AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.

A Study of Adsorption of Modified Corn Stalk on PCP

Jiqiang ZHANG *

College of Resources and Environmental Engineering, Binzhou University, Binzhou 256603, China

Abstract The comprehensive utilization of corn stalks is an urgent agricultural and environmental problem to be solved in China. In this test, we use corn stalk as adsorbent for adsorption of PCP in water, and compare the impact of three modification methods (alkali treatment, pyrolysis, graft copolymerization) on corn stalk adsorption properties. Results show that the modified corn stalk's adsorption of PCP is increased from 5.4 mg/g to 13.9 mg/g, 17.8 mg/g and 22.5 mg/g, respectively; the corn stalk after graft copolymerization and modification has the greatest adsorption capacity; after modification, both the adsorption capacity and adsorption rate constant of corn stalk on PCP are increased significantly.

Key words Corn stalk, PCP, Adsorption, Modification

1 Introduction

PCP (Pentachlorophenol) is often widely used as herbicides and pesticides, but it is toxic and carcinogenic[1]. PCP enters the water through a variety of ways, causing a serious threat to the ecological environment and human health. The adsorption method is an effective method to rapidly remove PCP from the water. Corn stalks have a huge annual yield, but most of them are not effectively used, causing environmental pollution and waste of resources, so it is necessary to explore resource-oriented utilization of corn stalks[2]. The corn stalks are porous and often used as adsorbent, but the adsorption capacity is small[3]. Therefore, this paper compares the impact of three modification methods (alkali treatment, pyrolysis, graft copolymerization) on corn stalk's adsorption of PCP in order to achieve resource-based utilization of waste.

2 Materials and methods

2.1 Modification treatment The corn stalk is taken from the suburbs of Binzhou, and after being dried, pulverized and sifted, it is used for modifying treatment. (i) Corn stalk alkali modification. The corn stalk is mixed with 1 mol/L NaOH solution, stirred with a magnetic stirrer for 24 h and dried after leaching and washing. (ii) Corn stalk pyrolysis modification. A certain number of corn stalks are weighed and placed in a crucible and pyrolyzed in a muffle furnace at 450 ℃ for 4 h (sparged with nitrogen to maintain a reducing atmosphere), and dried after natural cooling. (iii) Corn stalk graft copolymerization. A certain number of corn stalks are weighed and placed in 250 mL round bottom flask with three necks, and heated at 100 ℃ for 60 min after adding 10 mL of epichlorohydrin and 20 mL of dimethylformamide; then 10 mL of diethylenetriamine is added to react at 100 ℃ for 60 min; finally 30 mL of triethylamine is added to react at 100 ℃ for 120 min, and it is washed and dried.

2.2 Adsorption test 0.1 g of unmodified corn stalk powder or 0.1 g of corn stalk powder under three modification treatments (alkali treatment, pyrolysis, graft copolymerization) is put in 250 mL Erlenmeyer flask, respectively, and 100 mL of 25 mg/L PCP solution is added for adsorption test in air bath constant temperature shaker at 25 ℃ and 100 rpm. The sampling is conducted at regular time intervals, and the supernatant is centrifuged in a high speed centrifuge. After adding color-developing agent, the spectrophotometry is used to determine the concentration of PCP. Corn stalk adsorption amount q_e(mg/g) is calculated as follows[4]:

$$q_e = (c_e - c_0) \times V/m \quad (1)$$

where c_e and c_0 are the PCP concentration (mg/L) after adsorption equilibrium and before adsorption, respectively; V is the solution volume (L); m is the mass of corn stalk (g).

2.3 Adsorption kinetics analysis The pseudo kinetic equation is used for fitting of adsorption data and studying the adsorption kinetic characteristics of corn stalk under different modification treatments on PCP[5]. Pseudo-first-order kinetics equation is as follows:

$$\ln(q_e - q_t) = \ln q_e - k_1 t \quad (2)$$

where t is time (min); q_e is the equilibrium adsorption amount (mg/g); q_t is the adsorption amount at time t (mg/g); k_1 is the pseudo-first-order adsorption rate constant (min^{-1}).

