CHINESE GEOGRAPHICAL SCIENCE
Volume 13, Number 3, pp. 242–246, 2003
Science Press, Beijing, China

DISTRIBUTION OF MERCURY IN TYPICAL WETLAND PLANTS IN THE SANJIANG PLAIN

LIU Ru-hai, WANG Qi-chao, WANG Yan, ZHANG Lei, SHAO Zhi-guo
(*Northeast Institute of Geography and Agricultural Ecology, Chinese Academy of Sciences, Changchun 130012, P. R. China*)

ABSTRACT: Total mercury concentration of typical wetland plants was analyzed in this paper. There were great differences of total mercury concentration among different plants: moss>hydrophyte>sedge>herbage>shrub. Total mercury concentrations show an increasing trend from vascular plants to bryophytes, and from dry to wet lands. The mercury concentration of wetland plants was higher than that of crops. The wetland soil was the source of mercury in the air close to the ground, so it affected the concentration of mercury in the plant. In different parts of a plant, mercury concentration was in the order of: dead stand>root>leaf>stem. Mercury concentration increased at the initial stage and decreased in the end of the growing season. According to the mercury content and biomass, mercury stock of plants was 39.4μg/m^2 above ground in *Calamagrostis angustifolia* wetland and 35.8μg /m^2 in *Carex lasiocarpa* wetland.
KEY WORDS: wetland; plant; mercury; the Sanjiang Plain

CLC number: X173 Document code: A Article ID: 1002-0063(2003)03-0242-05

1 INTRODUCTION

Plant can accumulate mercury from air, soil and water. The concentration of mercury in plant is affected by the source, form of mercury and the physiology of plant. The concentrations of inorganic mercury and organic mercury in various plants are different, so the environmental exposure of mercury and the biotope of plants can be reflected by the concentration of mercury in plants. Wetland plays an important role in the transport and cycle of mercury (DRISCOLL *et al.*, 1994), and is an important source of methyl mercury of some lakes and rivers (ST LOUIS *et al.*, 1994). Wetland ecosystem has high primary productivity, the seasonal and perennial inundations of wetland make the plant decompose in the anaerobic condition, and the released mercury can be retained by soil or be transformed into more movable forms, for example, methyl mercury. Then mercury in wetlands will be transported to lakes and rivers, which affects the water quality, and enters into food chain. At last the health of human beings and wild animals is threatened. For example, the decrease of wading birds in Florida Everglades was due to the pollution of mercury (SUNDLOF *et al.*, 1994). In this paper, the mercury distribution and stock in plants of typical wetlands in the Sanjiang Plain were studied. The results will be helpful to understand the mercury cycle in wetlands and offer theoretical basis for the protection and utilization of wetlands.

2 MATERIAL AND METHODS

2.1 Selection of Sampling Sites and Samples Collection

The Sanjiang Plain lies in the northeast of Heilongjiang Province of China, with an total area of 108.9×10^{3}km^2. In the plain there were many wetlands, among which the area of marsh was 11.3×10^{3}km^2, the area of rivers and lakes was 4.3×10^3 km^2 in 1994(LIU and MA, 2000). It is the largest and continuous distri-

Received date: 2002-12-28
Foundation item: Supported by the National Natural Science Foundation of China (No. 40071072) and the Important Research Feild Project of Chinese Academy of Sciences (No. KZCX2-302)
Biography: LIU Ru-hai (1975–), male, a native of Tengzhou City of Shandong Province, Ph. D., specialized in the pollutants' behavior in environments and their control

bution area of fresh-water wetland in China. Thirty-seven sampling plots were selected in typical wetlands of the Sanjiang Plain in May 2001, and 70 plant samples were collected randomly, including *Calamagrostis angustifolia, Carex lasiocarpa, Carex meyeriana, Carex limosa, Carex paseudocuraica, Utricularia intermedia, Sphagnum* sp., *Betula fruticosa, Salix brachypoda* and so on. The samples of *Calamagrostis angustifolia* were collected in different growing seasons in the Sanjiang Wetland Ecology Experiment Station, Chinese Academy of Sciences. The leaves and stems of the shrub were collected separately. Several grass samples were collected in each plot and mixed as one sample. The root, stem and leaves of the collected grasses were divided quickly after the samples were brought to laboratory. In the mire, *Betula fruticosa* and *Salix brachypoda* grow at high places without water. *Calamagrostis angustifolia* and *Carex meyeriana* are located in the lower places with the seasonal inundation. *Carex lasiocarpa, Carex limosa* and *Carex paseudocuraica* grow at the lowest place with the permanent inundation. All the samples were air-dried inside room.

