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WATER ABSORPTION PROCESS IN HYDROGEL: SWELLING KINETIC IN SALINE SOLUTION

Vanessa Ohana Gomes Moreira[1], Raimundo Nonato de Assis Júnior[2], Túlio Cordeiro Aragão[3]

ABSTRACT: Hydrogels are polymers used as soil conditioners in semiarid regions with the objective of increasing irrigation efficiency. However, soils in semiarid regions are more affected by salinity problems, due to existing climatic conditions. The objective of this work was to evaluate the swelling kinetic of hydrogel copolymer of acrylamide and potassium acrylate submitted to solutions with different types of salts. The experiment was carried out in laboratory conditions using the treatments: T1 = H_20 (control); T2: potassium chloride (KCl); T3: sodium chloride (NaCl); T4: aluminum chloride ($AlCl_3$). The swelling kinetics was calculated using the mass of the dry gel and the mass of the swelled gel at time T. According to the F-test at 5% of significance, there was a significant difference between treatments for the evaluated variable. The reduction in swelling kinetics occurred in function of the valence of free cations in the solution increased, following the order $Al^{3+} > K^+ > Na^+$. This is due to the greater amount of positive charges from the ions present in the solution, affecting the absorption of water molecules by the polymer. It is concluded that the presence of ions in the solution reduces the swelling kinetics of hydrogel and the type of salt influences the absorption of water by the gel, being smaller as the ion valence increases.
KEYWORDS: superabsorbent polymer; kinetic properties; copolymer.

PROCESSO DE ABSORÇÃO DE ÁGUA EM HIDROGEL: CINÉTICA DE INTUMESCIMENTO EM SOLUÇÕES SALINAS

RESUMO: Hidrogéis são polímeros utilizados como condicionadores de solo em regiões semiáridas com o objetivo de aumentar a eficiência da irrigação. Porém, os solos das regiões semiáridas são mais propensos a problemas de salinidade, devido às condições climáticas existentes. O objetivo deste trabalho foi avaliar a cinética de intumescimento do hidrogel

[1] Agronomist, Master and PhD student in Soil Science, Federal University of Ceará, Pici Campus - Block 807, 60356-000, Fortaleza, Ceará, Brazil. E-mail: van_ohana1@hotmail.com
[2] Full Professor, PhD, Department of Soil Science, Federal University of Ceará, Pici Campus - Block 807, 60356-000, Fortaleza, Ceará, Brazil.
[3] Chemistry student, Department of Chemistry, Federal University of Ceará, Pici Campus - Block 940, 60440-900, Fortaleza - Ceará, Brazil.

copolímero de acrilamida e acrilato de potássio submetido a soluções com diferentes tipos de sais. O experimento foi conduzido em condições de laboratório utilizando os tratamentos: T1 =H_20 (controle); T2: cloreto de potássio (KCl); T3: cloreto de sódio (NaCl); T4: cloreto de alumínio ($AlCl_3$). A cinética de dilatação foi calculada usando a massa do gel seco e a massa do gel intumescido em tempo T. De acordo com o teste de Tukey a 5% de significância, houve diferença significativa entre os tratamentos para a variável avaliada. A redução da cinética de intumescimento ocorreu em função do aumento da valência dos cátions livres na solução, seguindo a ordem Al^{3+}> Na^{+} > K^{+}. Isso ocorre devido a maior quantidade de cargas positivas dos íons presentes na solução, afetando a absorção das moléculas de água pelo polímero. Conclui-se que, a presença de íons na solução reduz a cinética de intumescimento do hidrogel e o tipo de sal influencia na absorção de água pelo gel, sendo o intumescimento menor conforme aumenta a valência do íon.

PALAVRAS-CHAVE: polímero superabsovente, propriedades cinéticas, copolímero.

INTRODUCTION

Agriculture is under abiotic stresses (drought, salinity, temperature and others) which likely to increase due to land degradation, urbanization and climate change. Irrigation water is becoming scarce and the world is looking for water-efficient agriculture (NEETHUY et al., 2018). The use of newer technologies to increase the potency of water and nutrient use may become very necessary over time, especially in arid regions with limited water availability (ABOBATTA, 2018).

