



*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](mailto: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.*

# Research Advance on Carbon Storage of Artificial Grassland in China

Fuping TIAN<sup>1\*</sup>, Yongjie SHI<sup>1</sup>, Yu HU<sup>1</sup>, Zixuan CHEN<sup>2</sup>, Yuan LU<sup>1</sup>, Xiaofu ZHANG<sup>1</sup>, Runlin LI<sup>1</sup>

1. Lanzhou Institute of Husbandry and Pharmaceutical Sciences of CAAS/The Lanzhou Scientific Observation and Experiment Field Station of Ministry of Agriculture for Ecological System in Loess Plateau Areas, Lanzhou, 730050, China; 2. Institute of Biotechnology, Gansu Academy of Agricultural Sciences, Lanzhou 730070, China

**Abstract** As an essential part of the grassland ecological system, study on the carbon storage has great significances to the carbon reduction in grassland ecological system. The carbon storage in biomass, carbon storage in soil and soil respiration are summarized in this paper to provide scientific reference for the evaluation of carbon storage in artificial grassland.

**Key words** Artificial grassland, Carbon storage, Organic carbon in soil, Land Respiration

Global climate change and the increase of carbon have won worldwide attention<sup>[1]</sup>. The land plant turns CO<sub>2</sub> in the atmosphere into organic carbon through photosynthesis, some going into the atmosphere in the form of CO<sub>2</sub> while others penetrating into the land through withered leaves<sup>[2]</sup>. Grassland is one of the most important part of the ecological system and plays an important role in the global carbon circulation and climate changes<sup>[3–4]</sup>. Accounting for 40% of the global land, the Chinese grassland, as a large carbon bank, has saved 145.5 × 10<sup>6</sup> t<sup>[5]</sup> of biomass in average, which plays an essential role in the carbon circulation of the ecological system on land in China<sup>[6–7]</sup>. The artificial grassland plays a significant role in the agricultural and husbandry development in China. Therefore, it is essential to study the influence of carbon storage on the ecological system, and the accuracy of carbon balance. In recent years, Chinese scholars have done much research about the carbon circulation on the grassland<sup>[8–10]</sup>. However, there are few studies on the carbon circulation. Especially in recent 30 years, with the expansion of artificial grassland, there should be more and more studies on the carbon circulation in the grassland ecological system<sup>[11–12]</sup>. Considering the carbon storage in the grassland in China and abroad, this paper analyzed the studies about the carbon storage in the grassland in China, hoping to provide reference to the evaluation of carbon income and expense in the artificial grassland in China and carbon mechanism.

## 1 Study on the carbon storage of biomass in the artificial grassland

The plants on the artificial grassland in China include *Medicago*

*sativa*, *E. dahuricus*, *Elymus sibiricus*, *A. adsurgens*, *Melilotus officinalis*, *Lolium perenne*, *Astragalus sinicus*, *Onobrychis viciifolia*, *Coronilla varia*, *Trifolium alexandrinum*, *Bromus inermis*, *Agropyron cristatum*, *Lotus corniculatus*, *Festuca arundinacea* Schreb, *Avena sativa*, *Vicia sativa*, *Vicia villosa*, *Sorghum sudanense* (Piper) Stapf., *Lathyrus sativus*. *Medicago sativa* is the kind of fodder which is the most widely cultivated. Since the 21<sup>st</sup> century, *Medicago sativa* has been planted for 2.3 million to 2.6 million hm<sup>2</sup><sup>[13]</sup>, which accounts for 78.5% of the general artificial grassland in China<sup>[14]</sup>. So far, most studies are about *Medicago sativa*<sup>[15]</sup>. The carbon energy is related to the vegetation and soil types<sup>[16]</sup>. The artificial grass plantation can greatly improve and recover the carbon consolidation capacity<sup>[17]</sup>.

The carbon storage in the artificial grassland is closely related to the production power and biomass on the grassland. The carbon storage in the artificial grassland includes vegetation carbon storage and organic carbon storage in the soil. As an essential part of the ecological system, the carbon storage in the grassland concentrates on the soil layer, and includes underground biomass carbon storage and organic carbon storage in the soil<sup>[18]</sup>. Study on the biomass and accumulation of carbon element has significant roles in the evaluation of climate changes<sup>[19]</sup>. The data of biomass is the fundamental prerequisite of the carbon density and carbon storage. The biomass of artificial grassland directly influences its carbon storage. If the grassland quality increases, its assimilated carbon is larger than the amount it releases. On the contrary, the artificial grassland would become a huge carbon source, which would aggravate the global warming and greenhouse effect. The root is an essential carbon source and the artificial grassland is the main source of carbon in the soil. The biomass in the underground is two to five times of that on earth<sup>[20]</sup>. The fixed amount of carbon in the underground may be an essential part of the global carbon collection<sup>[21]</sup>. The carbon being transmitted from the root to the soil is larger than that in the leaves which are fell onto the ground. The carbon amount in the soil is huge and its relation to the bio-

Received: June 16, 2013 Accepted: August 26, 2013

Supported by National Basic Research Program of China (2010CB951502); Scientific Research Program of Public Welfare for Agriculture (201203006); The Planning Subject of 12th Five – Year Plan in National Science and Technology for the Rural Development in China (2012BAD13B07); The Central Public Research Institutes for Basic Research Funds Projects (BRF1610322012009).

