Slow-Release Potassium Silicate Fertilizer with the Function of Superabsorbent and Water Retention

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To improve the utilization of fertilizer and water resource at the same time, a new slow-release potassium silicate fertilizer with the function of superabsorbent and water retention (SRPS) was prepared, which possessed the core/shell structure. Its core was potassium silicate in an alginate matrix, and the shell was poly(acrylic acid-co-acrylamide)/kaolin (P(AA-co-AM)/kaolin) superabsorbent polymer. The product contained 26.6% K_2O and 10.4% SiO_2. The effects of the amount of acrylamide, crosslinking agent, initiator, degree of neutralization of acrylic acid (AA), and kaolin concentration on water absorbency were investigated and optimized. The water absorbency of the product was 85 times its own weight if it was allowed to swell in tap water at room temperature for 90 min. Release characteristics of potassium and silicon from SRPS in soil and water-retention capacity of the soil with SRPS were also investigated. A non-Fickian diffusion mechanism of nutrient release was proposed, and the release rate factor K, the release exponent n, and the diffusion coefficient D of nutrients in SRPS was calculated. This product with good slow-release and water-retention capacity, being nontoxic in soil and environmentally friendly, could be especially useful in agricultural and horticultural applications.

1. Introduction

The growth of plants and their quality are mainly a function of the quantity of fertilizer and water. So it is essential to try to improve the utilization efficiency of water resources and fertilizer nutrients. Increasing fertilizer use efficiency and preventing fertilizer loss to the environment are important goals of agronomic management. One method of reducing fertilizer nutrient losses involves the use of slow-release fertilizers, which have demonstrated many advantages over the conventional type, such as decreased rate of removal of the fertilizer from the soil by rain or irrigation water, sustained supply of nutrition for a prolonged period, increased efficiency of the fertilizer, lower frequency of application in accordance with normal plant requirement, minimized potential negative effects associated with overdosage, and reduced toxicity.[1-6] Slow-release potassium silicate fertilizer may contribute in achieving these goals of efficient fertilizer nutrient management and reduced environmental impact.

Silicon (Si) is the second most abundant element both on the surface of the Earth's crust and in the soils. Although Si has not been considered as an essential element for higher plants, it has been proved to be beneficial for the healthy growth and development of many plant species, particularly graminaceous plants such as rice and sugarcane and some cyperaceous plants. In addition, Si amendments proved effective in controlling several important plant diseases.[7] Recent research has demonstrated that both foliar and soilborne diseases of cucumber and other cucurbits can be suppressed by applying this element.[8]

Superabsorbents are loosely crosslinked hydrophilic polymers that can absorb and retain aqueous fluids up to thousands of times their own weight, and the absorbed water is hardly removable even under some pressure.[9] Because of their excellent characteristics, superabsorbent polymers had been widely used in agriculture and horticulture.[10] Recently, research on the use of superabsoebent polymers as water-managing materials for the renewal of arid and desert environment has attracted great attention, and encouraging results have been observed as they can reduce irrigation water consumption, improve fertilizer retention in soil, lower the death rate of plants, and increase plant growth.[11] However, its application in this field has met some problems because most of these polymeric superabsorbents are based on pure poly(sodium acrylate), and then they are too expensive and not suitable for saline-containing water and soils.[12,13] Recently, the preparation of polymer/clay superabsoebent composite has attracted great attention because of their relatively low production cost, excellent water retention, and considerable applications in agriculture and horticulture.[14] Kaolin (a clay mineral), whose structural unit consists of one Si–O tetrahedral layer and one Al–O octahedral layer, is a good substrate for superabsorbent composite materials. Besides, superfine kaolin powder has many hydroxyl groups and active points, such as the permanent charge, changeable charge, and exchangeable cation that can react with a high-water-absorption resin and form networks.[15]

On the basis of the above background and our previous studies on superabsorbent polymers[16,17] and slow-release fertilizers,[18,19] we prepared in this study slow-release potassium silicate fertilizer with the function of superabsorbent and water retention (SRPS), which possessed the core/shell structure. Its core was potassium silicate in an alginate matrix, and the shell was poly-(acrylic acid-co-acrylamide)/kaolin (P(AA-co-AM)/kaolin) superabsorbent polymer. The product we prepared not only has slow-release property but also could absorb water and preserve the soil moisture at the same time. These were significant advantages over the normal slow-release fertilizers and superabsorbent polymers for agriculture, which generally have only a slow-release property or water-retention function. The aim of the present work is to reveal the synthesis conditions of inversion suspension polymerization, slow-release, and water-retention properties of the SRPS. In addition, the release rate factor K,

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the release exponent n, and the diffusion coefficient D of nutrients in SRPS were calculated.