3 Results and discussions

3.1 The adsorption properties of unmodified corn stalks on PCP The unmodified corn stalks are taken for PCP adsorption test and compared with the modified corn stalks. The adsorption test results of unmodified corn stalk on PCP are shown in Table 1. In 0 -60 min, the adsorption amount of unmodified corn stalk on PCP increases rapidly with time and then tends to stabilize, and

Received: June 15, 2017 Accepted: August 15, 2017

Supported by Shandong Higher Education Institution Science and Technology Plan Project (J16LD03); Natural Science Foundation of Shandong Province (ZR2014EEP009); Doctoral Scientific Research Foundation of Binzhou University (2014Y17); Shandong Key Research and Development Plan (2015GNC111018, 2016GSF117021).

* Corresponding author. E-mail: zhangjiqiang1986@163.com

reaches adsorption equilibrium after 120 min. The adsorption amount of unmodified corn stalk on PCP is 5.4 mg/g, and the PCP removal rate is 21.6%.

3.2 The adsorption properties of modified corn stalks on PCP The corn stalks after alkali treatment, pyrolysis, graft copolymerization are selected for PCP adsorption test, and the test results are shown in Table 2. After the modification, the adsorption of corn stalk on PCP also first increases rapid and then tends to stabilize. After reaching the adsorption equilibrium, the adsorption amount of the corn stalk under alkali treatment on PCP is 13.9 mg/g, and the PCP removal rate is 55.7%; the adsorption amount of the corn stalk under pyrolysis on PCP is 17.8 mg/g, and the PCP removal rate is 71.2%; the adsorption amount of the corn stalk under graft copolymerization on PCP is 22.5 mg/g, and the PCP removal rate is 89.8%. Experimental results show that after modification, the adsorption capacity of corn stalk on PCP is significantly improved, and in the three modification methods, the corn stalk under graft copolymerization has the maximum adsorption of PCP and the modification effect is good.

Table 1 The adsorption properties of unmodified corn stalk on PCP

Time//min	PCP concentration//mg/L	PCP removal rate//%	Adsorption amount//mg/g
0	25.0	0.0	0.0
30	21.4	14.4	3.6
60	20.0	20.0	5.0
120	19.8	20.8	5.2
180	19.6	21.6	5.4

Table 2 The adsorption properties of modified corn stalk on PCP

Methods	Alkali treatment			Pyrolysis			Graft copolymerization		
Time//min	Concentration mg/L	Adsorption amount// mg/g	Removal rate %	Concentration mg/L	Adsorption amount//mg/g	Removal rate %	Concentration mg/L	Adsorption amount//mg/g	Removal rate %
0	25.0	0.0	0.0	25.0	0.0	0.0	25.0	0.0	0.0
30	18.7	6.3	25.1	10.7	14.3	57.1	7.4	17.6	70.5
60	11.9	13.1	52.4	8.4	16.6	66.3	5.0	20.0	80.0
120	11.7	13.3	53.3	7.9	17.0	68.0	3.1	21.9	87.6
180	11.1	13.9	55.7	7.2	17.8	71.2	2.6	22.5	89.8

3.3 The kinetics characteristics of adsorption of corn stalks on PCP The pseudo-first-order kinetics equation is used for data fitting of adsorption of corn stalk on PCP under different modification conditions, and calculation of equilibrium adsorption capacity and adsorption rate constant (Table 3). From Table 3, it is found that the correlation coefficient R^2 of experimental data and model is high, indicating that the pseudo-first-order kinetics equation is suitable for describing the kinetics process of adsorption of corn stalk on PCP. Under three modification treatments (alkali treatment, pyrolysis, graft copolymerization) and non-modification of corn stalk, the change trend of equilibrium adsorption theoretical value (q_e) calculated by the equation is close to that of experimental value, and the adsorption rate constant (k_2) also gradually increases, which indicates that both the adsorption amount and adsorption rate of modified corn stalk on PCP increase[6]. It is consistent with the actual adsorption test results of corn stalk on PCP.

Table 3 Kinetics equation fitting parameters of adsorption of corn stalk on PCP

Parameters	Modification methods			
	Non-modification	Alkali treatment	Pyrolysis	Graft copolymerization
q_e(mg/g)	5.6000	14.7000	18.5000	24.2000
k_1(min^{-1})	0.0209	0.0276	0.0291	0.0312
R^2	0.9262	0.9294	0.9483	0.9720

4 Conclusions

In this paper, we study the impact of modification on the PCP adsorption of corn stalk. When the corn stalk is unmodified, the PCP adsorption amount is 5.4 mg/g but the PCP removal rate is only 21.6%. After alkali treatment, pyrolysis and graft copolymerization on corn stalk, the equilibrium adsorption amount of PCP is increased to 13.9 mg/g, 17.8 mg/g and 22.5 mg/g, respectively, while the PCP removal rate is increased to 55.7%, 71.2% and 89.8%, respectively. The PCP adsorption amount and adsorption rate constant of modified corn stalk are significantly higher than those of unmodified corn stalk, and the modification effect is in the order of graft copolymerization > pyrolysis > alkali treatment.