\* Corresponding author. E-mail: chenxv@163.com

mass is worth studying<sup>[22–23]</sup>. The influences of different plants on the nutrition transition and microorganism are different<sup>[24]</sup>. The fallen product can enhance the organic material in the soil and the carbon amount in the microorganism in the soil<sup>[25]</sup>. Li Linghao has pointed out that there are few studies on the things which are fell onto the ground<sup>[27–28]</sup>.

## 2 Study on the organic carbon in the artificial grassland

The organic carbon in the soil is an essential part of the carbon bank on the land and is a key in the study of global carbon circulation and global changes<sup>[29]</sup>. The organic carbon storage in the soil refers to the amount of organic carbon in the soil of 1 m deep<sup>[30–31]</sup>. However, some soils are too thin to calculate, so it should be calculated based on depth<sup>[32]</sup>. The organic carbon in the soil is the material basis of the fertility of soil and the core in the study of global carbon circulation and climate changes<sup>[33,34]</sup>. The organic material of soil influences the soil structure and fertilizer, which directly leads to the reduction of agricultural productivity and environmental quality<sup>[35]</sup>. The active organic carbon refers to the reaction of some components towards the general organic carbon, and it can be considered as the indicator of early changes of organic carbon<sup>[36]</sup>. According to the density group technology, the organic carbon in the soil can be divided into LFOC and HFOC<sup>[37]</sup>. LFOC is an intermediate carbon bank of the animals and plants residue and humus<sup>[38]</sup>, and it is considered as the indicator of the ground mass and soil fertility during the adjustment of biomass<sup>[39–40]</sup> and the changes of carbon in the soil<sup>[41]</sup>. Therefore, the study on the distribution and changes of organic carbon in soil means a lot to the carbon circulation in the system<sup>[42]</sup>. The carbon element in the grassland ecological system largely stores in the underground soil bank<sup>[43]</sup>. There are many studies about the carbon circulation in the ecological system<sup>[44]</sup>. Carbon in the soil is an effective way to ease the greenhouse effect and the carbon level is an essential indicator to balance the soil quality<sup>[45]</sup>. In recent years, there are many studies on the organic carbon in the soil and its significance<sup>[46]</sup>. Many scholars have done research on the characteristics of soil carbon under different grassland forms<sup>[47–50]</sup>. There are many studies on the organic carbon storage in China<sup>[51–53]</sup>, and some scholars focus on the changes of soil carbon<sup>[54–55]</sup>. Generally speaking, the study on the carbon storage is in the initial stage<sup>[56]</sup>, and there are limited observed data. It is difficult to reveal the actual carbon in the grassland through evaluation of the vegetation or soil types.

In recent years, there are many studies on the carbon storage through grazing of natural grass and other management measures<sup>[58]</sup>. Studies on the dynamic changes of organic carbon bank focus on the surface<sup>[59]</sup>. Xu Lijun *et al.* studied the biomass of microorganism, but the depth of soil was only 0 to 10 cm, 10 to 20 cm<sup>[60]</sup>. Studies on the carbon in the soil are not clear, which need to be observed for a long time.

## 3 Study on the microorganism in the soil of the artificial grassland

The microorganism in soil is an essential part of the ecological system, and the amount and changes of microorganism is a significant indicator of the land fertility<sup>[61]</sup>. Soil microorganism biomass refers to the general biomass which is smaller than  $5 \times 10^3 \mu\text{m}^3$ . The soil microorganism biomass include SMB – C, SMB – N, SMB – P and SMB – S in broad sense, and the microorganism means the carbon in the microorganism in the narrow sense<sup>[62]</sup>. The soil microorganism biomass, as a biological indicator, has been widely studied by scholars in China and abroad<sup>[63–64]</sup>. The carbon in the soil microorganism biomass is also considered as one of the common indicator to evaluate the soil quality and to reflect the microorganism groups<sup>[65–66]</sup>. Compared with forest and the ecological system of farmland, studies on the soil microorganism in the grassland ecological system began late<sup>[67]</sup>. Right now, most studies are about the background of soil in the grassland<sup>[68–69]</sup>. All in all, the study of the field experiment can result in a convincing argument.