2. Experimental Section

2.1. Materials. Acrylic acid (AA; chemically pure, Beijing Eastern Chemical Works, Beijing, China) was distilled at reduced pressure before use (boiling point = 293−294 K at 0.5 mmHg). Acrylamide (AM; analytical grade, Shanghai Chemical Factory, Shanghai, China) was purified by recrystallization from benzene. Ammonium persulfate (APS; analytical grade, Xi'an Chemical Reagent Plant, Xi'an, China) was recrystallized from water before use. N,N'-Methylenebisacrylamide (NNMBA; chemically pure, Shanghai Chemical Reagent Factory, Shanghai, China) and kaolin (Linze Colloidal Co., Gansu, China) were used directly as received. The others were all analytical grade.

2.2. Preparation of SRPS. Potassium silicate (PS) was made from potassium carbonate and calcium silicate according to the literature.[20] PS powder (8g; below 90 mesh) was placed into 60 mL of 2 wt % sodium alginate solution and stirred vigorously until uniform. Then 0.2 M $CaCl_2$ was added dropwise with a pipet; white granules formed immediately because of crosslinking by Ca^{2+}. The white granules were left in the $CaCl_2$ solution for 10 min to ensure complete gelling and then separated from the solution, rinsed twice with distilled water, and dried at room temperature overnight.

Dried PS fertilizer granules (6 g) was added into a flask equipped with a mechanical stirrer, a condenser, and a drop funnel. Carbon tetrachloride (60 mL), 0.1 mL of polyethylene glycoloctyl phenyl ether (OP), and 0.25 mL of sorbite anhydride monostearic acid ester (Span-80) were added into the flask. The temperature was raised to 65 °C using a water bath while the contents were constantly stirred. After that, a series of samples with different amounts of APS, NNMBA, kaolin, AM, and AA with different degrees of neutralization was prepared by the following procedure. Typically, a mixed solution of 70% neutralized AA (4 g, by ammonia, 25−28%), AM (0.95 g), kaolin (0.7 g), NNMBA (crosslinking agent, 3.6 mg), and APS (initiator, 38 mg) was slowly dropped into the flask. The mixture was filtered to remove the carbon tetrachloride after being stirred for 2 h at 65 °C and then dried in a 70 °C oven to obtain the final product, slow-release potassium silicate fertilizer with the function of superabsorbent and water retention (SRPS).

2.3. Component and Structure Analysis of SRPS. Contents of potassium and silicon in the SRPS were determined by atomic absorption spectrophotometer (American TJA Corporation, model 1100-B). Acid digestion can be used for potassium recovery in the SRPS. Atomic absorption spectrometry was equipped with a self-made simple cell holder. It was changed into UV−vis spectrometry. It is successful to determine silicon in the SRPS with silicon molybdenum blue by atomic absorption spectrometry. The structure of SRPS was also subjected to a scanning electron microscopy (SEM) study. They were split into two halves, and the fractions obtained were adhered to sample holders with carbon LIT-C glue. The sample was coated with a layer of gold and observed in a JSM-5600LV SEM manufactured in Japan.

2.4. Characterization of the Shell Material of SRPS by FTIR. The shell material of SRPS, P(AA-co-AM)/kaolin was characterized by a Fourier transform infrared (FTIR) spectrophotometer (American Nicolet Corporation, model 170-SX). The sample of P(AA-co-AM)/kaolin was ground with dried KBr powder. The KBr disk was dried again and subjected to FTIR spectrophotometry.

2.5. Measurement of Water Absorbency of SRPS. A sample (1 g) of the SRPS was immersed into a certain amount of tap water and allowed to soak at room temperature for 90 min. The swollen SRPS was filtered through an 80 mesh sieve to remove nonabsorbed water and weighed. The water absorbency was calculated using the following equation

$$WA = \frac{M - M_0}{M_0} \tag{1}$$

Here, M and M_0 denote the weight of swollen SRPS and the weight of the dry SRPS, respectively, and WA is the water absorbency per gram of dried SRPS.

2.6. Slow-Release Behavior of SRPS in Soil. To study the slow-release behavior of SRPS in soil, the following experiment was carried out: 1 g of SRPS was well-mixed with 200 g of dry soil (below 26 mesh) and kept in a 200 mL beaker properly covered and incubated for different periods at room temperature. Throughout the experiment, the soil was maintained at 30 wt % water-holding capacity by weighing and adding distilled water if necessary, periodically. After 1, 3, 5, 10, 15, 20, 25, and 30 days incubation period, the remaining granular SRPS in the beakers was picked out, washed with distilled water, and then dried at room temperature overnight to estimate the contents of K and Si. For eight measurements, eight beakers were prepared at the same time. The remaining amounts of K and Si were estimated by the atomic absorption spectrophotometer.

