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Effects of simulation leakage of CCS on physical-chemical properties of soil

Junjie Ma[a,*], Xiaoli Zhu[a], Dapeng Liu[a], Sha Wang[a], Lu Xue[a], Qi Li[a], Jinfeng Ma[a], Xiaochun Li[a], Lijuan Nie[a], Xuefeng Zhao[a], Bo Qi[a], Yinmao Wei[a], Shaojing Jiang[b], Huagui Yu[b], Chunxia Huang[b]

[a] *College of Urban and Environmental Science, Northwest University, Xi' an, 710127, China*
[b] *Research Institute of Shanxi Yanchang Petroleum Co. Ltd., Xi' an, 710075, China*

Abstract

Because of the risk of leakage with CCS (Carbon Capture and Sequestration) projects, the near surface ecological impact is considered to be an important area on CCS. In order to research soil impact of CCS, physical-chemical properties of soil were analyzed through the simulation in CO_2 artificial climate chamber. The results showed as follows: Soil particle size distribution and the concentrations of heavy metal have no significant impacts with the elevated of CO_2 concentration. All ionic concentration except HCO_3^- descended slightly at low concentration and increased obviously at high concentration with the elevating of the CO_2 concentration. HCO_3^- and pH had no obvious variation with the change of the CO_2 concentration. AHN, TN, AP, TP and AK of soil had a slightly increasing with the elevating of CO_2 concentration. But AHN/TN, AP/TP had no significant change with the elevating CO_2 concentration.

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Keywords: CCS; risk; effect; soil properties.

1. Introduction

With the increasing emphasis on GHG abatement, it is imperative for many industry companies to take measures to cut down their CO_2 emissions, or capture the CO_2 emitted and sequester it [1]. CCS is considered as one of the most effective way to control the CO_2 emissions [2]. CCS includes three process: capturing CO_2 from power plants or industrial processes, transporting captured and compressed CO_2 (usually in pipelines), and injecting and storing it in

* Corresponding author. Tel.:.+86-29-88308421; fax: +86-29-88308428.
E-mail address: mjj@nwu.edu.cn

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deep formation or deep sea. Currently, many researchers have focused on CCS technology. However, few studies were reported about the risks induced by CO_2 leakage especially the risks of ecological environment impact on high concentration of CO_2.

Soil is the basic element of ecosystem. Soil Changing can lead to changes in other elements of the ecosystem [3]. CO_2 geological storage is the most important way in currently experimental studies and project implementation. If CO_2 leaked out to the surface from stored formation, soil physical-chemical properties would be affected firstly, and other factors would be impacted as well as especially crop. Therefore, the impact research on soil properties with high concentrations of CO_2 in CCS is an important subject.

2. Materials and measurement methods

2.1. Soil samples

Soil samples were come from the pots in which 4 kinds of C_3 crops (green beans, soybeans, buckwheat and potatoes) were cultivated 30days in CO_2 artificial climate chamber on normal atmospheric, 10000μmol/mol, 20000μmol/mol, 40000μmol/mol and 80000μmol/mol of CO_2 concentrations. The original soil cultivated C_3 crops were sampled from the farmland in Jingbian County, CO_2 injection test area of Shaanxi Yanchang Petroleum Co. Ltd.. The soil type belongs to regosols on Loess Plateau, and was named as Huangmiantu soil. Its texture is sandy loam.

In order to ensure water and fertilizer demands of the crop in the course of potted plants, the pots were watered once every 2-3 days and fertilized once a week. Fahraeus plant nutrient solution which was selected as the fertilizer and was fertilized 15ml one times [4].

2.2. Indicators and analysis methods

The soil physical-chemical properties include the indicators of soil texture, cations and anions of soil, soil fertility and soil heavy metal. According to international soil texture classification，soil particle size were classified to <0.001mm, 0.001-0.002mm, 0.002-0.005mm, 0.005-0.01mm, 0.01-0.02mm, 0.02-0.05mm, 0.05-0.1mm, 0.1-0.2mm and 0.2-0.25mm. Cations and anions of soil include K^+, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, HCO_3^- and SO_4^{2-}. Soil fertility indicators include total N, alkali-hydrolyzable N(AHN), available P(AP) and total P(TP) and available K(AK). Soil heavy metal include total Cu (TCu), total (T Zn), total Pb (TPb), total Cr (TCr), total Cd (TCd), total As (TAs), total N_i (TN_i) and total Hg (THg). Other indicators include pH, organic matter (OM) and cation exchange capacity (CEC).

