Annual Variation of CO₂ Absorption and Release in Xiangxi River of Three Gorges Reservoir

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Abstract: To analyze the annual variation of CO₂ absorption and release in Xiangxi River of Three Gorges Reservoir, this paper set up six monitoring points in the Yangtze River and Xiangxi River to monitor CO₂ emission flux at the air-water interface from July 2017 to June 2018 using static chamber method. During the investigation, this paper found that the variation rate of CO₂ in the Xiangxi River averaged 0.67-2.14 ppm/min while the number for the Yangtze River was 1.07 ppm/min and 2.82 ppm/min respectively. The variation rate of CO₂ was lower during water storage and higher during water discharge or in dry periods. The status of CO₂ changed from absorption to release during water storage and vice versa during water discharge.

1. Introduction
The absorption and release of CO₂ in reservoirs is one of the most popular topics on greenhouse gas at present [1]. The absorption and release of CO₂ in reservoirs features extreme complexity and high uncertainty in time and space, involving macro factors of carbon biogeochemical cycle in river basins [2], and is also closely related to factors such as the location of reservoir, reservoir clearing before flooding, reservoir construction and operation, air temperature, light intensity, wind speed, hydrodynamic force, phytoplankton photosynthesis, etc. [3-5]. Therefore, it is of great scientific significance to study the release and adsorption of CO₂ in reservoirs.

The absorption and release of CO₂ has always been a hot topic of research. At present, most of the studies are concentrated in Brazil, Canada, the United States, Finland, French Guiana and other places [6-10]. The existing researches in China focus on natural lakes and eutrophic reservoirs, such as Taihu Lake, East Lake, Hongfeng Lake, Baihua Lake, Dianchi Lake and Lugu Lake [11]. Fossil fuels has always been regarded as an important source of CO₂ release [12], while hydropower is considered a clean energy worthy of large-scale promotion. However, some studies show that reservoirs may also release a large amount of CO₂ [13,14]. For example, the production of CO₂ by hydropower plants is even greater than that produced by thermal power plants [15]. However, most of these studies focus on reservoirs in tropical areas, temperate peatland, or shallow-water areas, with few studies being carried out in deep-water reservoirs, canyon reservoirs and channel reservoirs. The Three Gorges Reservoir is the largest deep-water channel reservoir in China. In recent years, researchers have done a lot of research on the release and absorption of CO₂ in the Three Gorges Reservoir [16-19]. However, the open
water surface of the Three Gorges Reservoir, the complexity of water resources dispatching and management, various tributary forms and diverse environmental conditions \[20\] have jointly contributed to drastic differences between tributaries in the release of CO\(_2\) \[21\].

Xiangxi River is the closest first-class tributary to the dam in the Three Gorges Reservoir, with the dispatching of water resources from the Three Gorges Reservoir exerting the greatest impact on its water environment and hydrological conditions. At present, there have been a few reports on the study of CO\(_2\) in Xiangxi River, which revealed a significant correlation between PCO\(_2\) and water temperature, water level, pH, DO and chlorophyll \(a\). The variation of PCO\(_2\) is influenced by multiple factors, yet it is difficult to determine which factor plays a dominant role \[22\]. At present, there have been very limited observation and in-situ data of CO\(_2\) absorption and release in Xiangxi River, let alone reports on annual variation of CO\(_2\) absorption and release. Therefore, studies on CO\(_2\) absorption and release in Xiangxi River can not only provide reference for greenhouse gas researches in the Three Gorges Reservoir, but also serve as guidance for optimizing water resource dispatching of the Three Gorges Reservoir and reducing greenhouse gas emissions.

2. Material and Method

2.1. Survey region

Xiangxi River is located in the west of Hubei Province, north of Xiling Gorge of Yangtze River, with an altitude of about 23-3000m between 110 25'-111 06' east longitude and 31 04'-31 34' north latitude. The Xiangxi River originates from the east and west. The east source has an origin from Luomadian in Shenlongjia Forest, which flows to the west and southeast. The west source originates from the Red River in Shennongjia Forest, which flows from west to southeast. The two rivers meet at Xiangtan 2.5km west of Gaoyang Town in Xingshan County. The confluence, also called Xiangxi River, goes straight down from north to south, merging with tributaries such as Gaolan River along the way, and then flows past the Zigui County and Xilingxia Gorge into the Yangtze River. The main stream is 94km long with a total area of 3099 km\(^2\), with the estuary 38km away from the Three Gorges Dam \[22\].