The release results were analyzed according to the following equation based on Fick's law but applicable to spherical devices[21,22]

$$\frac{M_t}{M_0} = Kt^n \tag{2}$$

$$\frac{M_t}{M_0} = 6\left(\frac{Dt}{\pi r^2}\right)^{0.5} \tag{3}$$

where M_t/M_0 is the released fraction at time t, n is the release exponent, K is the release factor, D is the diffusion coefficient, and r is the radius of the spherical granular.

2.7. Maximum Water-Holding Ratio of the Soil. The sandy soil used in this study was representative of the area of Lanzhou, which lies in the northwest of China and is a dry and semidesert region. A 2 g sample of SRPS was well-mixed with 200 g of dry soil (below 26 mesh) and placed in a poly(vinyl chloride) (PVC) tube of 4.5 cm diameter; the bottom of the tube was sealed by nylon fabric (with an aperture of 0.076 mm) and weighed (W_1). The soil samples were slowly drenched by tap water from the top of the tube until the water seeped out from the bottom. After there was no seeping water at the bottom, the tube was weighed again (W_2). A control experiment, viz., with no SRPS, was also carried out. The maximum water-holding ratio ($W\%$) of the soil was calculated using the following equation.

$$W\% = \frac{100 \times (W_2 - W_1)}{200} \tag{4}$$

2.8. Measurement of the Water Retention of SRPS in Soil. A 2 g sample of SRPS was well-mixed with 200 g of dry sandy soil (below 2 mm in diameter) and kept in a beaker, and then 200 g of tap water was slowly added into the beaker and weighed (W_1). A controlled experiment, i.e., without SRPS, was also carried out. The beakers were maintained at room temper-
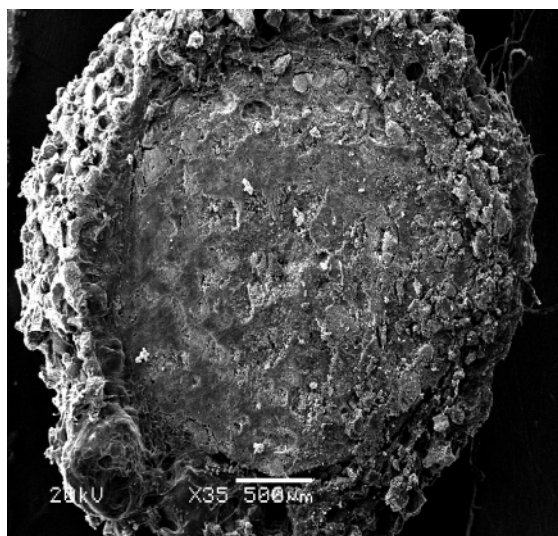
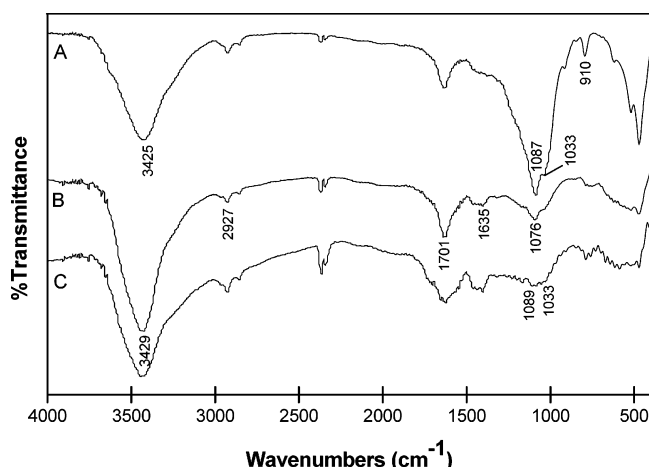**Figure 1.** SEM of cross section of a SRPS fertilizer granule.

Figure 2. FTIR spectra of kaolin (A), P(AA-co-AM) (B), and P(AA-co-AM)/kaolin (C).

ature and were weighed every 5 days (W_i) over a period of 30 days. The absorbed moisture content ($W\%$) was determined using eq 5. This was then used to evaluate evaporation.

$$W\% = \frac{100 \times (W_1 - W_i)}{200} \quad (5)$$

3. Results and Discussion

3.1. Composition and Physical Properties of SRPS. Atomic absorption spectrophotometer results showed that K and Si contents of SRPS were 26.6 wt % potassium (shown by K_2O) and 10.4 wt % silicon (shown by SiO_2). The structure of SRPS fertilizer granule was the core/shell structure. Its core was potassium silicate in an alginate matrix (68.7 wt %), and the shell was P(AA-co-AM)/kaolin superabsorbent polymer (31.3 wt %) (see Figure 1). The average weight of the SRPS fertilizer granules was 0.24 g. The average diameters of dry SRPS and swollen SRPS granules in tap water were 2.1 and 13.8 mm, respectively.