## 4 Study on the respiration of soil in the artificial grassland

Soil respiration is a main way to transmit carbon into the atmosphere through the land ecological system and an important component in the carbon circulation of ecological system. In order to learn about the general situation of carbon circulation, it is necessary to study and determine the supply, accumulation, decompose and transmission of organic material in the soil and to learn about the withered leaves and soil respiration<sup>[70]</sup>. Soil respiration is a main way to study the metabolism within microorganism, the root of plants, and the chemical oxygen in soil<sup>[71]</sup>. As a main way of soil carbon expose, the soil respiration has become the key issue in the study of global carbon circulation<sup>[72]</sup>. Studies on the land respiration include farmland, grassland, forest, wetland and tundra<sup>[73–74]</sup>. Currently, people have different understanding towards the soil respiration and<sup>[75]</sup>. People have many studies on the ecological system<sup>[76–77]</sup>, and scientists in China and abroad have carried out a series of studies on the observation method, process, influence mechanism, and evaluation<sup>[78–81]</sup>. Raich *et al.* pointed out the influence of temperature and precipitation on the temporal and spatial changes of soil respiration<sup>[82]</sup>. Ryan *et al.* studied the influence of changes in land respiration on the climate and plants<sup>[83]</sup>. In conclusion, land respiration is essential to the carbon balance in ecological system<sup>[84]</sup>. The understanding of the relation between ecological system and soil respiration needs long-term field location experiment<sup>[85]</sup>. The measurement of soil respiration dates back to 1990s<sup>[86–87]</sup>. Studies on the land respiration largely focus on the influence of meteorological factors on the land respiration instead of the biological factors, which led to poor comparability<sup>[89–91]</sup>. There are few studies on the land respiration<sup>[11]</sup>. Pang Yingying *et al.* studied the daily changes and seasonal changes of land respiration<sup>[12]</sup>. Xu Lijun *et al.* measured the land respiration of different kinds of plants<sup>[92]</sup>. However, the observed data was not

systematic, especially in terms of artificial grassland<sup>[93]</sup>.

## 5 Conclusions

At present the study on the carbon storage in the artificial grassland largely focus on the *Medicago sativa*. The study of carbon storage in the artificial grassland includes carbon storage of biomass, organic carbon of soil, and microorganism of soil and land respiration. However, most studies of soil carbon storage paid attention to the surface soil<sup>[94]</sup>. Studies on the carbon storage on the grassland were mostly carried out incessantly and can not reflect the characteristics of carbon storage on the grassland. Different studies result in different evaluation values of carbon storage on the artificial grassland. The disadvantages of soil respiration in the artificial grassland are short observation time, few materials on the daily and seasonal dynamic changes and their influences on factors. Studies on the carbon storage in the artificial grassland and studies on the long-term location observation are hardly seen in China. The evaluations of carbon storage in different artificial grasslands are uncertain. In conclusion, the priority, right now, is to study the carbon storage in the grassland, to reveal the carbon consolidation mechanism, and to intensify the mechanism of reduction of carbon emission and increase of carbon storage.