2.2 Determination of Samples

The samples were digested by the method of V_2O_5-H_2SO_4-HNO_3, and THg (total mercury) was determined by the method of atomic absorption using F732-V mercury detector, and the standard and blank were determined by the same method, the results were satisfactory. The recoveries of THg exceeded 90%. The minimum detection limit of THg was 3.3ng/g.

3 RESULT AND DISCUSSION

3.1 Total Mercury Concentration in Wetland Plants

Great differences of THg concentration were found in plants(Table 1), the average THg contents of *Carex lasiocarpa, Carex meyeriana, Carex limosa,* and *Carex paseudocuraica* were 51.2ng/g, 23.1ng/g, 82.5ng/g, and 46.5ng/g respectively. These great differences in the large sedge plants indicated that the absorbing capacities of various plants were different. The sequence of THg concentration in different kinds of plants was: moss> hydrophyte >sedge>herbage> shrub, which indicated that the THg concentration in plants increased from dry to wet conditions. Moss had strong capacity to absorb mercury. Hydrophytes could accumulate mercury successfully and had stronger capacity to absorb mercury than terrestrial plants (ZILLIOUS *et al.*, 1993), so inundation was an important factor affecting the mercury content in plants. THg concentration in wetland plants in the Sanjiang Plain was higher than those in plants of the northern China (23ng/g)(DOBROVOLISKI, 1987), and was higher than those in wetland plants (10.2±6.8ng/g for sedge and larger plant) near by Canada Experimental Lake Area (MOORE *et al.*, 1995).

Table 1 THg concentration in parts above ground of plants in mire (ng/g)

Plant	*n*	Range	Mean	Std
Calamagrostis angustifolia	18	13.4–46.1	31.8	9.8
Carex lasiocarpa	15	15.2–90.1	51.2	21.3
Carex meyeriana	6	14.1–29.3	23.1	6.1
Carex limosa	1		82.5	
Carex paseudocuraica	3	38.4–52.7	46.5	7.3
Utricularia intermedia	9	24.1–123.3	48.3	30.9
Sphagnum sp.	5	43.7–142.1	94.9	43.5
Betula fruticosa	1		25.1	
Salix brachypoda	2		24.3	

The correlation between the mercury content of plant and that of turf was not significant (r=0.32, P=0.1). This indicated that the THg concentration of wetland soil was not the direct cause that affected the THg concentration of plants (LIU *et al.*, 2002). It was thought that the mercury that plants absorbed from soil could be neglected in the region where there was no serious pollution source (BISHOP *et al.*,1998). So the mercury of plants came mostly from the atmosphere deposition. The research in the riparian wetland in the Elbe River of Germany showed that after rainfall, the mercury released from soil increased three times because of the increase of soil moisture (WALLSCHLAGER *et al.*, 2000). So the wetland environment with perennial inundation was in favor of the release of mercury, and made for the comparatively high atmospheric concentration of mercury above wetland soil. The air mercury content in the height of 10cm above *Carex lasiocarpa* wetland in the Sanjiang Plain was 82.5±4.8ng/m^3 (n=5), higher than that of *Calamagrostis angustifolia* wetland (35.9±2.2ng/m^3 (n=2)). The released mercury from soil made the air mercury concentration close to ground increase. Mercury contained in the air can be absorbed by leaf of plant. These factors could result in the high concentration of mercury in plants indirectly.

