

HORIZONTAL PERMEABLE REACTIVE BARRIERS FOR GROUNDWATER RECHARGE WITH WASTEWATER: KINETICS AND ADSORPTION ASSAYS.

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INTRODUCTION

The Permeable Reactive Barrier (PRB) is a passive "in situ" treatment zone made up by reactive materials which transform or retain contaminants when water flows through them (EPA, 1998). It is considered as one of the most viable "green" alternatives due to their cost - results ratio in "in situ" soil and groundwater decontamination, being its application suitable for wastewater treatment in small communities.

In this project, a horizontal PRB (Figure 1) made of activated carbon, zeolite, and palygorskite is being studied for the regeneration of urban wastewater for aquifer recharge, one of the uses referred to in the Royal Decree 1620/2007

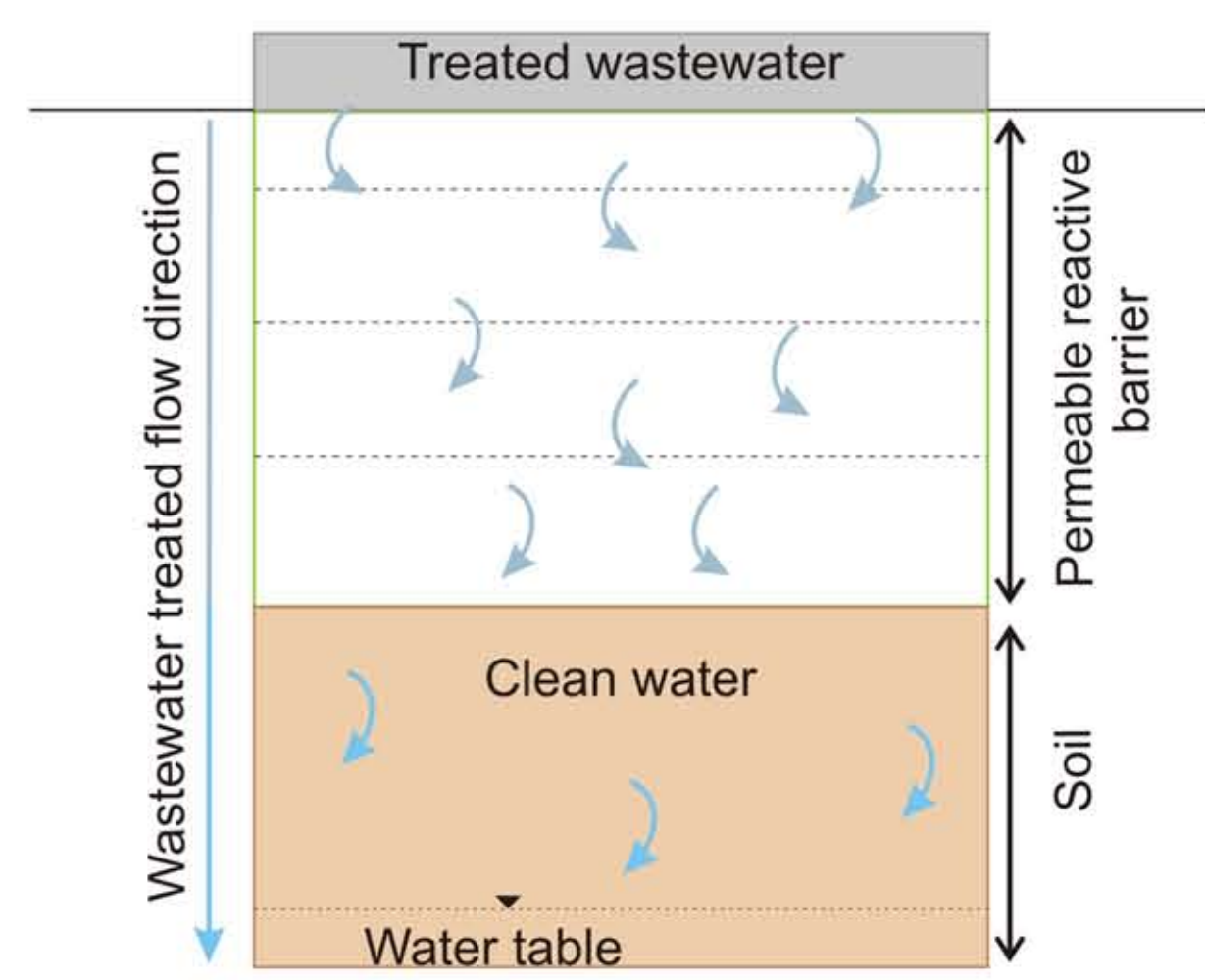


Figure 1. Horizontal Permeable Reactive Barrier Scheme

The barrier will be installed in a research plot located at the Experimental Wastewater Treatment Plant of Carrión de los Céspedes (PECC) (Seville-Spain) (Figure 2). There, non-conventional wastewater treatments and their applicability and development in small towns are studied.

The main aim of this study is to investigate the capacity of the four reactive materials to remove the different substances still remaining in the treated wastewater (de Bustamante *et al.*, 2009) in order not to diminish the groundwater quality when carrying out the aquifer recharge.