## References

- [1] REN JZ, LIANG TG, LIN HL, *et al.* Study on grasslands responses to global climate change and its carbon sequestration potentials [J]. *Acta Prataculturae Sinica*, 2011, 20(2):1–22. (in Chinese).
- [2] FANG JY, GUO ZD. Looking for missing carbon sinks from terrestrial ecosystems [J]. *Chinese Journal of Nature*, 2007, 29(1): 1–6. (in Chinese).
- [3] ZHANG F, QI B, WEN F, *et al.* Analysis of the change of carbon storage in alpine arid grassland [J]. *Acta Prataculturae Sinica*, 2011, 20(4): 11–18. (in Chinese).
- [4] Scurlock J M, Olson R J. Estimating net primary productivity from grassland biomass dynamics measurements[J]. *Global Change Biol*, 2002, 8:736–753.
- [5] Li Fu-Mei, Li Xiao-Tao, Liu Wei, *et al.* Carbon and nitrogen storage in plant and soil as related to nitrogen and water amendment in a temperate steppe of northern China[J]. *Biol Fertil Soils*, 2011, 47:187–196.
- [6] Fang J Y, Guo Z D, Piao S L, *et al.* Terrestrial vegetation carbon sinks in China, 1981–2000[J]. *Sci China Ser D*, 2007, 50:1341–1350.
- [7] Piao SL, Fang JY, Ciais P, *et al.* The carbon balance of terrestrial ecosystems in China [J]. *Nature*, 2009, 458:1009–1013.
- [8] GUAN HL, GUO YZ, ZHANG YF, *et al.* Effect of different mode of alternating crop-planting on content of organic carbon and microbial biomass carbon in the soil within tobacco root regions in Yunnan, China [J]. *Journal of Agro-Environment Science*, 2011, 30(1):133–138. (in Chinese).
- [9] HOU XY, XU HH. Research on carbon balance of different grazing systems in *Stipa breviflora* desert steppe [J]. *Scientia Agricultura Sinica*, 2011, 44(14): 3007–3015. (in Chinese).
- [10] WU JX, CHENG X, JIAO JG, *et al.* Changes in land use and land cover and soil organic carbon storage in the densely populated village landscapes of China's Yangtze Plain from the 1940 to 2002 [J]. *Acta Ecologica Sinica*, 2010, 30(6): 1397–1411. (in Chinese).
- [11] XU LJ, WANG B, YU Z, *et al.* Soil respiration in fields of *Medicago sativa* L. cv. *aohan* with different growth years [J]. *Arid Zone Research*, 2009, 26(1): 14–20. (in Chinese).
- [12] PANG YY, DENG B, ZHANG YJ, *et al.* Soil respiration of alfalfa fields in the agro-pastoral ecotone of northern China and its environment on responses [J]. *Acta Agrestia Sinica*, 2011, 19(3): 732–734. (in Chinese).
- [13] HONG FZ. *Alfalfa science* [M]. Beijing: China Agriculture Press. 2009:1–2. (in Chinese).
- [14] CHENG JM, CHENG J, GAO Y. Alfalfa growth characteristics and soil water dynamics of grassland converted from cropland in semi-arid region [J]. *Acta Agrestia Sinica*, 2011, 19(4): 565–569. (in Chinese).
- [15] TAI JC, YANG HS, ZHANG GQ, *et al.* Influence of planting years on nitrogen-fixing capacity of rhizosphere and contents of carbon and nitrogen in artificial pastures of alfalfa [J]. *Chinese Journal of Soil Science*, 2010, 41(3): 603–607. (in Chinese).
- [16] JIANG LL, HAN XG, DONG N, *et al.* Plant species effects on soil carbon and nitrogen dynamics in a temperate steppe of Northern China [J]. *Plant Soil*, 2011, 346:331–347.
- [17] LIU J, LIU JM, ZHOU JH. Carbon sequestration and grassland restoration in China [J]. *Journal of Anhui Agricultural Sciences*, 2011, 39(10): 6050–6052. (in Chinese).
- [18] CHEN XP, SHANG ZH. Progress of carbon cycle research in China grassland ecosystem [J]. *Chinese Journal of Grassland*, 2011, 33(4): 99–110. (in Chinese).
- [19] LU Xuyang, YAN Yan, FAN Jihui, *et al.* Dynamics of above- and below-ground biomass and C, N, P accumulation in the alpine steppe of northern Tibet [J]. *J. Mt. Sci.*, 2011, 8: 838–844.
- [20] WU YB, CUI XY. Responses of root carbon reserves and root turnover to experimental CO<sub>2</sub> enrichment in grasslands [J]. *Acta Ecologica Sinica*, 2009, 29(1): 378–388. (in Chinese).
- [21] Hungate B A, Holland E A, Jackson R B, *et al.* The fate of carbon in grasslands under carbon dioxide enrichment [J]. *Nature*, 1997, 88: 576–579.
- [22] HU YL, WANG SL, HUANG Y, *et al.* Effects of litter chemistry on soil biological property and enzymatic activity [J]. *Acta Ecologica Sinica*, 2005, 25(10): 2662–2668. (in Chinese).
- [23] WANG CY, ZHOU JB, XIA ZM, *et al.* Effects of mixed plant residues from the Loess Plateau on microbial biomass carbon and nitrogen in soil [J]. *Acta Ecologica Sinica*, 2011, 31(8): 2139–2147. (in Chinese).
- [24] LIN KM, ZHANG ZQ, CAO GQ, *et al.* Decomposition characteristics and its nutrient dynamics of leaf litter mixtures of both Chinese fir and *Phoebe bournei* [J]. *Acta Ecologica Sinica*, 2006, 26(8): 2732–2738. (in Chinese).
- [25] WANG QK, WANG SL, YU XJ, *et al.* Effects of *Cunninghamia lanceolata*-broadleaved tree species mixed leaf litters on active soil organic matter [J]. *Chinese Journal of Applied Ecology*, 2007, 18(6): 1203–1207. (in Chinese).
- [26] LI LH. Effect of land use change on carbon storage in soil of grassland ecosystem [J]. *Journal of Plant Ecology*, 1998, 22(4): 300–302. (in Chinese).
- [27] YIN CJ, HUANG DH, CHEN ZZ. 1994. Quantitative relationships between the litter decomposition of four species in Inner Mongolia grassland and climatic factors [J]. *Acta Ecologica Sinica*, 14(2):149–154. (in Chinese).
- [28] ZHAO J, LIAO YN, ZHANG GZ. The soil microbial activity effect after the plant residues in different phenological periods and litter of *aneurolepidium* Chinese return steppe [J]. *Journal of Inner Mongolia University*, 1994, 25(3):300–304. (in Chinese).
- [29] CHEN C, LV CH, FAN L, *et al.* Effects of land use change on soil organic carbon: A review [J]. *Acta Ecologica Sinica*, 2011, 31(18): 5358–5371. (in Chinese).
- [30] CUI YQ, MA JY, LIU XN, *et al.* Effects of human activities on soil organic carbon pool [J]. *Journal of Desert Research*, 2011, 31(2): 407–414. (in Chinese).
- [31] JIANG Y, ZHUANG QL, LIANG WJ. Soil organic carbon pool and its affecting factors in farmland ecosystem [J]. *Chinese Journal of Ecology*, 2007, 26(2): 278–285. (in Chinese).
- [32] ZHU LQ, ZHU XL, LI XX. The research progress on soil organic carbon [J]. *Journal of Henan University (Natural Science)*, 2006, 36(3):72–75. (in Chinese).
- [33] Parfitt R L, Yeates G W, Ross D J, *et al.* Relationships between soil biota, nitrogen and phosphorus availability, and pasture growth under organic and conventional management [J]. *Applied Soil Ecology*, 2005, 28:1–13.
- [34] LIU X, LI FM, LIU DQ, *et al.* Soil organic carbon, carbon fractions and nutrients as affected by land use in semi-arid region of Loess Plateau of China [J]. *Pedosphere*, 2010, 20(2):146–152.
- [35] Girma Abera, Endelkache Wolde-meskel, Lars R. Bakken. Carbon and nitrogen mineralization dynamics in different soils of the tropics amended with legume residues and contrasting soil moisture contents [J]. *Biol Fertil Soils*, 2012, 48:51–66.
- [36] ZHANG G, CAO ZP, HU CJ. Soil organic carbon fractionation methods and their applications in farmland ecosystem research: A review [J]. *Chinese*