Soil particle size distribution were analyzed using laser particle size analyzer (WJL-602, Shanghai, China). Soil cations and anions, cation exchange capacity(CEC), organic matter(OM), total N, alkali-hydrolyzable N, available K, available P and total P, contents of some heavy metal were detected by ICP-MS (X SERIES 2, Waltham, USA), X-ray spectrometer (Axios, Almelo, The Netherlands)，Atomic Fluorescence Spectroscopy (AFS-230, Beijing, China) respectively. pH were detected using pH meter (pHS-3C, Shanghai, China).

2.3. Soil samples

A set of data on soil physical-chemical properties of each planting crop can be analyzed under different CO_2 concentration gradient. By means of excluding irrelevant data, the average values were calculated for soil samples that cultivated four kinds of C_3 crops on different CO_2 concentration.

3. Results and discussions

3.1. Soil particle size distribution

The results of soil particle size analysis showed that the percentage of clay, silt and sand changed within 6.16-6.94%, 11.93-13.75% and 79.30-82.28% respectively (Fig.1). The texture type of all soil samples were all belonged to sandy loam. The changing of CO_2 concentration had no significant impacts on soil particle size distribution [5]. CO_2 as a weak acid gas had not enough ability to affect soil particles.

3.2. Soil nutrients

The analysis results of soil nutrients showed that the concentration of N and P of soil had a slightly increasing with the elevating of CO_2 concentration in the pots of the climate chamber after 30days planting. But the concentration of available K of soil had significant changes with the elevating of CO_2 concentration.

Both alkali-hydrolyzable N and total N had a small rise in pace with CO_2 elevation. But the ratio of alkali-hydrolyzable N and total N had no significant change with the elevating CO_2 concentration (Fig.2).

Along with the increasing of CO_2 concentration, both available P and total P had a small rise. Because the available P increased more obviously than total P, the trend of available P / total P increased with the elevating CO_2 concentration (Fig.3).

When CO_2 concentration is smaller than 20000μmol/mol, the concentration of available K had no distinctive change with the control group. But when CO_2 concentration is greater than 40000μmol/mol, the concentration of available K suddenly become to two times of the control group (Fig.3). On the contrary, CEC of soil descended with the increase of CO_2 concentrations. OM of soil had not be affected by changes of CO_2 concentration (Fig.4).

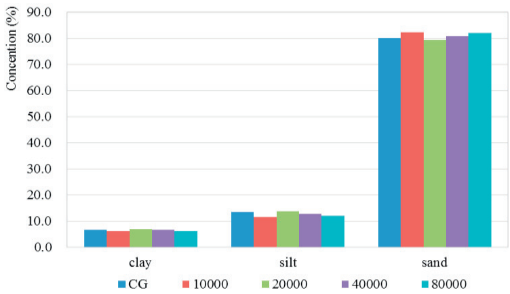

Fig. 1. The percentage of particle size under different CO_2 concentration

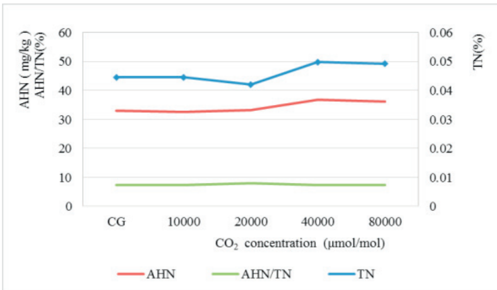

Fig. 2. Content of alkali-hydrolyzable N, total N and alkali-hydrolyzable N/total N under different CO_2 concentration

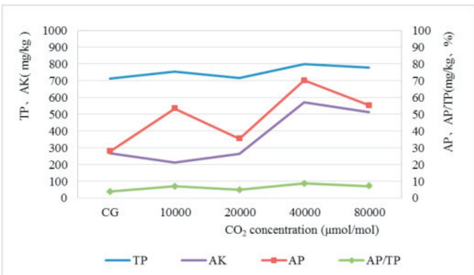

Fig. 3. Content of available P, available K, total P and available P/total P under different CO_2 concentration

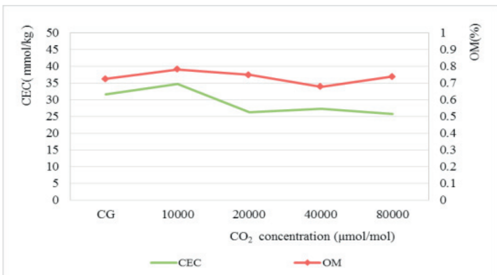

Fig. 4. Content of available K, CEC and OM under different CO_2 concentration

N, P and K are important nutrients of crop. Alkali-hydrolyzable N, available K, and available P are mainly impacted by reduced uptake of crop at 40000μmol/mol and 80000μmol/mol. The high concentration of total N and total P can be explained by the reducing of OM decomposition rates resulted from low level of oxygen in soil air at 40000μmol/mol and 80000μmol/mol. The no significant change of AHN/TN, AP/TP and OM can be explained by the similar original matters and decomposition mechanisms.