2.2. Distribution of sampling sites

There were 6 monitoring points in this study, four of which were set up in the midstream of channel from upstream to downstream and marked as XX04, XX03, XX02 and XX01. The other two points were arranged along the left bank of Yangtze River at the intersection with Xiangxi River from upstream to downstream, marked as XXCJ01 and XXCJ02. The location of each monitoring point is shown in Table 1.

| Sample No. | Location                                | Distance to Estuary (km) | Longitude (N)      | Altitude (E)        |
|------------|-----------------------------------------|--------------------------|--------------------|---------------------|
| XX01       | Downstream near Chujiawan                | 25.40                    | 110°41'39.92"      | 31°16'27.11"        |
| XX02       | Midstream near Jiajiadian                 | 21.70                    | 110°47'0.25"       | 31°7'23.74"         |
| XX03       | Upstream near Xiakou Town                | 6.40                     | 110°45'10.58"      | 31°3'31.1"          |
| XX04       | The end of backwater near Lijiagou        | 0.50                     | 110°45'47.99"      | 30°58'26.34"        |
2.3 Time of sampling
The monitoring and sampling were carried out from July 24, 2017 to June 30, 2018 in the second half of each month. Sampling starts at 8:00 a.m. in a consistent order.

2.4 Method of sampling
In this study, the sampling sites were located at the center line of stream, and the static chamber method was used to observe CO₂ emission flux at the water-gas interface.

Gas concentration was analyzed by Agilent 7890A gas chromatograph. First measure the standard peak area of standard gas by gas chromatograph, and then measure the peak area of sample. Repeat the procedures three times for each gas sample, take the average value as the peak area and calculate the gas concentration based on the following formula:

\[
\text{Sample concentration} = \left( \frac{\text{Peak area of gas sample}}{\text{peak area of standard gas}} \right) \times \text{standard gas concentration}
\]

Finally, the gas concentration and time of the sample were regressed. Record the slope of the curve S when the regression coefficient of the curve reached about 0.95.

The gas flux was calculated using the following formula (Lambert, 2005):

\[
F = \frac{K \times F_1 \times F_2 \times V}{S \times F_3}
\]

where \( F \) is gas flux, mg m⁻² d⁻¹; \( K \) is the concentration slope in the time-concentration graph, mg kg⁻¹ min⁻¹; \( F_1 \) is the conversion coefficient between mg kg⁻¹ and μg m⁻³ (CO₂: 1798.45); \( F_2 \) is the conversion coefficient between minutes and days (1440); \( V \) is the volume of air entering the buoyancy tank, m³; \( S \) is the surface area of floating box on water, m²; \( F_3 \) is the conversion coefficient between μg and mg (1000). A positive value indicates that the gas is discharged from the water body to the air while a negative value means that the water body absorbs the gas in the air.

In the sampling, 100 ml of gas was extracted from the static chamber every 5 min for consecutive 5 times, and the gas samples were sent back to the laboratory for analysis as soon as possible. The concentration of CO₂ in gas samples was analyzed linearly using gas chromatograph, and the slope was calculated as the variation rate of CO₂ in water.

3 Results and Analysis
During the investigation, the average variation rate of CO₂ in Xiangxi River was between 0.67-2.14 ppm/min. The variation rate of CO₂ at XXCJ01 and XXCJ02 were 1.07 ppm/min and 2.82 ppm/min respectively. There was a large standard deviation of CO₂ variation rate between monitoring points, and the CO₂ variation rate of water body fluctuated drastically in different months.

The variation rate of CO₂ in the water changed with time, which fluctuated greatly from September to November of 2017 and April to June of 2018, and less from December of 2017 to March of 2018, with a stable variation rate of CO₂. Thus, it is concluded that the variation rate of CO₂ was lower during water storage and higher during water discharge or in dry periods. The dispatching of water resources in the Three Gorges was speculated to be one of the most important factors causing changes of CO₂ release and absorption.

The absorption and release of CO₂ during water storage and discharge of the Three Gorges Reservoir showed different characteristics. During the water storage period, that is, from July to October of 2017, the CO₂ was released into the air instead of being absorbed by the water. In August, the absorption rate of CO₂ at XX01 section was 5.41 ppm/min, while in October, the release rate of...
CO₂ at this point was 2.11 ppm/min. There was a similar trend in XX03 section. In July, the absorption rate of CO₂ in XX03 section was 1.92 ppm/min, while in October, the release rate of CO₂ at this point was 8.17 ppm/min. During the period of water discharge, that is, from April to June of 2018, CO₂ was absorbed by water instead of being released in every section of Xiangxi River. In April, the release rate of CO₂ in XX01 section was 6.13 ppm/min, while in June, the absorption rate of CO₂ at this point was 2.09 ppm/min. In XX03 section, CO₂ was released at the rate of 1.89 ppm/min in April, while in June, CO₂ was absorbed by water at a rate of 2.11 ppm/min.

Fig. 1 Variation Rate - Time of CO₂ in Water Body during Investigation

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