3.2. FTIR Analysis of P(AA-co-AM)/Kaolin (The Shell Material). Figure 2 shows the infrared spectra of kaolin, P(AA-co-AM), and P(AA-co-AM)/kaolin. The peaks observed at 3429 cm^{-1} (Figure 2C) could be attributed to −OH groups of the acrylate unit and kaolin and N−H stretching of the acrylamide unit. The peaks observed at about 2927 cm^{-1} (parts A−C of
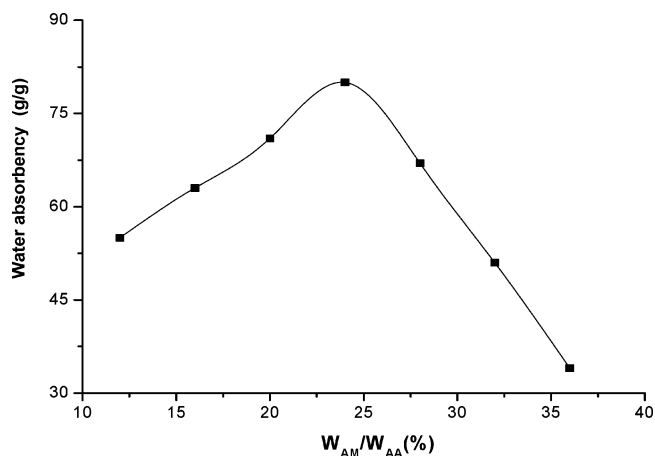

Figure 3. Effect of the amount of AM on water absorbency.

Figure 2) correspond to the C−H stretching of the P(AA-co-AM) and kaolin. Comparing the spectrum of P(AA-co-AM)/kaolin and that of P(AA-co-AM), the appearance of the absorption bands in Figure 2C at 1701 cm^{-1} (C=O stretching of acrylate unit), 1635 cm^{-1} (the carbonyl moiety of acrylamide unit), 1076 cm^{-1} (−CO−O− stretching of acrylate unit), and 1089 and 1033 cm^{-1} (Si−O stretching of kaolin) gives direct evidence for the interaction between kaolin and P(AA-co-AM). This result is in agreement with the literature.[15]

3.3. Influence of the Parameters on Water Absorbency. The key properties of superabsorbent polymers are the water absorbency and the elastic modulus of the swollen crosslinked gel, both of which are related to the crosslinking density of the network. To improve the water absorbency capacity of the SRPS, various reaction parameters are employed. The complete details of the influence of the reaction parameters on water absorbency in tap water, such as the content of AM and kaolin, neutralization degree, crosslinking agent, and initiator, are given below.

3.3.1. Effect of the Amount of AM on Water Absorbency. The hydrophilic group plays an extremely important part in water absorbency.[23] In the P(AA-co-AM)/kaolin polymeric system, the ratio of different hydrophilic groups can be adjusted by changing the proportion of AA to AM. The effect of the amount of AM on water absorbency of SRPS is shown in Figure 3. The water absorbency increases as the amount of AM rises from 12 to 24 wt % and decreases when the amount of AM is >24 wt %. It is known that AM is a nonionic monomer. It almost does not ionize in solution, so the ions in solution have little influence on it, which would improve the salt-resistance ability of SRPS. Therefore, with the increase of the amount of AM, water absorbency would increase with that. On the other hand, −COO$^-$ group has better hydrophilic ability than −CONH$_2$, so water absorbency would decrease with the further increase of the amount of AM. In other words, the maximum in the dependence of water absorbency on the amount of AM could be attributed to the cooperation effect between the salt-resistance property of the −CONH$_2$ group and the high hydrophilic ability of the −COO$^-$ group.