3.3. Concentrations of cations and anions

The soil ionic concentrations of soil had different trends with the elevating of CO_2 concentration (Fig.5). All ionic concentration except HCO_3^- descended slightly at low concentration and increased obviously at high concentration with the elevating of the CO_2 concentration. The concentration of SO_4^{2-}, Ca^{2+}, Na^+, K^+ and Cl^- reached the minimum value at 10000μmol/mol of CO_2 concentration. Only Mg^{2+} reached the minimum value at 20000μmol/mol. When CO_2 concentration were greater than 20000μmol/mol, The concentration of SO_4^{2-}, Ca^{2+}, Na^+ and Mg^{2+} increased more significantly than that of K^+ and Cl^- with the elevating of the CO_2 concentration. HCO_3^- concentration and pH had no obvious variation with the change of the CO_2 concentration.

Soil ions are the most active components. Their concentrations were controlled by many balance systems, i.e. acid-base system, redox system, colloidal system, soil-plant system etc. When CO_2 of soil air is increased gradually, the concentration of CO_2 in soil solution will be synchronized rise, pH of soil solution will be reduced[5]. But because of the existing of colloidal system on base saturation and ion exchanges of soil colloid and soil solution, the base cations come from colloid surface can prevent the reducing of pH in soil solution. These are the reasons when the CO_2 concentration rose from normal concentration (380μmol/mol) to 80000μmol/mol, soil pH were only reduced 0.1unit, and the cations of Na^+, K^+, Ca^{2+}, Mg^{2+} were risen rapidly. The minimum of Ca^{2+}, Na^+, K^+ at 10000μmol/mol and Mg^{2+} at 20000μmol/mol were corresponded to the most vigorous growth of C_3 crops at, i.e. the cations were the most obviously absorbed by crops as nutrients at 10000μmol/mol of CO_2 concentration[6].

Among the anions of soil solution, SO_4^{2-}, Cl^- had simulate rules with the cations that were corresponded to the situation of crop growth. But HCO_3^- and pH had no distinguish with the changes of CO_2 concentration. The reasons were still need further study.

3.4. Concentrations of some heavy metal

All heavy metals were not distinctly impacted with the elevating of CO_2 concentration (Fig.6). But there were different ways affected by CO_2 for different heavy metals. Compared with the control group, total Zn and total As increased slightly with the increasing of CO_2 concentration. On the contrary, total Cr and total Ni decreased slightly with the increasing of CO_2 concentration. Total Cu, total Pb, total Cd and total Hg kept balance at all CO_2 concentration. These are obviously related with that heavy metals are almost exist within soil particles.

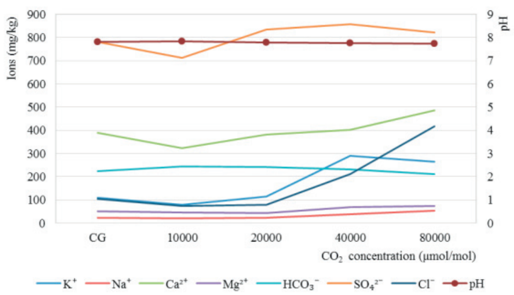

Fig.5. Concent of soil cations and anions under different CO_2 concentration

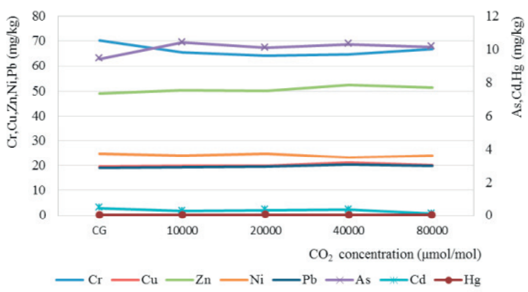

Fig.6. Contents of heavy metals under different CO_2 concentration

4. Conclusion

(1) Soil particle size distribution and the concentrations of heavy metal have no significant impacts with the elevated of CO_2 concentration.

(2) All ionic concentration except HCO_3^- descended slightly at low concentration and increased obviously at high concentration with the elevating of the CO_2 concentration. HCO_3^- and pH had no obvious variation with the change of the CO_2 concentration.

(3) AHN, TN, AP, TP and AK of soil had a slightly increasing with the elevating of CO_2 concentration. But AHN/TN, AP/TP had no significant change with the elevating CO_2 concentration.

(4) Because the demand quantity of soil tested was too much, different batches of soil may exist tiny difference.

Acknowledgements

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