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A prediction model for equilibrium adsorption capacity of the saline soil in the estuary region of Yangtze River

A.J. Shao, S.W. Wang*, D.Y. Sun

Hebei GEO University, Hebei,China

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In order to study the changes of water and salt in the estuary region of Yangtze River, the composition and the proportion of the salt in Yinyang and Daxing were determined by long-term monitoring. To understand the relationship between the salt in the soil and in external solutions in these areas, adsorption experiments of the soil samples in Yinyang and Daxing at different concentrations (0~10g/L) were carried out. The adsorption capacity of the soil in these areas is negative, which means that the soils in these areas are mainly desorbed in solutions with concentrations in the range of 0~10g/L. It is found that these soils are well described by using the Freundlich linear isothermal formula. The fitting formula provides a kind of guidance for future production practice.

Keywords: estuary region of Yangtze River, adsorption; desorption, saline soil, Freundlich model

INTRODUCTION

Adsorption is a process in which the solute is transferred from a liquid phase to a solid surface by ion exchange, while desorption is the opposite process in which the ions of a substance in the solid phase enter the liquid phase [1]. Adsorption reduces the concentration of the substance in the solution and desorption increases its concentration in the solution. Adsorption and desorption are two opposite processes of the same chemical function, so they can share the same predictive model.

The adsorption process is extremely complex and has important theoretical significance and application value [2-5]. Since the 1970s, scholars at home and abroad have done a lot of researches on solute adsorption characteristics of saturated soil and unsaturated soil, and established the corresponding adsorption model. The most commonly used adsorption models are Langmuir adsorption model and Freundlich adsorption model [6-12]. The adsorption and desorption of solute are mainly related to the concentration of solute in the solid phase and in the liquid phase. The mathematical expression of the reaction concentration relation is the adsorption mode. However, because of the complexity of the adsorption process, many problems are still unclear. So it is impossible to accurately construct the expression of the whole adsorption process. Researchers usually use empirical expressions to describe the adsorption progress.

The Freundlich adsorption model belongs to the linear isothermal adsorption formula, which has the advantages of a smaller number of parameters and a better effect [13-15]. So the Freundlich adsorption model was chosen to determine the parameters of the saline soil in the Changjiang estuary, which can reduce the workload of adsorption experiments and provide some guidance for production practice.

STUDY AREA

The estuary region of Yangtze River covers up to Anhui Datong and down to the Subaqueous Delta front. The full length is around 700 km. There is northern subtropical monsoon climate in this area, which has long sunshine time and abundant rainfall. Rainfalls are mainly concentrated from May to September, which accounts for more than 60% of the annual rainfall. From February to June and in September, the rainfall is larger than the evaporation, which decreases the salt content in the soil. In the other months, evaporation is higher than the rainfall, which increases the salinity of the soil. The solute concentrations in the soil are in a dynamic change process.

In order to study the change of water and salt in the estuary region of Yangtze River, the Yinyang town and Daxing town in Jiangsu province were monitored. The distance between Yinyang and the estuary region of Yangtze River is 4 km. The distance between Daxing and the estuary region of Yangtze River is 22 km. The monitoring surface directions are nearly north-south and perpendicular to the river dike or parallel to the adjacent river. There are 3 monitoring points from south to north at a distance from the river embankment of 200 m, 500 m and 1000 m, respectively (Fig. 1). The salt content of soil was determined by a salt sensor every five days and the water salinity of the Yangtze river was determined by a conductivity meter every five days. The chemical composition (eight ions) of soil salt content was determined twice a year in May and October, respectively.

*) To whom all correspondence should be sent:

E-mail: wsw84946108@163.com

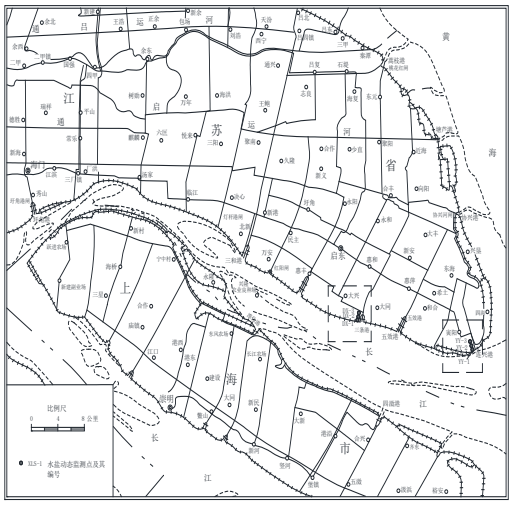

Fig. 1. Layout of monitoring section

EXPERIMENTAL

Based on the measured results of the water and salt in the estuary region of Yangtze River, the groundwater is composed of HCO^{3-}, Cl^{-}, SO_4^{2-}, K^{+}, Na^{+}, Ca^{2+}, Mg^{2+}. Therefore, according to the proportion of these 8 ions the solution was configured to simulate the impact of groundwater on soil adsorption. The chemical composition of the solution is shown in Table 1.