3.3.2. Effect of the Amount of Kaolin on Water Absorbency. Kaolin powder as network points plays an important role in the formation of the composite superabsorbent.[14] The effect of the amount of kaolin on the water absorbency in tap water is shown in Figure 4. The water absorbency increases with an increase of kaolin till reaching a maximum at 18 wt %. However, when the amount of kaolin is >18 wt %, the water absorbency decreased with the increase of the amount of kaolin.
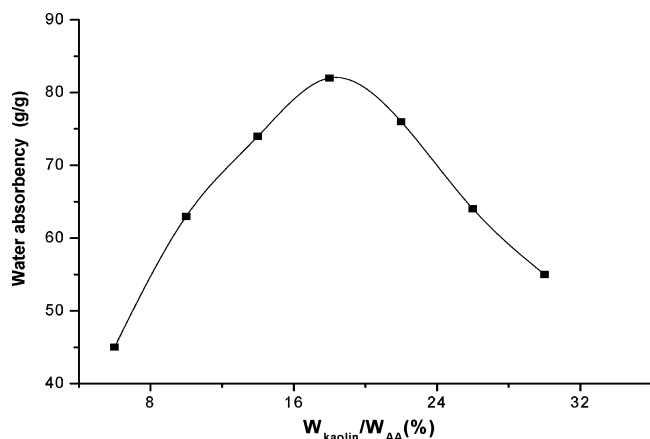
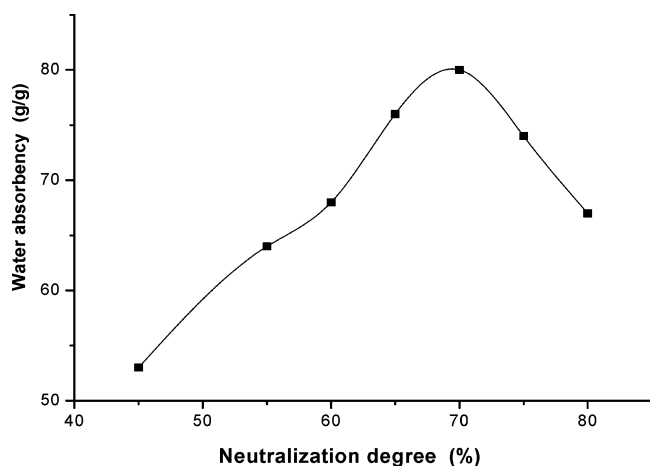**Figure 4.** Effect of the amount of kaolin on water absorbency.

Figure 5. Effect of neutralization degree of AA on water absorbency.

The behavior may be attributed to the reaction between P(AA-co-AM) and kaolin. When the amount of kaolin is low, the reaction could improve the polymeric network and, as a result, the water absorbency increases. On the other hand, when the amount of kaolin is high, the additional kaolin results in the generation of more crosslinking points that increase the crosslinking density of the composite, and then the elasticity of the polymer chains decreases. Moreover, the content of hydrophilic groups is lower at higher amounts of kaolin, and then the osmotic pressure difference decreases, which results in the shrinkage of the P(AA-co-AM)/kaolin. The results are in conformity with Flory's network theory,[24] and a similar observation has been reported by others.[25]

3.3.3. Effect of Neutralization Degree of AA on Water Absorbency. The effect of degree of neutralization of AA on water absorbency of SRPS is presented in Figure 5. Neutralization degree is defined as the molar percentage of carboxyl in AA neutralized by ammonia. It is clear that the water absorbency increases from 45% to 70% and decreases with a further increase in the neutralization degree of AA. This behavior may be interpreted in terms that a cooperative absorbing effect between carboxylate and carboxylic acid groups is superior to that of either group. When AA is neutralized, the carboxylic acid group turns into a carboxylate group, since, in water, the negatively charged carboxyl groups attached to the polymer chains set up an electrostatic repulsion, which tends to expand the network. In a certain range of neutralization degree, the electrostatic repulsion increases with the increase of neutralization degree, resulting in the increase of water absorbency. However, when the neutralization degree of AA is >70%, the excessive
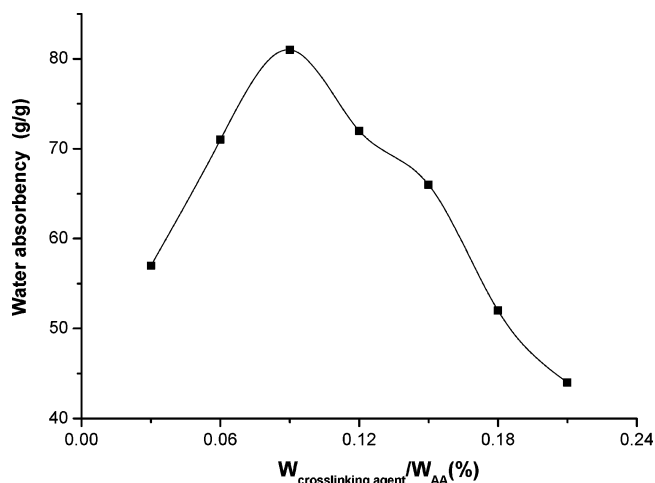

Figure 6. Effect of the amount of crosslinking agent on water absorbency.

ammonia ions would reduce the electrostatic repulsion by screening the negative charges of carboxyl groups, thus resulting in the decrease of water absorbency of the P(AA-co-AM)/kaolin polymer.