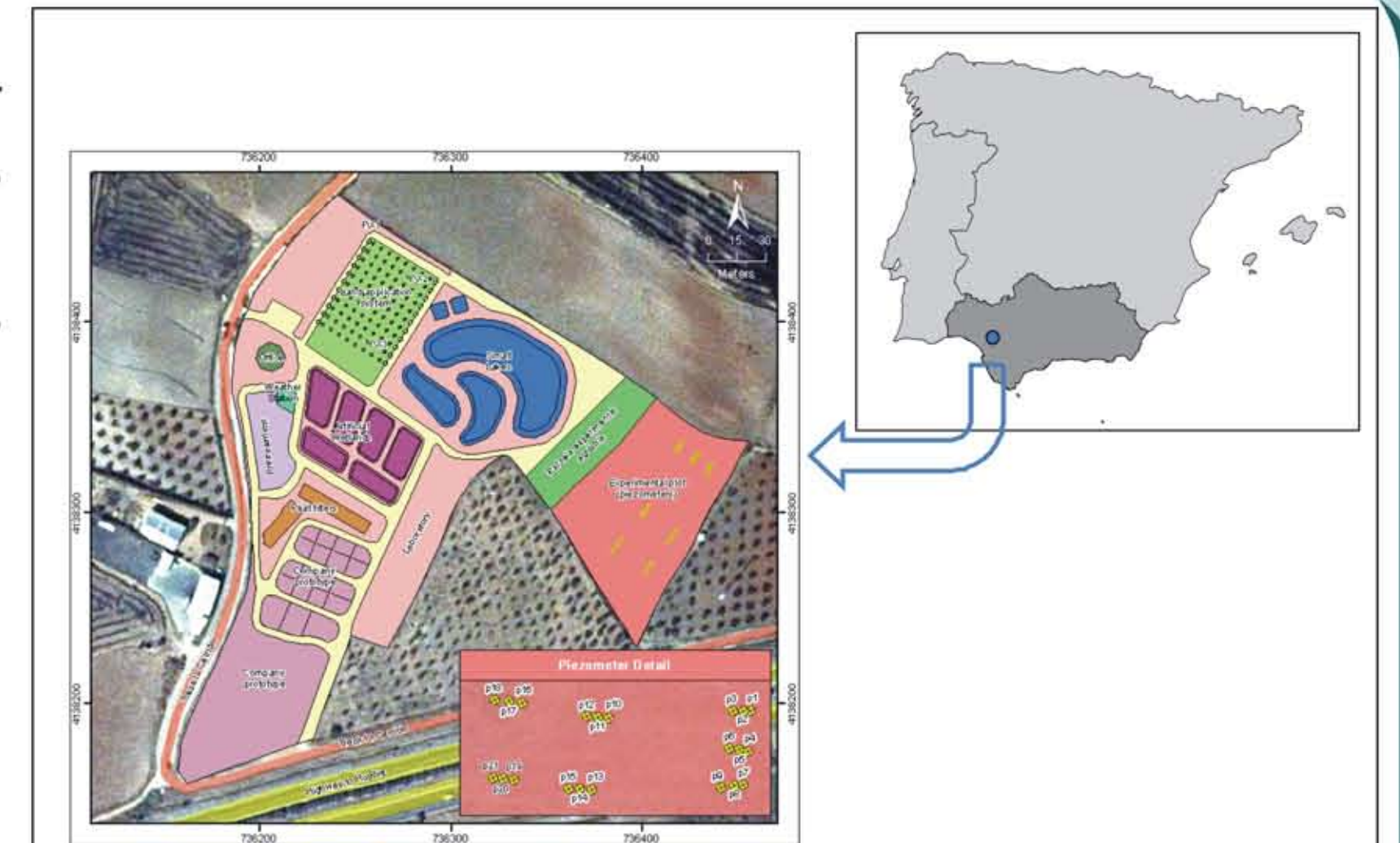


Figure 2. Location of Carrión de los Céspedes Wastewater Treatment Plant

METHODS

The wastewater used in this study has been obtained from the PECC. It was taken after passing through a secondary treatment. Both, sewage effluent and groundwater have been characterized through periodic sampling in order to meet the critical parameters of the effluent, which must be reduced with the horizontal PRB before water reaches the aquifer. The studied materials have been activated carbon, zeolite, palygorskite and peat. In this work sorption studies with different wastewater/reactive material rates and kinetics studies have been carried out.

WATER CHARACTERIZATION

Table 1. Characteristical groundwater and treated wastewater effluent parameters.

	Treated Wastewater Effluent	Groundwater
COD (mg/l)	55.15	<0.4 – 15.4
TOC (mg/l)	22.2	<0.5 – 5.7
NO ₂ ⁻ (mg/l)	0.5	N.D.*
NO ₃ ⁻² (mg/l)	177.9	N.D. – 7.01
PO ₄ ³⁻ (mg/l)	2.75	N.D.
NH ₄ ⁺ (mg/l)	30.35	N.D. – 2.3
K ⁺ (mg/l)	19.90	N.D. – 10.6

*N.D. → Non Detected

The concentration of 7 parameters (Table 1) in effluent overcome the groundwater values as much as 400%. For that reason they have been determined as critical factors for a special follow-up in order not to deteriorate the groundwater quality.

SORPTION ASSAYS

Table 2. Sorption parameters for the adsorption of contaminants in different reactive materials