Hydrogels are cross-linked hydrophilic polymers that have the capacity to absorb large amounts of water or aqueous solutions (10-1000 times their original volume) in relatively small periods (OMIDIAN et al., 2005). When the absorption is greater than 100 times the weight of the gel, they are called superabsorbent. In agriculture, the addition of hydrogels to soil can improve water holding capacity, decrease evapotranspiration and allow plants to mitigate the drought stress (CHIRINO et al., 2008).

Polymers hydrogel influence soil permeability, density, structure, texture, and evaporation and infiltration rates of water through the soils (EKEBAFE et al., 2011). Have been used as water retaining material in arid and semiarid region under limitation of supplementary irrigation sources and salinity conditions which affect negatively on gradual growth and productivity of crops (ABOBATTA, 2018).

The semi-arid region of the Brazilian northeast, due to the characteristics of climate, relief, geology and drainage, among other factors, presents favorable conditions for the occurrence of soils affected by excess sodium or salts (CASTRO & SANTOS, 2019). This effect of soil salinity can affect the water absorption and the efficiency of the polymer, decreasing the values of the degree of swelling, compared to the values of the study in distilled water (BORTOLIN et al., 2012; GARCIA et al., 2019).

Given the insufficient conclusive results obtained for the use of this type of material, especially when applied to saline and sodium soils, the objective of this study was to evaluate the swelling kinetics of the hydrogel in solutions with different salts (sodium, potassium and aluminium) under laboratory conditions.

MATERIAL AND METHODS

The analysis was realized at the Soil Physics Laboratory of the Federal University of Ceara. The copolymer hydrogel was synthesized with acrylamide (40%) and potassium acrylate (60%) at the Laboratory of Polymer of the Federal University of Ceara. Its main characteristics are white color, particles of size 1 to 3 mm with granules and microgranules.

The treatments used consisted of solutions with different types of salts: T1 = H20 (control); T2: potassium chloride (KCl); T3: sodium chloride (NaCl); T4: aluminum chloride (AlCl3). It was used, 1g of KCl, NaCl and $AlCl_3$ in 420ml of distilled water, separately in beakers, according to treatments T2, T3 and T4, respectively.

For the T1 treatment, the gel was immersed only distilled water. After that, 1g of hydrogel was added and dissolved in the solutions. Five repetitions were performed for each treatment. It was waited 3 hours for complete water absorption by the superabsorbent polymer in all solutions. After that, was utilized a common sieve to obtain and retain only the swollen gel. The water absorption capacity of hydrogels was observed by measures of swelling kinetic. The swelling kinetic of hydrogel was calculated using the equation 1:

Cinética de intumescimento:

$$(W) = (Wt - W_0/W_0) * 100$$

Where:

W_0 - represents the mass (g) of the dry hydrogel.

Wt - is the mass (g) of hydrogel swollen at time t.

The results were subjected to analysis of variance by F and Tukey tests at 5% significance, using the SAS software. The graphics were make using the SIGMAPLOT software version 14.0.

RESULTS AND DISCUSSION

According to test F at 5% of significance, there was a significant difference between treatments for the evaluated variable (Table 1).

Table 1. Summary of analysis of variance components (ANAVA) for the welling kinetics in relation to saline solutions.

FV	GL	MEAN SQUARE
Treatments	3	1033363,8*
Error	16	-
C.V.(%)	8,1	-

FV: source of variation; GL: Degree of freedom; CV: Coefficient of variation; * significant at 5% by the F test.

Figure 1 shows the behavior of averages in relation to effect of presence of salts in the solution and the kinetics of swelling of hydrogel absorbs water according with Tukey test.