- Journal of Applied Ecology, 2011, 22(7): 1921–1930. (in Chinese).
- [37] Biederbeck V O, Janzen H H, Campbell C A, *et al.* Labile soil organic matter as influenced by cropping practices in an arid environment[J]. Soil Biology and Biochemistry, 1994, 26: 1647–1656.
  - [38] LI YM, WANG YS, CAO GM, *et al.* Preliminary research of effect of cultivation on soil organic carbon in alpine meadow [J]. Progress in Geography, 2005, 24(6): 59–65. (in Chinese).
  - [39] Barrios E, Kwesiga F, Buresh R J, *et al.* Light fraction soil organic matter and available nitrogen following trees and maize[J]. Soil Science Society of America Journal, 1997, 61: 826–831.
  - [40] D. K. Benbi, Kiranvir Brar, A. S. Toor, *et al.* Soil carbon pools under poplar-based agroforestry, ricewheat, and maize-wheat cropping systems in semi-arid India[J]. Nutr Cycl Agroecosyst., 2012, 92: 107–118.
  - [41] ZHANG JB, SONG CC. The sensitive evaluation indicators of effects of land-use change on soil carbon pool [J]. Ecological Environment, 2003, 12(4): 500–504. (in Chinese).
  - [42] DANG YA, WANG GD, LI SQ, *et al.* Distribution characteristics of soil organic carbon fractions of the typical soil types on the Loess Plateau [J]. Journal of Natural Resources, 2011, 26(1): 1890–1899. (in Chinese).
  - [43] Kitchen DJ, Blair JM, Callahan MA. Annual fire and mowing alter biomass, depth distribution, and C and N content of roots and soil in tallgrass prairie [J]. Plant Soil, 2009, 323: 235–247.
  - [44] LI LH, CHEN ZZ. The global carbon cycle in grassland ecosystems and its responses to global change I. Carbon flow compartment model, inputs and storage [J]. Chinese Bulletin of Botany, 1998, 15(2): 14–22. (in Chinese).
  - [45] YANG J, SHEN YY, NAN ZB, *et al.* 2010. Effects of conservation tillage on crop yield and carbon pool management index on top soil within a maize-wheat-soy rotation system in the Loess Plateau [J]. Acta Prataculturae Sinica, 19(1): 75–82. (in Chinese).
  - [46] Wang X H, Piao S L, Ciais P. Are ecological gradients in seasonal Q10 of soil respiration explained by climate or by vegetation seasonality[J]. Soil Biology and Biochemistry, 2010, 42(10): 1728–1734.
  - [47] Scurlock O J M, Hall D O. The global carbon sink: A grassland perspective [J]. Global Change Biology, 1998, 4: 229–233.
  - [48] LI MF, DONG YS, QI YC, *et al.* Effect of land-use change on the contents of C & N in temperate grassland soils [J]. Grassland of China, 2005, 27(1): 1–6. (in Chinese).
  - [49] KONG YH, YAO FJ, PENG S, *et al.* Study on the characteristics of soil carbon accumulation and conversion of carbon sink and source of grassland under different land use types [J]. Prataculturae Science, 2010, 27(4): 40–45. (in Chinese).
  - [50] WANG SW, YAN XY, LIN JH, *et al.* Distributions of soil organic carbon and total nitrogen under different land uses in northeast of Sanjiang Plain [J]. Soil, 2010, 42(2): 190–199. (in Chinese).
  - [51] YANG CD, LONG RJ, CHEN XR, *et al.* Characteristics of carbon, nitrogen and phosphorus density in top soil under different alpine grasslands on the eastern Qilian Mountains [J]. Chinese Journal of Grassland, 2008, 30(1): 1–5. (in Chinese).
  - [52] ZHONG HP, FAN JW, YU GR, *et al.* The research progress of carbon storage in grassland ecosystem [J]. Prataculturae Science, 2005, 22(1): 4–11. (in Chinese).
  - [53] LIU N, ZHANG YJ. Effects of grazing on soil organic carbon and total nitrogen in typical steppe [J]. Prataculturae Science, 2010, 27(4): 11–14. (in Chinese).
  - [54] RONG L, LI SJ, LI XW, *et al.* Carbon dynamics of fine root (grass root) decomposition and active soil organic carbon in various models of land use conversion from agricultural lands into forest lands [J]. Acta Ecologica Sinica, 2011, 31(1): 0137–0144. (in Chinese).
  - [55] ZHANG JH, LI GD, NAN ZR, *et al.* The spatial distribution of soil organic carbon storage and change under different land uses in the middle of Heihe River [J]. Scientia Geographica Sinica, 2011, 31(8): 982–988. (in Chinese).
  - [56] YANG HF, MU SJ, SUN CM, *et al.* Summary of research on estimation of organic carbon storage in grassland ecosystem [J]. Chinese Journal of Grassland, 2011, 33(5): 107–117. (in Chinese).
  - [57] YANG TT, WU XY, WANG JT, *et al.* Estimation of carbon storage in grassland ecosystem in China [J]. Journal of Arid Land Resources and Environment, 2012, 26(3): 127–130. (in Chinese).
  - [58] G. E. Schuman, H. H. Janzen, J. E. Herrick. Soil carbon dynamics and potential carbon sequestration by rangelands [J]. Environmental Pollution, 2002, 116: 391–396.