		Freundlich			Langmuir		
		n	K _F	R ²	b	K _L	R ²
Activated Carbon	NH ₄ ⁺	2.743	3.36·10 ⁻²	0.737	0.880	5.52·10 ⁻²	0.880
	Na ⁺	0.523	4.60·10 ⁻⁴	0.991	-0.589	-1.17·10 ⁻²	0.943
Zeolite	NH ₄ ⁺	1.009	1.83·10 ⁻¹	0.985	0.701	8.77·10 ⁻²	0.980
Palygorskite	NH ₄ ⁺	1.668	8.04·10 ⁻²	0.995	0.701	8.77·10 ⁻²	0.980

In general, Freundlich isotherm shows the best fit (Table 2). As for the rest of critical parameters not showed in Table 2, NO₂⁻ and NO₃⁻² are completely eliminated after the treatment with activated carbon preventing their fit to sorption models.

The COD and TOC with 9.4 and 0 mg/l values respectively, reached the target range after activated carbon wastewater treatment. Similarly is the case of peat, activated carbon and zeolite for PO₄³⁻.

KINETIC ASSAYS

As shown in Table 3, the best fits are obtained with pseudo-second order models.

The best PO₄³⁻ kinetic sorption results are obtained with zeolite and peat (Figure 3a), with a reduction rate of nearly 100% and 85% respectively. However, only the zeolite reaches the phosphate concentration measured in the groundwater.

For the special follow-up cations (NH₄⁺ and K⁺), both are well removed from wastewater with the palygorskite treatment (Figure 3b & c). In both cases the removal percentage is nearly 80%.

According to the kinetic assays (Figure 3), after 8 hours of contact time, there is no significant increase in the reduction of the studied parameters.