After drying and filtering the soil of Yinyang and Daxing, 100 g samples of soil were added into wide-mouth bottles. According to the soil:water ratio of 1:0.5 (close to saturated water content), then 50 mL of solutions of concentration of 0 g/L, 0.5 g/L, 1 g/ L, 2 g/L, g/L, 6 g/L, 10 g/L were added to the soils under stirring with glass rods. The wide-mouth bottles should be placed in a room with a small temperature change after capping the lid. The solution concentration was measured after the adsorption reached the equilibrium.

According to the previous data [13], the solution adsorption can achieve equilibrium in 20 days. Therefore, the samples were allowed to stay for 20 days, and then the soil solution was centrifuged out. The concentration of the solutions was determined by conductivity method (Table 2). The conductivity and solution concentration were fitted (Fig. 2).

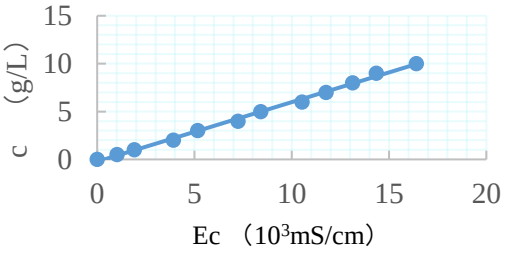

Fig. 2. Relationship between conductivity and solution concentration..

The empirical formula of conductivity and solution concentration is as follows:

$$c=0.6209Ec-0.2282 \quad R=0.998 \qquad (1)$$

In this formula, c is solution concentration (g/L), Ec is electrical conductivity (mS/cm). The adsorption capacity of salt in soil can be calculated by formula (2).

$$S = \frac{\omega(c_0+c_1-c)}{m} \qquad (2)$$

In this formula, S is the amount of salt adsorbed by the soil, that is, the quantity of salt adsorbed by the dry soil of the unit mass (g/kg); ω is the volume of the solution (in this study is 50 ml); m is the soil sample mass (in this study is 100 g); c is the concentration of the soil solution when it is balanced (g/L); c0 is the concentration of soil solution when adding distilled water (solution concentration is 0 g/L and c1 is the concentration of the added solution (0.5g/L, 1 g/ L, 2 g/L, 4 g/L, 6 g/L, 10 g/L). When S is positive, it indicates that the soil sample has adsorbed salt from the solution. When S is negative, it indicates that the salt in the soil sample desorbs into solution.

Table 1. Chemical composition of solution

Chemical composition	Molecular weight	Proportional/mol	100 mmol/L mass g	10g/L mass g	10L mass concentration 10g/L
$CaCl_2$	110.99/2	10	0.555	0.9609	9.609
Na_2SO_4	142.04/2	10	0.7102	1.2295	12.295
$MgCl_2$ （$6H_2O$）	203.31/2	15	0.712 （1.5248）	1.2335 （2.6398）	26.398
NaCl	58.4/2	65	3.4986	6.5761	65.761
Total		100	5.776 （6.5886）	10 （11.4063）	114.063

Note: The data in brackets are the quality plus $6H_2O$.

Table 2, Conductivity of solution at different concentrations

c (g/L)	0	0.5	1	2	3	4	5	6	7	8	9	10
Ec (10^3mS /cm)	0.005	1.010	1.910	3.920	5.165	7.230	8.400	10.530	11.765	13.125	14.340	16.400

Table 3. Results of adsorption experiments

Preparation of solution concentration c_1	g/L	0	0.5	1	2	4	6	10
Yinyang	c (g/L)	3.252	3.786	4.398	5.524	7.710	9.849	13.835
	S (g/kg)	0.000	-0.017	-0.073	-0.136	-0.229	-0.299	-0.292
Daxing	c (g/L)	0.311	0.845	1.482	2.510	4.832	6.953	11.293
	S (g/kg)	0.000	-0.017	-0.086	-0.099	-0.260	-0.321	-0.491

The dry soils of Yinyang and Daxing were respectively added to seven different concentrations of solutions. Every specimen has a parallel sample, and the experimental results were obtained by the arithmetic average value. The results of the adsorption experiment are shown in Table 3.