THg content in farmland crops in the Sanjiang Plain were lower than that in wetland plants. Hg concentration of leaf, stem and root were 20.0, 5.7 and 51.9ng/g for rice, 14.3, 5.7 and 43.7ng/g for corn respectively. Hg concentration of leaf and stem for soybean was 7.1 and 8.5ng/g respectively. The sequence of THg content of plants was: wetland plants>rice >corn>soybean. This may be relative with the type of plant and the biotope. Compared with wetland soil, the mercury content in paddy field soil was lower. So the difference of release of mercury in soil could cause the difference of mercury content in air close to the ground. The sequence of total mercury content in the different parts of crop was: root>leaf>stem, which was similar to wetland plants.

3.2 THg Concentration in Parts of Plants

The sequences of the THg content in each part of *Calamagrostis angustifolia* in the Sanjiang Plain was: dead stand>root>leaf>stem (Fig. 1). The leaf of plant had more powerful capacity to absorb air mercury than the stem because there were more pores in surface of leaf than those of stem. After the leaf was withered, nutrition component was transported into the stem and root of the plant. So the mass of leaf decreased and the mercury in withered leaf was condensed. There was significant correlation between the THg content in stem and that in leaf of *Calamagrostis angustifolia* (r=0.87, P<0.001) (Fig. 2).

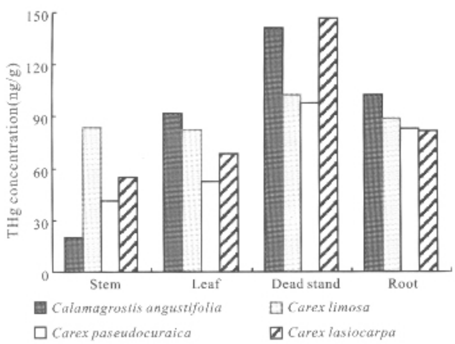

Fig.1 Hg concentration in the parts of plants

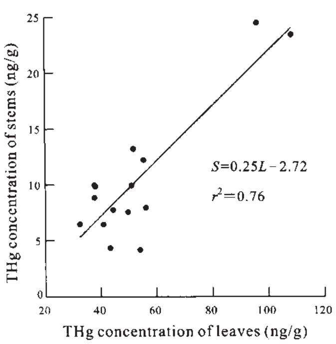

Fig.2 Relation of Hg concentration between the stems and leaves

3.3 Seasonal Variation of Mercury Concentration in Plants

THg concentrations of plants changed obviously in growth period (Fig.3). The THg concentration at the initial stage of growing period was higher and up to the maximum in August, and then decreased. The temporal change character was different from that of tree. THg content in tree increased with time (RASMUSSEN *et al.*, 1991), and it was possibly induced by the difference of physiological characters of arbor and herbage. LODENIUS (1994) thought that the seeding in background area could efficiently absorb various forms of mercury from air, but little from soil. As mentioned above, the sequence of total mercury contents of every part of plants was: dead stand>leaf>stem, but the ratio of every part accounted for total biomass was variable in growing period. This variance would affect the change of THg content in plants. The seasonal variation of biomass of ecosystem of *Calamagrostis angustifolia* and *Carex lasiocarpa* wetland in the Sanjiang Plain was studied by YANG *et al.* (2002), the result showed that the ratio of the biomass of leaf of *Carex lasiocarpa* to total over-ground biomass increased firstly, then decreased with the growing of plants. In *Calamagrostis angustifolia* wetland, the stem biomass accounted for the most of the over-ground biomass, and the ratio of leaf to the over-ground biomass decreased with the growing. The emission of plant mercury into the atmosphere might be another reason of the decrease of the mercury concentration in plant.