Table 3. Kinetics parameters for the adsorption of contaminants in different reactive materials

		Pseudo-first order			Pseudo-second order			Second order		
		q _e	K	R ²	q _e	K	R ²	C ₀	K	R ²
Activated Carbon	NH ₄ ⁺	0.067	0.138	0.938	0.096	4.460	0.986	39.84	0.001	0.901
	PO ₄ ³⁻	0.012	0.209	0.998	0.046	0.366	0.066	4.577	0.012	0.978
Palygorskite	NH ₄ ⁺	0.069	0.175	0.896	0.172	9.084	0.996	24.04	0.008	0.977
	PO ₄ ³⁻	0.002	-5.445	0.223	0.007	2458.995	0.956	1.071	0.045	0.044
Zeolite	NH ₄ ⁺	0.028	0.067	0.114	0.087	19.33	0.995	14.06	0.003	0.332
	PO ₄ ³⁻	0.005	0.166	0.781	0.007	82.105	0.976	1.425	0.273	0.563
Peat	PO ₄ ³⁻	0.032	0.142	0.768	0.045	2.621	0.611	0.435	0.485	0.833

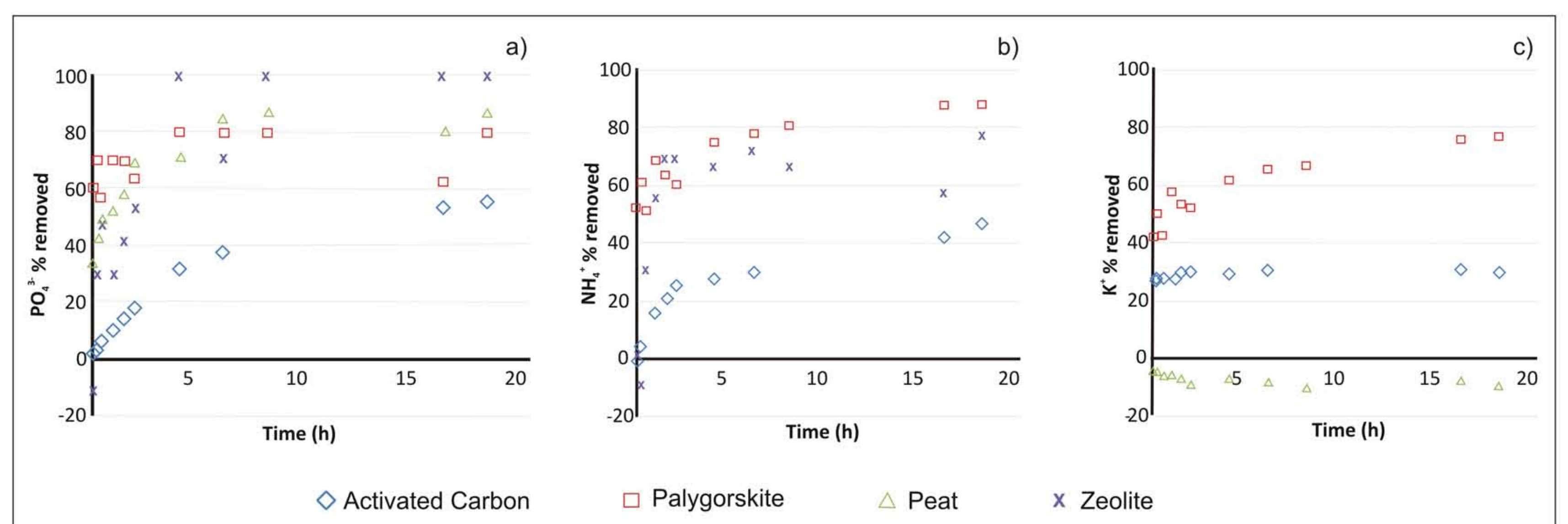


Figure 3. Removal of different ions with activated carbon, palygorskite, peat and zeolite. a) PO₄³⁻; b) NH₄⁺; c) K⁺.

CONCLUSIONS

The studied materials are selective about the sorption of analytes from treated wastewater:

- **Activated carbon:** is the most effective material in terms of COD and TOC elimination, two of the critical parameters identified in the characterization of the studied area.
- **Zeolite:** eliminates fast 100% of PO₄³⁻ and 80% of NH₄⁺.
- **Palygorskite:** due to its cationic exchange behaviour, reduces NH₄⁺ and K⁺.
- **Peat:** best results with it are expected to be obtained in continuous kinetic assays, when microbial activity can be developed.

The results point out that the removal of NO₂⁻ and NO₃⁻² should not be a problem, since they are quite well removed with the four studied materials. Thus, the overall results suggest that the effluent of the Horizontal - PRB will reach the analytes concentrations measured in the aquifer in less than 10 hours of contact time, so the groundwater quality will not be deteriorated.

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