 ± 5.8	54.4 ± 7.4
NO_3-N ($mg\ L^{-1}$)	1.7 ± 1.5	0.8 ± 0.5
TN ($mg\ L^{-1}$)	74.2 ± 16.1	60.7 ± 13.8
TP ($mg\ L^{-1}$)	9.5 ± 2.2	6.9 ± 1.3

Na (mg L^{-1})	110.9 ± 14.4	118.7 ± 11.4
Mg (mg L^{-1}) [2)]	0.23	0.21
Ca (mg L^{-1})	19.5 ± 2.4	23.6 ± 3.1
K (mg L^{-1})	30.2 ± 4.6	28.4 ± 5.3
Cl (mg L^{-1})	83.7 ± 31.3	79.5 ± 32.5
B (mg L^{-1}) [2)]	< 0.02	< 0.02
Cd (mg L^{-1}) [2)]	0.03	0.02
Cr (mg L^{-1}) [2)]	1.38	0.1
Co (mg L^{-1}) [2)]	0.04	0.01
Ni (mg L^{-1}) [2)]	0.2	0.07
Pb (mg L^{-1}) [2)]	0.02	0.02
Zn (mg L^{-1}) [2)]	0.02	< 0.01
TC (NTU/100 mL)	1,79 $x10^7$ ± 1120	1,95 $x10^6$ ± 980
FC (NTU/100 mL)	3,78$x10^6$ ± 458	6,91 $x10^5$ ± 652
E.Coli (NTU/100 mL)	5,02 $x10^6$ ± 879	1,05 $x10^4$ ± 540
HE (eggs $10L^{-1}$)	< 10	< 10

The results show that the effluent characteristics are compatible with the international guidelines for aquifer recharge (Asano *et al.* (2007)). Values of conductivity and nutrients are not a risk to soil salinity or ground water contamination. The levels of pathogenics will be reduced through soil treatment.

A suitability map for aquifer recharge (Figure 1) was generated from eight thematic maps previously built (digital terrain model, land use map, economic criteria buffer map, water supply sources buffer map, population buffer map, slope map, soil texture map and type of soil map) associated to economic, environmental and technical restrictions. The areas without restricted water sources and economical criteria were the most restrictive variables and the aquifer depth and soil texture, the least restrictive ones.



Taking in account the soil properties and topography, because they are the critical factors in site selection for aquifer recharge, and adopting and infiltration rate of 1 m d^{-1}, four infiltration beds of 320 m^2 each would be enough for the infiltration of the maximum flow-rate produced at the CW (240 m^3 d^{-1}).

Figure 1 – Suitability map for aquifer recharge

CONCLUSIONS

Potential aquifer recharge with treated wastewater from CW was studied in the Beira Interior region. GIS-based multi-criteria analysis showed to be a powerful tool to integrated technical, environmental, social and economical variables. A suitability map for wastewater infiltration was generated and an area of 1 280 m^2 was selected for the construction of infiltration beds. Aquifer recharge with treated wastewater can contribute for sustainable water management in the Beira Interior region, reducing effluent discharges into water streams and gaining a new source of water for aquifer.

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