  - [59] Faye Raiesi. Soil properties and C dynamics in abandoned and cultivated farmlands in a semi-arid ecosystem [J]. Plant Soil, 2012, 351: 161–175.
  - [60] XU LJ, WANG B, XIN XP. 2011. Soil nutrient and microbial characteristics associated alfalfa cultivated grassland [J]. Acta Prataculturae Sinica, 19(3): 406–411. (in Chinese).
  - [61] ZHANG CX, NAN ZB. Research progress of soil microbial biomass in China [J]. Prataculturae Science, 2010, 27(6): 50–57. (in Chinese).
  - [62] HE YT, DONG YS, QI YC, *et al.* Advances in researches on soil microbial biomass of grassland ecosystems and its influencing factors [J]. Progress in Geography, 2010, 29(11): 1350–1359. (in Chinese).
  - [63] LIU MQ, HU F, HE YQ, *et al.* Seasonal dynamics of soil microbial biomass and its significance to indicate soil quality under different vegetations restored on degraded red soils [J]. Acta Pedologica Sinica, 2003, 40(6): 937–944. (in Chinese).
  - [64] WU JG, AI L. Soil microbial activity and biomass C and N content in three typical ecosystems in Qilian Mountains, China [J]. Journal of Plant Ecology, 2008, 32(2): 465–476. (in Chinese).
  - [65] Rogers B F, Tate R L III. Temporal analysis of the soil microbial community along a toposequence in Pineland soils [J]. Soil Biology and Biochemistry, 2001, 33(10): 1389–1401.
  - [66] Powlson D S, Prookes P C, Christensen B T. Measurement of soil microbial biomass provides an early indication of changes in total soil organic matter due to straw incorporation [J]. Soil Biology and Biochemistry, 1987, 19(2): 159–164.
  - [67] YAO T, MA LP, ZHANG DG. Research progress on microbiological ecology of rangeland in China [J]. Prataculturae Science, 2005, 22(11): 1–7. (in Chinese).
  - [68] MA XG, FAN LQ, LU N, *et al.* Effects of land use pattern on soil microbial biomass C and N after 4 years lucerne on the Loess Plateau [J]. Prataculturae Science, 2005, 22(10): 13–17. (in Chinese).
  - [69] YANG CD, LONG RJ, CHEN XR, *et al.* Study on microbial biomass and its correlation with the soil physical properties under the alpine grassland of the east of Qilian Mountains [J]. Acta Prataculturae Sinica, 2007, 16(4): 62–68. (in Chinese).
  - [70] GENG YB, DONG YS, QI YC. Review about the carbon cycle researches in grassland ecosystem [J]. Progress in Geography, 2004, 23(3): 74–81. (in Chinese).
  - [71] XU LJ, XIN XP, GUO MY, *et al.* The soil respiration characteristics of alfalfa pasture in Hailar regions [J]. Prataculturae Science, 2010, 27(11): 7–12. (in Chinese).
  - [72] Singh J S, Gupta S R. Plant decomposition and soil respiration in terrestrial ecosystems [J]. Botany Review, 1997, 43: 449–528.
  - [73] ZHOU P, LIU GB, XUE S. Review of soil respiration and the impact factors on grassland ecosystem [J]. Acta Prataculturae Sinica, 2009, 18(2): 184–193. (in Chinese).
  - [74] Aslam T, Choudhary M A, Saggar S. Influence of land use management on CO<sub>2</sub> emissions from a silt loam soil in New Zealand. Agriculture [J]. Ecosystems and Environment, 2000, 77: 257–262.
  - [75] BAO F, ZHOU GS. Review of research advances in soil respiration of grassland in China [J]. Journal of Plant Ecology, 2010, 34(6): 713–726. (in Chinese).
  - [76] Bardgett R D, Bowman W D, Kaufmann R, *et al.* A temporal approach to linking aboveground and belowground ecology [J]. Trends in Ecology and Evolution, 2005, 20(1): 634–641.
  - [77] Trumbore S. Carbon respired by terrestrial ecosystems—recent progress and challenges [J]. Global Change Biology, 2006, 12(2): 141–153.
  - [78] Buchmann N. Biotic and abiotic factors controlling soil respiration rates in Picea abies stands [J]. Soil Biology and Biochemistry, 2000, 32(11): 1625–1635.
  - [79] Jenkinson D S, Adams D E, Wild A. Model estimates of CO<sub>2</sub> emissions from soil in response to global warming [J]. Nature, 1991, 351(6322): 304–306.
  - [80] Wang C J, Pan G X, Tian Y G, *et al.* Changes in cropland topsoil organic carbon with different fertilizations under long-term agro-ecosystem experiments across mainland China [J]. Sci China Life Sci, 2010, 53: 858–867.
  - [81] CHEN ST, HU ZH, ZHANG Y, *et al.* Review of the factors influencing the temporal and spatial variability of soil respiration in terrestrial ecosystem [J]. Environmental Science, 2011, 32(8): 2184–2192. (in Chinese).
  - [82] Raich J W, Schlesinger W H. The global carbon dioxide flux in soil respiration and its relationship to vegetation and climate [J]. Tellus, 1992, 44B(2): 81–89.