References

[1] LAN SH, ZHANG H, LAN HX, *et al*. Effect of additional carbon concentration on PCP degradation by micro-aerobic magnetic activated sludge [J]. China Pulp & Paper, 2017, 36(1):42-46. (in Chinese).

[2] HAN FT. The harm of maize straw burning and comprehensive control measures [J]. Modern Agricultural Sciences and Technology, 2015 (19):234-234. (in Chinese).

(To page 54)

References

[1] Science and Technology Department, China Rural Technology Development Center Group. Water-saving agriculture in China [M]. Beijing: China Agricultural Science and Technology Press,2006. (in Chinese).

[2] TANG SZ, HU XT, CAI HJ, *et al.* New ideas and development tendency of theory for water saving in modern agriculture and ecology[J]. Journal of Hydraulic Engineering, 2004,12(12):1 -7. (in Chinese).

[3] YAN X. Study on the high efficient utilization of nutrient resources and the status quo of the chemical fertilizer utilization in China[D]. Beijing: Chinese Academy of Agricultural Sciences, 2008. (in Chinese).

[4] ZHANG YM, ZHANG JB, HU CS, *et al.* Effect of fertilization and irrigation on wheat-maize yield and soil nitrate nitrogen leaching in high agricultural yield region in North China Plain[J]. Chinese Journal of Eco-Agriculture, 2011,19(3):532 -539. (in Chinese).

[5] HUANG L, GAO Y, XIU XQ, *et al.* Effects of irrigation amount and stage on yield and water consumption of different winter wheat cultivars [J]. Transactions of the Chinese Society of Agricultural Engineering, 2013, 29(14): 99 -108. (in Chinese).

[6] DETTORI M, CESARACCIO C, MOTRONI A, *et al.* Using CERES-wheat to simulate durum wheat production and phenology in Southern Sardinia, Italy[J]. Field Crops Research, 2011,120(1): 179 -188.

[7] PAOLO ED, RINALDI M. Yield response of corn to irrigation and nitrogen fertilization in a Mediterranean environment [J]. Field Crop Research, 2008, 105(3):202 -210.

[8] HE JQ, DUKES MD, HOCHMUTH GJ, *et al.* Evaluation of sweet corn yield and nitrogen leaching with CERES-maize considering input parameter uncertainties[J]. Transactions of the ASABE, 2011, 54(4): 1257 -1268.

[9] MA DH, ZHAO CX, WANG YF, *et al.* Effects of nitrogen fertilizer rate and post-anthesis soil water content on photosynthetic characteristics in flaa leaves and yield of wheat[J]. Acta Ecologica Sinica,2008,28(10): 4896 -4901. (in Chinese).

[10] HAN ZJ, YU ZW, WANG D, *et al.* Effects of supplemental irrigation based on measured soil moisture on nitrogen accumulation, distribution and grain yield in winter wheat[J]. Acta Ecologica Sinica,2011,31(6): 1631 -1640. (in Chinese).

[11] YANG XL, LU YL, TONG YA, *et al.* Effects of long-term N application and straw returning on N budget under wheat-maize rotation system[J]. Plant Nutrition and Fertilizer Science,2013,19(1):65 -73. (in Chinese).

[12] DUAN WX, YU ZW, ZHANG YL, *et al.* Effects of supplemental irrigation on water consumption characteristics and dry matter accumulation and distribution in different spike-type wheat cultivars based on testing soil moisture[J]. Acta Phytoecologica Sinica, 2010,34(12):1424 -1432. (in Chinese).

[13] TANG L, MI GH, ZHANG FS. Assimilation, distribution and regulation of C^{14} in winter wheat grouting period[J]. Journal of China Agricultural University, 2000,5(1):75 -79. (in Chinese).

