BIOGEOCHEMICAL BEHAVIORS OF DISSOLVED IRON IN SANJIANG PLAIN, CHINA: DISCHARGE, CHEMICAL FORMS, AND YEAR-TO-YEAR VARIATION

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1. INTRODUCTION

Water-logged conditions can be an important terrestrial Fe source to aquatic environments by promoting iron dissolution due to reduction. The results of our research in 2005 and 2006 in the Sanjiang plain has shown that high concentration of dissolved iron is present not only in natural wetlands but also in paddy field. However, it remains ambiguous whether paddy field actually acts as an dissolved Fe source to discharge it downstream, where water movements are strongly controlled by farming practices. When little of water be drained out of paddy field, it cannot play a major role even if its water contains high concentration of dissolved Fe. Thus, the actual hydro-biogeochemical situation was studied in paddy fields in Sanjiang plain by 1) a door-to-door investigation about water management practices from farmers and 2) a measurement of water infiltration rate into paddy soil.

Additionally, we show here the results about a possible importance of colloidal Fe as a chemical forms of dissolved Fe, which we have not determined previously, and about a large year-to-year variation of dissolved Fe concentration in a wetland site between 2005 and 2007 probably affected by an annual hydrological regime.

2. MATERIALS AND METHODS

A door-to-door investigation about water management in paddy field

We visited a wide range of paddy fields in the Sanjiang plain in the beginning on June, 2007 (15 places) and in the end of August (4 places) (Fig. 1). The way of farming practices in respective paddy fields was surveyed by interviewing farmers, particularly on water managements.

Measurement of water infiltration rate in paddy field

Water infiltration rate, an important indicator frequently used to represent the water permeability of paddy field when flooded, was measured by a simple method. Paddy soil under water surface was covered with a small chamber. A decrease in water volume in this closed system resulting from water infiltration was measured volumetrically; a change in water volume with time was monitored using a measuring pipette. The infiltration rate (V mm d^{-1}) is calculated from the following equation:

$$V = 1440 \times (y \times a) / (t \times A)$$

where y, a, t, and A are a change in water level in pipette (mm) over the measurement period of 2 minutes, the cross sectional surface area of the pipette (cm^2), the time for measurement (min), and the cross sectional surface area of the cylinder (cm^2), respectively. The value 1440 is a coefficient to convert data from minute basis to day basis (60min＊24h).

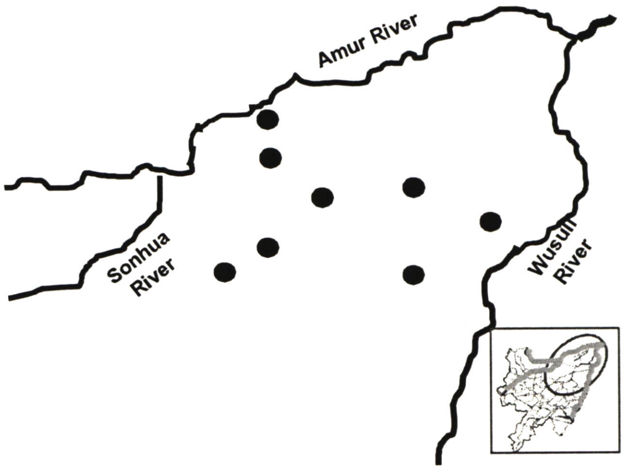

Fig. 1
Location of paddy field sites in Sanjiang plain, China, where door-to-door hearing was conducted

Research about soil interstitial water and surface water in natural wetland

The soil interstitial water and surface water was sampled at the Sanjiang wetland ecological experimental station (47°35'N, 133°31'E) in August, 2007. The soil interstitial water was collected from the depths of 10cm, 50cm with a tension lysimeter technique, and surface water (0cm) was collected by a plastic bottle directly. Chemical analyses were made by the methods described in our previous report.

Iron chemical methods about colloid and other forms

Fractionation and respective analytical methods of iron species are illustrated in Fig. 2. Colloidal Fe is measured as follows; after a filtration with a 0.45μm disposable filter, water sample was acidified (1mL conc. HCl /100ml) and then filtered with a molecular weight cut off of 50,000 disposable filter. It is assumed that colloidal Fe has MW more than 50,000 and consequently removed by this filter, whereas organic-bound Fe is expected to have MW less than 50,000 and pass through it. The filtered water sample was preserved in a glass vial pre-burnt at 550°C and analyzed with an atomic absorption photometer (HITACHI, Ltd.Tokyo Japan. Z-8000). The colloid Fe concentration was calculated from the difference with and without filtration by MW 50,000 cut-off filter.