tee the effective length of aerobic treatment.

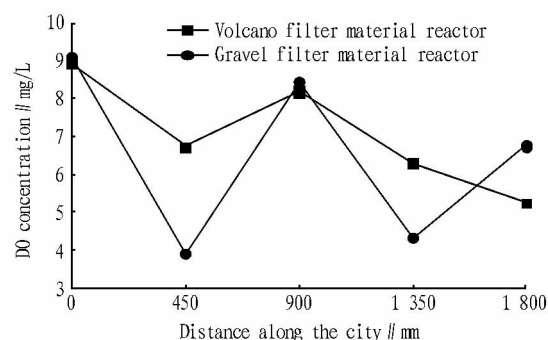


Fig. 4 DO concentration of filter bed in the first and third aeration filter bed

**2.3 Study on the congestion of stuff in the filter bed** The stuff congestion in the artificial strengthened ecological filter bed is a hard core to crack in the operation<sup>[5]</sup>. The way to solve the stuff of traditional biological filter bed should be to take out the stuff automatically or mechanically and then to clean the filter bed. During the operation, proper measures should be applied to ease or avoid congestion. First of all, the pre-treatment of influent was the key to solve the congestion in the filter bed. There was sediment zone in this experiment so as to get clean water, and then put the clean water into the cascade aeration machine. Through twice precipitation, the suspended substances and particles can be reduced by 50% and 70%. The effect of such kind of technology was distinct. Secondly, while the artificial strengthened ecological filter bed was designed, the space between the filter bed and the aeration zone changed the way traditional biological filter tube was deployed. The design of aeration not only solved the congestion of tube in the operation, but also enhanced the efficiency to use DO. Besides, the equipment can put off the congestion caused by falling biological membrane through the control of operation form. There was a discharge in the equipment. After certain time, when the entire biological filter bed was empty and the falling biological membrane became dry, large amount of water was put in to cleanse the filter bed so as to prolong the period of using filter

bed. In the actual operation, the proper congestion had positive influence on the degradation of organisms and the removal of N and P. The congestion of stuff was a sign of appropriate ecological filter bed.