3.3.4. Effect of the Amount of Crosslinking Agent on Water Absorbency. Crosslinking density is an extremely important swelling control element.[26] Relatively small changes in crosslinking density can play a major role in modifying the properties of superabsorbent polymers. The dependence of water absorbency of SRPS on degree of crosslinking is shown in Figure 6. As we can see from Figure 6, the amount of crosslinking agent increased, water absorbency increased up to a certain level, but with higher amount of crosslinking agent, water absorbency decreased drastically. As we know, the amount of crosslinking agent determined the crosslinking density of the hydrogel network. When the amount of crosslinking agent was <0.09 wt %, water absorbency increased with the increase of the amount of crosslinking agent. This could be attributed to the lower crosslinking density with a smaller amount of crosslinking agent, which would cause the solubility of SRPS to increase. When the amount of crosslinking agent was >0.09 wt %, a further increase of the crosslinking density of the hydrogel network would decrease the space among the grids of the three-dimensional network. This would make it more difficult for the network to be swollen by water, which was responsible for the decrease of water absorbency. These results were also in accordance with the theory of Flory.[24]

3.3.5. Effect of the Amount of Initiator on Water Absorbency. Figure 7 shows the effect of the amount of initiator on water absorbency of SRPS. The water absorbency increases as the amount of initiator rises from 0.45 to 0.96 wt % and decreases when the amount of initiator is >0.96 wt %. According to the theory of Flory,[24] the molecular weight in free radical polymerization will decrease with an increase of initiator concentration. With the decrease of the molecular weight, the relative amount of polymer chain ends increases. As reported in a previous study, the polymer chain ends do not contribute to the water absorbency. Therefore, the increase of the amount of initiator is responsible for the decrease in water absorbency. When the amount of initiator is <0.96 wt %, the polymerization reaction is slower, the polymer network is less, and the water absorbency is lower under the same reaction condition. On the other hand, at a higher amount of initiator, such as >0.96 wt %, large quantities of free radicals produced by the initiator may cause the faster reaction velocity and the chain transfer to polymers, which would result in the increase of crosslinking density and, consequently, the increase of the water absorbency.
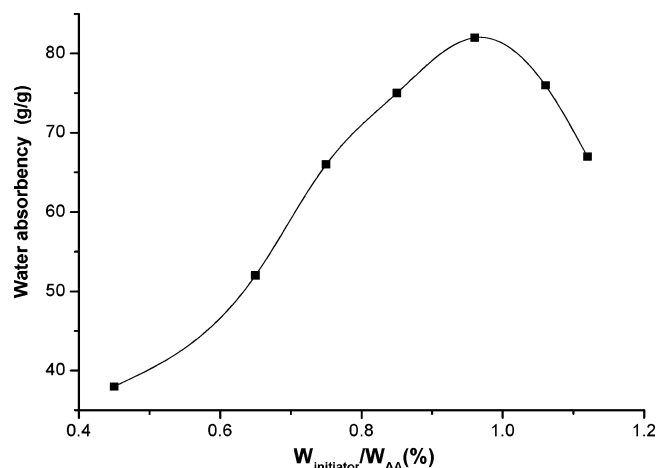
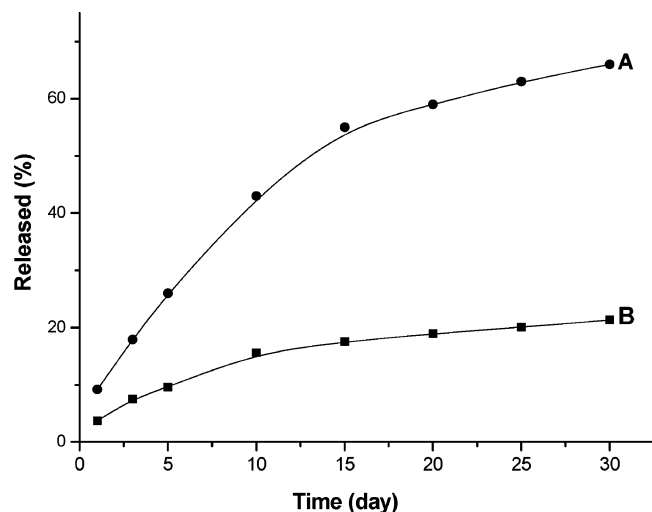**Figure 7.** Effect of the amount of initiator on water absorbency.

Figure 8. Release behaviors of potassium (A) and silicon (B) in soil.

3.4. Slow-Release Behavior of SRPS in Soil. One of the most important characteristics of the SRPS we prepared was its slow-release property. Figure 8 shows the K and Si slow-release behaviors of SRPS in soil. It could be seen from Figure 8 that the K and Si in SRPS released 17.9 and 7.5% on the third days, 26 and 9.6% on the fifth days, and 66 and 21.3% on the 30th days, respectively. With the sum of nutrients release lower than 15% on the third day and not above 75% on the 30th day, this indicated that the slow-release character of the SRPS we prepared agreed with the standard of slow-release fertilizers of the Committee of European Normalization (CEN)[27] and also indicated that the SRPS had an excellent slow-release property.