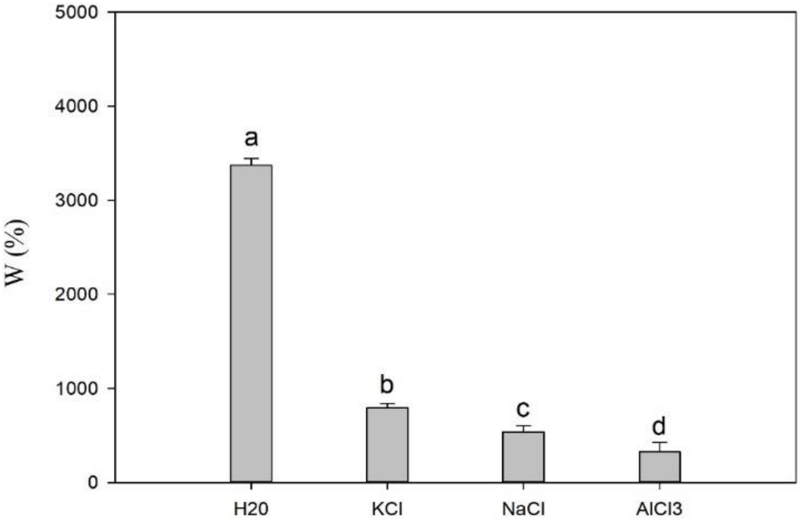

Figure 1. Hydrogel swelling kinetics in solutions with different salts. The bars represent the standard error. Different letters differ significantly at the 5% probability level for Tukey test.

The highest average of swelling kinetics (337%) was obtained in the hydrogel immersed in distilled water (T0). Followed by the averages of KCl (T1), NaCl (T2) and $AlCl_3$ (T3) (59.5%, 54.2% and 37.2%, respectively). These results suggest that the salinity of the solution affects the degree of swelling of the hydrogel, however differently according to the salts present in the solution. It is noticed that the reduction occurred as the valence of free cations in the solution increased, following the order of reduction Al^{3+}> Na^{+}> K^{+}.

This result is probably due to the greater amount of positive ions present in the solution. The interactions between hydroxyl groups and cations occur more strongly as the valence increases, which explains the greater reduction for Al^{3+}.

Similar results are presented in several studies, where the presence of soluble salts reduced the water absorption capacity of polyacrylamide hydrogels (BOWMAN et al., 1990; DORRAJI et al., 2010; WANG & GREGG, 1990).

Bortolin et al. (2012) explain that when the hydrogel is immersed in a solution containing positive ions, localized interactions between hydroxyl groups occur, which can induce the formation of ionic pairs between species. As a result, electrostatic repulsions occur between the segments of the polymer chains, making localized expansions of hydrogel networks difficult.

For the Na^+ ion, the formation of ionic complexes ($-COO-Na^+$), contributions to the reduction of electrostatic repulsion between the polymeric chains, reducing the phenomenon of expansion of the hydrogel-forming chains and, consequently, the absorption of water and swelling (GARCIA et al., 2019).

According to James & Richards (1986), divalent cations, present in irrigation water (Ca^{2+}; Mg^{2+}) develop strong interactions with polymeric gels and can displace the water molecules present in the polymer, reducing the water absorption capacity of hydrogels. According to these authors, although monovalent cations (Na^+) can also replace water molecules, the effect is not as pronounced as divalents, with a reversal of the process when Na^+ is repeatedly saturated with deionized water.

With this, it is noticed that the analysis of the soil and the assessment of salinity of water for irrigation before recommending the quantity to be used of the polymer are essential to obtain good results. This attention should be greater in soils with problems of salinity and sodicity, since the results show that there is a greater loss of swelling capacity with the presence of these ions in the solution.

CONCLUSION

The presence of ions in the solution reduces the swelling kinetics of acrylamide and acrylate copolymer hydrogel. The type of salt influences the absorption of water by the gel, being smaller as the ion valence increases.

The reduction in swelling kinetics occurred in function of the valence of free cations in the solution increased, following the order $Al^{3+} > K^+ > Na^+$.

Attention should be paid to the classification of the soil and water use for irrigation as to salinity in the recommendation of the dose of hydrogel to be used.

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