[14] JIANG GY, WEI JJ, LIU P, *et al.* Spring wheat growth and water use efficiency under drip irrigation[J]. Agricultural Research in the Arid Areas, 2012,30(6):50 -54. (in Chinese).

[15] DANG JY, PEI XX, WANG JA, *et al.* Effects of irrigation time on the growth and water -fertilizer use efficiencies of winter wheat[J]. Chinese Journal of Applied Ecology, 2012, 23(10):2745 -2750. (in Chinese).

[16] LI YL, XIE YH, HONG JP, *et al.* Effects of nitrogen application rate on photosynthetic characteristics, yield, and nitrogen utilization in rainfed winter wheat in southern Shanxi[J]. Acta Agronomica Sinica, 2013, 39(4): 704 -711. (in Chinese).

[17] ZHANG YL, YU ZW, ZHENG CY, *et al.* Effects of different irrigation treatments on water consumption characteristics and grain starch components accumulation in strong gluten wheat Jimai 20[J]. Scientia Agricultura Sinica,2009,42(12):4218 -4227. (in Chinese).

[18] ZHAO XF, WANG LJ, LI RQ, *et al.* Effect of irrigation times and nitrogen application rate on population dynamics and grain yield of winter wheat[J]. Journal of Triticeae Crops,2009,29(6):1004 -1009. (in Chinese).

[19] YANG XL, LU YL, TONG YA, *et al.* Effects of long-term N application and straw returning on N budget under wheat -maize rotation system [J]. Plant Nutrition and Fertilizer Science,2013,19(1):65 -73. (in Chinese).

[20] DANG YH, XI LH, GUO SL, *et al.* Relationship between soil nitrate, nitrogen balance and utilization in rainfed land[J]. Plant Nutrition and Fertilizer Science,2009,15(3):573 -577. (in Chinese).

[21] BAI XB, YUE SC, LI SQ, *et al.* Effects of various cultivation systems on soil water space-time dynamics and yield of rainfed spring maize[J]. Agricultural Research in the Arid Areas, 2015, 33(3): 164 -170. (in Chinese).

[22] XIE WY, ZHOU HP, GUAN CL, *et al.* Characteristics of N, P and K uptake at different growth stages of spring millet on dry land[J]. Chinese Agricultural Science Bulletin, 2009,25(3):158 -163. (in Chinese).

[23] SHEN RK, WANG K. Field test and study on yield, water use and N uptake under varied irrigation and fertilizer in crops[J]. Transactions of the Chinese Society of Agricultural Engineering, 2001,17(5):40 -43. (in Chinese).

[24] ZHAO JY, YU ZW. Effects of nitrogen fertilizer rate on uptake, distribution and utilization of nitrogen in winter wheat under high yielding cultivated condition[J]. Acta Agronomica Sinica,2006,32(4):484 -490. (in Chinese).

[25] ZHANG DS, DONG XY, LIU SQ. Effect of different nitrogen application on growth and nitrogen metabolic indices of spring wheat[J]. Acta Agriculturae Boreali-Sinica, 2006,21(B11):42 -45. (in Chinese).

[26] WANG Y, BAI LX, ZHAO J, *et al.* Dynamic variations of soil moisture and water use efficiency of maize under sprinkler irrigation[J]. Transactions of the Chinese Society of Agricultural Engineering,2012,28(S1): 92 -97. (in Chinese).

(From page 46)

[3] FENG LS, LI CH, LIU HY, *et al.* Study on properties of removing dyes from aqueous soulution by taking maize straw as adsorbent [J]. Journal of Anhui Agricultural Sciences, 2010, 38(24):13325 -13328. (in Chinese).

[4] TANG S, CHEN Y, XIE R, *et al.* Preparation of activated carbon from corn cob and its adsorption behavior on Cr(VI) removal [J]. Water Science & Technology, 2016, 73(11):2654 -2661.

[5] HUANG H, WANG YX, TANG JC, *et al.* Properties of maize stalk biochar produced under different pyrolysis temperatures and its sorption capability to naphthalene [J]. Environmental Science, 2014, 35(5):1884 -1890. (in Chinese).

[6] CHEN S, YUE Q, GAO B, *et al.* Removal of Cr(VI) from aqueous solution using modified corn stalks: Characteristic, equilibrium, kinetic and thermodynamic study[J]. Chemical Engineering Journal, 2011, 168(2):909 -917.