The proposed mechanism of nutrient release is presented in Figure 9. First, the P(AA-co-AM)/kaolin shell would be slowly swollen by the water in soil after being added into soil and transformed to hydrogel, which would contribute to an increase of the aperture size of the three-dimensional network of P(AA-co-AM)/kaolin, so that it benefits the diffusion of the fertilizer nutrition in the PS core of hydrogel. Then the water layer between the hydrogel and the PS core could also be formed (as shown in Figure 9A).[28,29] Second, the absorbed water would continue to slowly diffuse into the PS core and dissolve the soluble part of PS, and then this part of the soluble fertilizer nutrition would slowly be released into the soil through the P(AA-co-AM)/kaolin shell with the dynamic exchange of the water in the hydrogel and the water in the soil. In this stage, diffusion would be the release rate-limiting step (as shown in

Table 1. Release Factors (K), Release Exponents (n), and Diffusion Coefficient (D) for K and Si Release from SRPS in Soil

nutrients	n	K	$D \times 10^5$ (cm²/d)
K	0.60	9.50	6.66
Si	0.51	4.11	0.63

Figure 9B). Last, under the effect of water, ions, and microorganisms existing in the soil, the insoluble part of the PS fertilizer would be degraded into soluble part and then slowly released into the soil with the above dynamic exchange. In this stage, the degradation rate determines the nutrients release rate (as shown in Figure 9C).

The n value is an empirical parameter characterizing the release mechanism. On the basis of the diffusion exponent, an n value of 0.5 indicates the nutrient-release mechanism approaches to a Fickian diffusion-controlled release, whereas $n = 1.0$ indicates the nutrient-release mechanism approaches to zero-order release. The n value from 0.5 to 1.0 is a nutrient-release mechanism for non-Fickian diffusion or chain-relaxation control release.[30,31] From the plot of log(M_t/M_0) versus log(t), the release exponent (n) and the release factor (K) have been calculated. Table 1 summarizes the values for K and Si release from SRPS in soil. The n value is in the range 0.51−0.60. Therefore, the nutrient-release mechanism is non- Fickian diffusion and is controlled by a combination of diffusion and degradation of PS fertilizer. Additionally, fertilizer-application strategies involving Si as a nutrient input offer improved control over several important diseases, thus reducing the reliance on frequent fungicide use. Si also has been reported to control certain insect pests and improve plant utilization of other nutrients such as phosphorus. This implies that insecticides and fertilizers might be better managed if Si soil amendments are used.[7]

3.5. Maximum Water-Holding Ratio of the Soil. Besides its slow-release property, another one of the most important characters of the SRPS we prepared is its water-retention capacity or, in other words, its effective utilization of water in arid and desert regions to transform them into "green and fertile lands". It was reported[32] that the use of superabsorbent polymer in the agricultural field could increase the maximum water-holding capacity and water-retention capacity of soil. Therefore, the experiments to test the water-holding capacity and water-retention behaviors of soil with SRPS were performed. The experiment results of the maximum water-holding ratio of the soil indicated that the maximum water-holding ratio of the soil without SRPS was 40.15% and that of the soil with SRPS was 72.65% (the mass ratio of SRPS to soil was 1:100), 32.50% higher than the former. This showed that the SRPS we prepared still had excellent water absorbency in soil, could obviously improve the water-holding capacity of the soil, and could efficiently store rainwater or irrigation water resources. This was one of the significant advantages over the normal slow-release fertilizers.