### 3 Conclusion

Firstly, the distinct pretreatment of cascade aeration can satisfy the requirement of artificial strengthened ecological filter bed. When the height of cascade aeration was within 0.6 m, the DO of cascade aeration was stable, and both had positive relation. The data suggested that the optimal cascade height should be 0.6 m. Secondly, through the study of the property of the artificial strengthened ecological filter bed, the dissolution and use efficiency of volcano rock and gravel were quite different. In order to enhance the degradation of filter bed on the organism, the volcano filter material greatly improved the efficiency to process water quality. Thirdly, the study on the technology to filter materials relieved the congestion of traditional biological filter bed, and promised a broad future for the application of artificial strengthened ecological filter bed in the purification of living sewage in the north China.

### References

- [1] GAO CF, ZHAO J, LANG XM. Applied research on artificial strengthen ecological filter bed technology for the improvement of the water in Tiaozi River project[J]. Journal of Anhui Agricultural Sciences, 2010, 38(30): 17006–17008, 17023. (in Chinese).
- [2] HAN RP, LU YS, YANG J, *et al.* Pilot test on multiple layer microbial-earthworm eco-filter system for sewage treatment[J]. Acta Scientiae Circumstantiae, 2004, 24(3): 450–454. (in Chinese).
- [3] XIONG WY, LI YL. Theory and application of pollution control for black and odorous river in eco-purification system with re-aeration[J]. Sichuan Environment, 2004, 23(2): 17–18. (in Chinese).
- [4] YAO L. Study on influencing factors of waterfall reoxygenation[J]. Journal of Anhui Agricultural Sciences, 2011, 16(10): 15431–15433. (in Chinese).
- [5] Beijing Water Environmental Technology and Equipment Research Center. Waste treatment engineering technical manual: Wastewater Vol. [M]. Beijing: Chemical Industry Press, 2000. (in Chinese).
- [6] ZHANG ZJ. Wastewater treatment theory and design[M]. Beijing: China Architecture & Building Press, 2003. (in Chinese).
- [83] Ryan M G, Law B E. Interpreting, measuring, and modeling soil respiration [J]. Biogeochemistry, 2005, 73(1): 3–27.
- [84] Houghton R A. Balancing the global carbon budget[J]. Annu. Rev. Earth Planet. Sci., 2007, 35(1): 313–347.
- [85] LIU LX, DONG YS, QI YC. The development on the soil respiration of grassland ecosystem [J]. Progress in Geography, 2004, 23(4): 35–42. (in Chinese).
- [86] MA XH, LV XG, YANG Q, *et al.* Primary research on carbon cycle of Three River Plain wetland [J]. Scientia Geographica Sinica, 1996, 16(4): 323–330. (in Chinese).
- [87] LIU SH, FANG JY. Effect factors of soil respiration and the temperature's effects on soil respiration the global scale [J]. Acta Ecologica Sinica, 1997, 17(5): 469–476. (in Chinese).
- [88] ZHAN XY, YU GR, ZHENG ZM, *et al.* Carbon emission and spatial pattern of soil respiration of terrestrial ecosystems in China: Based on geostatistic estimation of flux measurement [J]. Progress in Geography, 2012, 31(1): 197–108. (in Chinese).
- [89] LI ZG, HOU FJ. Analysis of soil respiration diurnal dynamics and factors influencing it in enclosed natural grasslands under different topographies in the Loess Plateau[J]. Acta Prataculturae Sinica, 2010, 19(1): 42–49. (in Chinese).
- [90] WANG JG, FAN J, WANG L, *et al.* Soil respiration and assessment of the carbon budget in the process of returning farmland to forest and grassland under different land use patterns [J]. Journal of Agro-Environment Science, 2011, 30(10): 2024–2032. (in Chinese).
- [91] WANG XG, ZHU B, WANG YQ, *et al.* Soil respiration and its sensitivity to temperature under different land use conditions [J]. Acta Ecologica Sinica, 2007, 27(5): 1960–1968. (in Chinese).
- [92] XU LJ, TANG HJ, YANG GX, *et al.* Soil respiration characteristic and response to soil-atmosphere in different alfalfa rangeland [J]. Acta Botanica Boreali-Occidentalia Sinica, 2010, 30(9): 1882–1886. (in Chinese).
- [93] HAN GX, ZHOU GS, XU ZZ. Research and prospects soil respiration of farmland ecosystems in China [J]. Acta Phytoecologica Sinica, 2008, 32(3): 719–733. (in Chinese).
- [94] PANG YY, DENG B, ZHANG YJ, *et al.* CO<sub>2</sub> flux of alfalfa pasture with different ages [J]. Pratacultural Science, 2011, 28(7): 1239–1245. (in Chinese).