The saline soil adsorption amounts s of Yinyang and Daxing are negative, indicating that the saline soils in these areas mainly desorbed in the solutions of 0~10 g/L concentration. The amount of desorption increases as the solution concentration increases. The increasing rate of desorption of the saline soil in Daxing is greater than in Yinyang.

MODEL

The concentration of soil solution was tested compared with the concentration of soil solution when distilled water was added. So the desorption amount of the soil sample should be subtracted from the value in the distilled water when the data are collated. The adsorption amount of salt in the solution was fitted with the solution concentration (Fig.3).

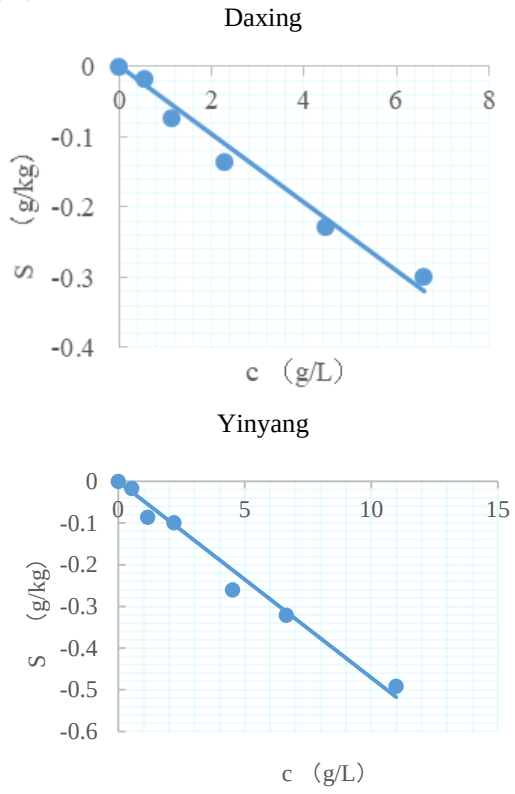

Fig. 3. Relationship between desorbed quantity and solution concentration

The desorption amount of Yinyang and Daxing soil sample is linearly related to solution concentration, which conforms to Freundlich linear isothermal adsorption formula. The linear model of soil in Yinyang area is S=-0.0484c, R=0.99. The linear model of soil in Daxing is S=-0.0471c, R=0.99. Both of them fit well with Freundlich linear isothermal adsorption formula.

CONCLUSION

(1) In this paper, the salinity changes of two observation points (Yinyang and Daxing) in the estuary region of Yangtze River were observed for *a long time, and the main composition and proportion of salt in the area were obtained.

(2) The adsorption experiment of the soil in Yinyang and Daxing area was carried out, and the adsorption of the soil was calculated by conductivity method. The adsorption amount of the soil in the 0~10g/L solutions of Yinyang and Daxing area are negative, which indicates that the soil in 0~10g/L solution is the desorption process in this area.

(3) The adsorption models of saline soil in Yinyang area and Daxing area fit Freundlich linear isothermal adsorption formula well

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МОДЕЛ ЗА ПРЕДСКАЗВАНЕ НА РАВНОВЕСНОТО АДСОРБИРАНО КОЛИЧЕСТВО ОТ СОЛЕНА ПОЧВА В ЕСТУАРНАТА ОБЛАСТ НА РЕКА ЯНЦЗЕ

А. Шао, Ш. Уанг*, Д. Сун

ГЕО университет на Хебей, Хебей, Китай

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(Резюме)

За изучаване на промените във водата и солеността в естуарната област на река Янцзе са проследени дългосрочно съставът и съотношението на солите в районите на градовете Инянг и Даксинг. За установяване на връзката между съдържанието на сол в почвата и във водите в тези райони са проведени адсорбционни опити с почвени проби от Инянг и Даксинг при различни концентрации (0~10g/L). Адсорбционният капацитет на почвите в тези райони е негативен, което означава, че тези почви основно се десорбират в разтворите с концентрация в областта от 0~10g/L. Установено е, че тези почви се описват добре с линейната изотермна формула на Freundlich. Тази формула дава основа за бъдеща производствена практика.