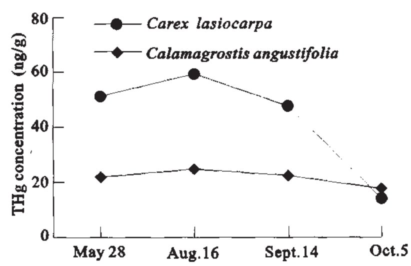

Fig.3 Seasonal dynamics of THg content in two typical wetland plants

3.4 Estimate of Mercury Mass in Plants

The mass of mercury in plants in the Sanjiang Plain was shown in Table 2. According to the mercury concentration and the biomass of plants (YANG *et al.*, 2002), we estimated that the stocks of mercury in the *Carex lasiocarpa* overground and underground were

Table 2 Mass of mercury in typical wetland plants in the Sanjiang Plain

	Carex lasiocarpa			*Calamagrostis angustifolia*		
	Biomass (kg/m^2)	THg content (ng/g)	Hg mass ($\mu g/m^2$)	Biomass (kg/m^2)	THg content (ng/g)	Hg mass ($\mu g/m^2$)
Above-ground	0.700	51.2	35.8	1.2377	31.8	39.4
Underground	2.325	69.2	160.9	3.4666	102.6	355.7
Total			196.7			395.0

35.8$\mu g/m^2$ and 160.9$\mu g/m^2$, those in the *Calamagrostis angustifolia* were 39.4$\mu g/m^2$ and 355.7 $\mu g/m^2$ respectively. The stocks were higher compared with the experimental lake area in Canada (31$\mu g/m^2$) (MOORE *et al.*, 1995), which is a peat bog with the main plants of trees and shrubs. The difference in community types of these two areas was the main factor affecting the difference of mercury concentration in plants. The mercury mass in the above-ground part of plants was the mercury accumulated in the whole growth period. The atmosphere mercury was the main source of mercury in plants. The increase of the deposition rate of atmospheric mercury was mainly related to industrial activities. The deposition rate of mercury was from <3$\mu g/(m^2 \cdot a)$ in the relative no pollution area to >10$\mu g/(m^2 \cdot a)$ (ST LOUIS *et al.*, 1994; SWAIN *et al.*, 1992; IVERFELDT, 1991) in the part of USA and Scandinavia. The sampling plots were far away from the pollution source, but the stock of mercury in above-ground part of plant was higher than that of the wet and dry deposition in this area. So the emission of mercury from soil and water was one of the sources of the plant mercury.

Generally, the ratio of the methyl mercury to total mercury in soil and sediment is less than 2%, but the ratio in aquatic alga can be 100% (RASMUSSEN *et al.*, 1994). Mercury in plant can be transported or accumulated in environment with the time and the change of wetland environment. HEYES *et al.* (1998) did the research on the decomposition of plant in inundation environment. They found that about 40% of organic matter was decomposed within 2.5 years, and the mercury concentration in the plant residue increased, and the mass and concentration of methyl mercury increased evidently. The methyl mercury in the residue may be transported into the water and soil. The wetland plants play an important role in the function of wetland as the sink of mercury and source of methyl mercury. In the wetland without anthropogenic disturbance, one part of mercury in plants will be accumulated in the form of peat, another part of them enter into the mercury cycle in the soil-atmosphere-plant system, and the fewer parts will be transported to other areas through water and atmosphere. When the wetlands were disturbed (for example drainage, reclamation), the system would be damaged, and mercury would be transported and emitted in much shorter time. The wetland would lose the function of sink of mercury. VEIGA *et al.* (1994) thought that the high mercury concentration in the fish and human being in Amazon Basin was related to the damage of wetlands caused by the deforestation. The wetland plants play an important role in the cycle of mercury in wetlands and the function of sink of mercury.

4 CONCLUSIONS

The mercury concentration in plants was high in the Sanjiang Plain. There was an increasing trend of total mercury concentration from vascular plants to bryophytes, and from dry to wet sites. Mercury concentration in the parts of plant was different. There was significant correlation between the leaf and the stem of *Calamagrostis angustifolia*. Mercury concentration was affected by the physiology and biotope of plants. Mercury concentration of plant exhibited clear temporal variation, increasing at the initial stages and decreasing in the end of the growing season. The mercury stock of plant was 39.4$\mu g/m^2$ aboveground in *Calamagrostis angustifolia* wetland and 35.8$\mu g/m^2$ in *Carex lasiocarpa* wetland. Plants played an important role in the cycle of mercury in the mire.

ACKNOWLEDGEMENT

Special thanks to the Sanjiang Wetland Ecology Experiment Station, Chinese Academy of Sciences are for the helps of sampling and pretreatment of samples.