3.6. Water-Retention Behavior of SRPS in Soil. The most important application of SRPS is for agriculture and horticulture, especially for saving water in dry and desert regions and for accelerating plant growth.[33] So, it is necessary to investigate the water-retention ability of SRPS in soil. Figure 10 shows the water-retention behavior of the soil with and without SRPS. From Figure 10, we find that the water-evaporation rate of soil with SRPS obviously decreased compared to that of the soil without it. The water-evaporation ratio of soil without SRPS reached 56.2 and 97.6 wt % on the 15th and 30th days, respectively, while that of the soil with SRPS was 41.2 and 76.4 wt %, respectively. After 30 days, the water content of
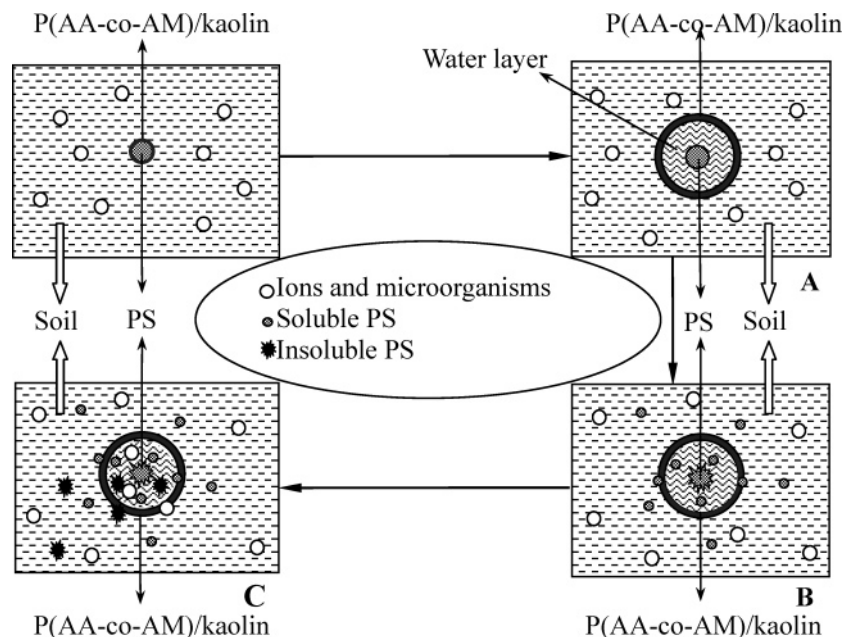
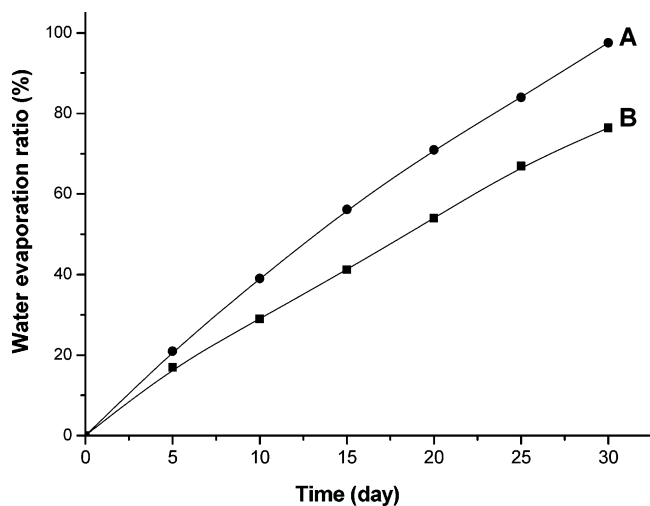**Figure 9.** Slow-release mechanism of nutrient in SRPS.

Figure 10. Water-retention behaviors of soil without SRPS (A) and soil with SRPS (B).

the soil without SRPS was 2.4 wt %, while that of the soil with SRPS was 24.6 wt %. From these experimental results, it could be inferred that SRPS had good water-retention capacity in soil and that, with SRPS use, water can be saved and managed so that it can be effectively used for the growth of a plant. The reason was that the shell material of SRPS could absorb and store a large quantity of the water in soil and allow the water absorbed in it to be slowly released with the decrease of the soil moisture. Simultaneously, nutrients could also be released slowly with the water. Therefore, the swollen SRPS was just like an additional nutrient reservoir for the plant−soil system and, thus, could increase the utilization efficiency of water and fertilizer at the same time.

The study shows that, besides its slow-release property, the SRPS has excellent water absorbency, water-retention capacity, and moisture-preservation capacity in soil and can obviously improve the water-holding capacity of soil. These are significant advantages over the conventional slow-release fertilizers, which always only had a slow-release property. Thus, the SRPS has good potential for use in agriculture and horticulture, especially in dry-prone regions.

4. Conclusions

A slow-release potassium silicate fertilizer with the function of superabsorbent and water retention (SRPS) was prepared, which possessed the core/shell structure. Its core was potassium silicate in an alginate matrix, and the shell was poly(acrylic acid-co-acrylamide)/kaolin superabsorbent polymer. Atomic absorption spectrophotometer results showed that the product contained 26.6% potassium (shown by K_2O) and 10.4% silicon (shown by SiO_2). The product had good slow-release properties: the nutrients released did not exceed 75% on the 30th day; the diffusion coefficients D of K and Si in SRPS are about 6.66×10^{-5} cm^2/d and 0.63×10^{-5} cm^2/d, respectively. The addition of SRPS into soil could greatly improve the water-holding ability and water-retention property of the soil, as well as improve the availability of fertilizer and water resource to plants, simultaneously. Moreover, this new approach showed promise in utilizing a natural resource such as kaolin in the production of the shell material, which could significantly reduce the production cost and make the technique more environmentally friendly. The results of the present work indicate that the SRPS is a good slow-release fertilizer with excellent water-retention capability. Therefore, SRPS would find good application in agriculture and in the renewal of arid and desert environments.

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