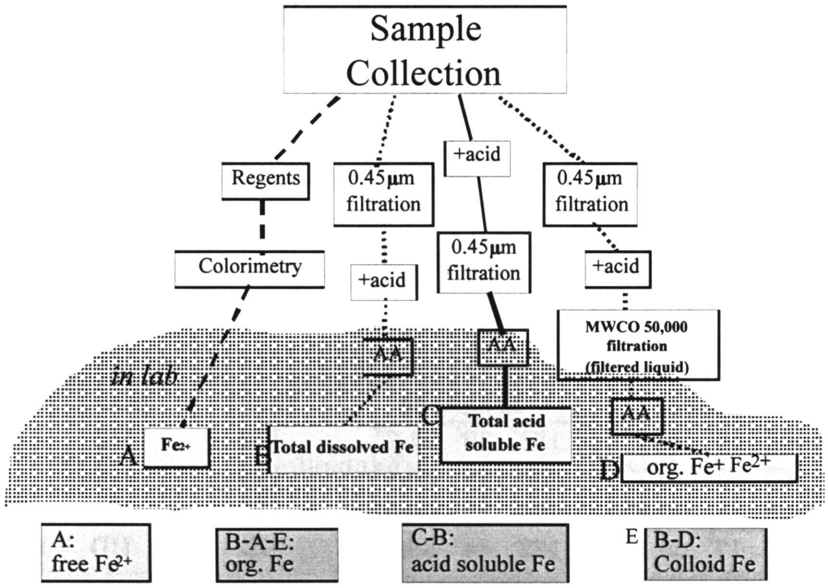

Fig. 2
Fractionation and analyses for Fe species

3. RESULTS AND DISCUSSION

Water dynamics in the paddy field

Major information collected through a door-to-door investigations to farmers are as follows. Of the total 19 rice paddies surveyed, only one farm (the "859 Farm") uses river water; most of farms (18 among 19) use groundwater as an irrigation water. Most of the farms pumped groundwater up from of depth of approximately 40 m to 50 m. Electric pumps were used to pump out the groundwater. Paddy fields of "859 Farm," the only farm to use river water, were located close to the Wusuli River with a distance of approximately 17 km.

The agricultural practices common in Japan, namely mud leveling (late April), intermittent drainage (mid-June to early July), and drainage (late August to early September), are also common in paddy fields in the Sanjiang Plain. But a noticeable difference from Japan is a re-use of paddy water; in many farms, the drainage channels are blocked to store overflowing water, except on an occasion of heavy rain. Flowing irrigation technique, as often in Japan, is not applied to paddy fields in Sanjiang Plain. Irrigation is carried out just to supplement paddy water decrease due to evapotranspiration. Efforts to reuse surface water and efficient use of rainwater as much as possible arise from a motivation to reduce ground water pumping. Such a situation to save irrigation water suggests that outflows of surface water from paddy fields are basically quite limited.

The measurement of infiltration of paddy water beneath the soil showed that water infiltration was extremely low at any sites (Tab. 1). This situation stands to reason when considering an intrinsic small hydraulic gradient and a prevailing low-permeable clay layer in the soil. This result suggests that discharge of surface water from paddy field through underground can be regarded negligible in this region.

Results from the above studies represent that there may be little way for surface and soil water to go out from paddy fields in Sanjiang plain, with an exception of flooding period. Thus, it is suggested that the transport of dissolved Fe into rivers is fundamentally restricted in paddy fields even if its water would have high iron concentrations. It is expected that the land use change from wetlands to rice paddies contributes to significantly lower the source intensity of dissolved Fe.

Table 1. Water infiltration rate in paddy fields measured at four farms in Sanjiang plain (June, 2007)

Farm No.	Latitude	Longitude	Site 1	Site 2
1	47° 35′ 29.7″	133° 39′ 24.7″	UD	UD
2	47° 35′ 29.7″	133° 39′ 24.7″	UD	UD
3	47° 35′ 20.8″	133° 29′ 58.0″	UD	UD
4	47° 17′ 35.1″	132° 44′ 35.0″	UD	UD

UD: under the detection limit (≤ 0.2mm d^{-1})

<u>Dissolved iron concentration and forms in the soil interstitial water</u>

Chemical analysis of total dissolved Fe in surface water and soil interstitial waters in wetland sites showed that the concentration was highest at a depth of 10cm and was decreased at depths of 0 cm and 50 cm. In contrast, acid soluble iron concentration was highest at a depth of 0cm (surface water) and drastically decreased with the increase in soil depth. Such patterns found for different Fe species were essentially the same as those observed in 2005 and 2006, enabling us to confirm the trend of vertical profile for dissolved iron in wetlands.