REFERENCES

BISHOP K H, LEE Y H, MUNTHE J *et al.*, 1998. Xylem sap as a pathway for total mercury and methylmecury transport from soils to tree canopy in the boreal forest [J]. *Biogeochemistry*, 40:102–113.

DRISCOLL C T, YAN C, SCHOFIELD C L *et al.*, 1994. The mercury cycle and fish in the Adirondack lakes[J]. *Environ.*

Sci. Technol., 28(3): 136A–143A.

DOBROVOLISKI V V (Translator: ZHU Yan-ming), 1987. *Trace Elements Geography* [M]. Beijing: Science Press, 153–154. (in Chinese)

HEYES A, MOORE T R,RUDD J W M, 1998. Mercury and methylmercury in decomposing vegetation of a pristine and impounded wetland [J]. *Journal of Environmental Quality*, 27(3):591–599.

IVERFELDT A, 1991. Mercury in forest canopy throughfall water and its relation to atmospheric deposition [J]. *Water, Air and Soil Pollut.*, 56:553–564.

LIU Ru-hai, WANG Qi-chao, LU Xian-guo *et al.*, 2002. The geochemistry characteristic of mercury in Sanjiang Plain Marsh[J]. *Acta Sci. Circums.*, 22(5):661–663. (in Chinese)

LIU Xing-tu, MA Xue-hui, 2000. Influence of large-scale reclamation on natural environment and regional environmental protection in the Sanjiang Plain [J]. *Scientia Geographica Sinica*, 20(1):14–19. (in Chinese)

LODENIUS M, 1994. Mercury in terrestrial ecosystems: a review [A]. In: WATRAS C J, HUCKBEE T W(eds.). *Mercury Pollution: Integration and Synthesis*[C].Florida: Lewis Publ., 343–354.

MOORE T R, BUBIER J L, HEVES A *et al.*, 1995. Methyl and total mercury in boreal wetland plants, experimental lakes area, northwestern Ontario [J]. *Journal of Environmental Quality*, 24(5): 845–850.

RASMUSSEN P E, MIERLE G, NRIAGU J O, 1991. The analysis of vegetation for total mercury[J]. *Water, Air and Soil Pollut.*, 56:379–390.

RASMUSSEN P E, MIERLE P E, NRIAGU J O, 1994. ercury in vegetation of the Precambrian shied[A]. In: WATRAS C J, HUCKBEE T W (eds.). *Mercury Pollution: Integration and Synthesis*[C]. Florida: Lewis Publ., 417–425.

ST LOUIS V L, RUDD J W M, KELLY C A *et al.*, 1994. Importance of wetlands as sources of methyl mercury boreal forest ecosystem[J]. *Can. J. Fish. Aquat. Sci.*, 51:1065–1076.

SUNDLOF S F, SALDING M G, WENTWORTH J D *et al.*, 1994. Mercury in livers of wading birds (Ciconiiformes) in southern Florida[J]. *Arch. Environ. Contam. Toxicol.*, 27: 299–305.

SWAIN E B, EEGATROM D R, BRIGHAM M E *et al.*, 1992. Increasing rates of atmospheric mercury deposition in mid-continental North America[J]. *Science*, 257:784–787.

VEIGA M M, MEECH J A, ONTAE N, 1994. Mercury pollution from deforestation[J]. *Nature*, 368:816–817.

WALLSCHLAGER D, KOCK H H, SCHROEDER W H *et al.*, 2000. Mechanism and significance of mercury volatilization from contaminated floodplains of the German river Elbe [J]. *Atmospheric Environment*, 34: 3745–3755.

YANG Yong-xing, WANG Shi-yan, HE Tai-rong *et al.*, 2002. Study on plant biomass and its seasonal dynamics of typical wetland ecosystem in the Sanjiang Plain [J]. *Grassland of China*, 24(1): 1–7. (in Chinese)

ZILLIOUS E L, PORCELLA D B, BENOIT J M, 1993. Mercury cycling and effects in freshwater wetland ecosystems [J]. *Environmental Toxicology and Chemistry*, 12: 2245–2264.