In 2005 and 2006, three dissolved Fe species were analyzed: total dissolved Fe, organic-bound Fe and free Fe^{2+}. In 2007, in addition to the above species, colloidal Fe was also analyzed. The result of relative proportion of dissolved Fe species (free Fe^{2+}, colloidal Fe and organic-bound Fe) in a wetland site is shown in Fig. 3. Colloidal Fe comprised approximately 80% of dissolved Fe, while organic-bound Fe and free ferrous iron accounted for only 15% and 5%, respectively. It was found from the analyses in 2007 that dissolved Fe is dominantly present as colloidal Fe at any depths in a wetland site.

The vertical distribution of total dissolved iron concentration in wetland in summer period is compared among 2005, 2006, and 2007 in Fig. 4. The overall level of dissolved Fe was appreciably higher in 2006 than in 2005 at the identical wetland site. The annual precipitation and monthly precipitation in August are both higher in 2006 (630 mm and 172.5mm) than in 2005 (480 mm and 126.2mm). The dissolved Fe level in 2007 was also comparatively high, being nearly equivalent to that in 2006. The precipitation data has not yet been available for 2007, but the water level was appreciably elevated on the period of this observation. The results thus suggest that dissolved Fe concentration in surface and interstitial water in a wetland site could vary, possibly affected by the hydrological regime.

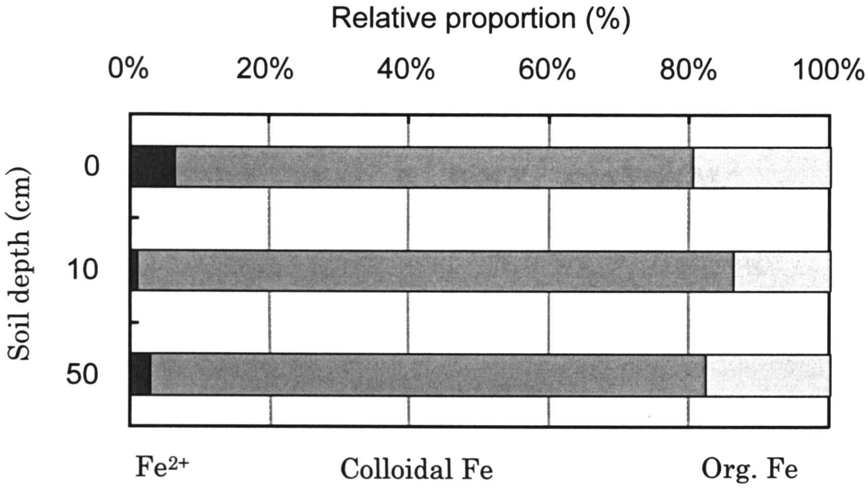

Fig. 3
Relative proportion of three dissolved Fe species as a function of depth in a wetland site (August, 2007)

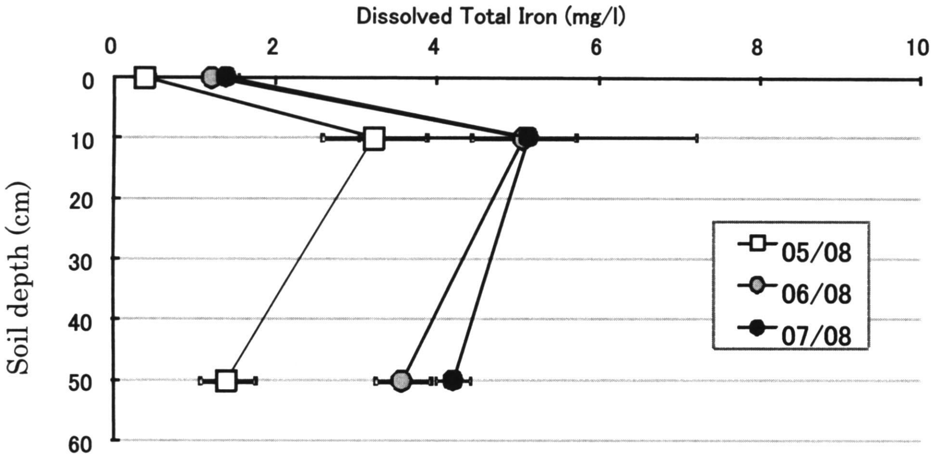

Fig. 4
Comparison of vertical distribution of total dissolved Fe in a wetland site in summer among different years