Annual Variation of CO_2 Absorption and Release in Caotang River of Three Gorges Reservoir

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Abstract. To analyze the annual variation of CO_2 absorption and release in Caotang River of Three Gorges Reservoir, this paper selected six sections from the Yangtze River and Caotang River between July 2017 and June 2018, and monitored CO_2 emission at the water-gas interface using static closed chamber. The results are as follows: during the investigation, the variation rate of CO_2 averaged 0.66-2.05 ppm/Min in Caotang River, and the number was 1.02 ppm/Min and 2.67 ppm/Min in Yangtze River. In November, CO_2 in Caotang River experienced dramatic variation as it was released from the water body to the atmosphere. The highest release rate occurred at the CT02 section, which was up to 42.58ppm/min. From July to October of 2017, most sections of the river absorbed CO_2 without a fixed pattern in space. From January to March of 2018, the absorption and release rate of CO_2 slowed down, with its absolute value between 0.20-2.28 ppm/min. The release or absorption rate of CO_2 from April to June was slightly higher than that from January to March.

1 Introduction

The absorption and release of CO_2 in reservoirs is one of the most popular topic of greenhouse gas studies at present[1]. The absorption and release of CO_2 in reservoirs is extremely complex, with huge uncertainties in time and space as it involves macro factors of carbon biogeochemical cycle in river basins[2] and factors like reservoir location, reservoir cleanup before flooding, construction and operation, temperature, sunshine, wind speed, hydrodynamic force, phytoplankton photosynthesis[3-5]. Therefore, it is of great significance to study the release and adsorption of CO_2 for scientific investigation of reservoirs.

The absorption and release of CO_2 has always been the focus of researches. Current studies are concentrated in Brazil, Canada, the United States, Finland, French Guiana and other places[6-10]. The existing researches in China are more involved in studies of natural lakes and eutrophic reservoirs such as Taihu Lake, East Lake, Hongfeng Lake, Baihua Lake, Dianchi Lake and Lugu Lake [11]. The use of fossil fuels has always been regarded as an important source of CO_2 emission [12], while hydropower is regarded as a clean energy and has been widely promoted. However, some studies show that reservoirs may also release a vast amount of CO_2 [13,14], and CO_2 released by hydropower stations could be even greater than that produced by thermal power[15]. However, most of these studies focused on reservoirs in tropical areas, temperate peatland or shallow water while there are relatively few studies on deep-water reservoirs, canyon reservoirs and river reservoirs. The Three Gorges Reservoir is the largest deep-water river reservoir in China, which has served as the basis of researches on the release and absorption of CO_2 in recent years[16-19]. However, due to the open water surface, complex dispatch and management of water resources as well as diverse tributary forms and environmental conditions of the Three Gorges Reservoir[20], there are huge differences among tributaries in terms of CO_2 release [21].

Caotang River is an important tributary of the Three Gorges Reservoir. The narrow pipe effect caused by the narrow water surface of Kuimen, the estuary angle as well as flow characteristics like top support effect, reverse flow and other interactions between main stream and tributaries have distinguished the Caotang River from other tributaries during water storage. At present, there are very limited observations and in-situ data of CO_2 absorption and release in Caotang River, and there have been few reports on annual variation of CO_2 absorption and release. Therefore, this study carried out annual monitoring of CO_2 absorption and release at the intersection of Caotang River and Yangtze River to provide references for greenhouse gas studies in the Three Gorges Reservoir, aiming at reducing greenhouse gas emissions and promoting rational dispatch of water resources in the Three Gorges Reservoir.

2 Material and method

2.1 Study site

Caotang River is located in the northeast of Chongqing and north of Qutang Gorge of Yangtze River. It originates from the junction of Fengjie County and Wuxi County between 109°31′03″-109°45′20″ east longitude and 31°02′40″-31°10′06″ north latitude. The basin covers Caotang, Baidi and Fenhe. It consists of Fenhe River and Shima River, with a total length of 33.3 km and a watershed area of 394.8 km^2. The flow averages 7.51 m^3/s, and the annual runoff totals 237 million m^3 [22,23]. The backwater level in the reservoir extends to Zhuyi Caotang Town.

2.2 Sampling point

There are 6 monitoring sections in this study, including four monitoring points along the intermediate line of Caotang River from upstream to downstream, which are marked as CT04, CT03, CT02 and CT01 respectively. In addition, there are two monitoring points along the left bank of the Yangtze River in the upstream and downstream at the intersection of Caotang River and Yangtze River, which are marked as CTCJ01 and CTCJ02. The location of each monitoring point is shown in Table 1.

Table 1. The situation of monitoring points

Sampling Point No.	Location	Distance from Estuary（km）	Longitude（N）	Latitude（E）
CT01	Downstream	0.50	109°34'26.12"	31°2'52.5"
CT02	Midstream	3.5	109°35'40.38"	31°3'17.05"
CT03	Upper stream	7.0	109°35'43.02"	31°3'43.6"
CT04	Source	12.0	109°44'59.51"	31°9'30.21"
CTCJ01	Estuary-Yangtze River	0.50	109°33'28.89"	31°2'40.36"
CTCJ02	Estuary-Yangtze River	0.50	109°34'50.27"	31°2'22.8"

2.3 Sampling time

The monitoring and sampling started on July 24, 2017 and ended on June 30, 2018, which was performed in the latter part of each month. Sampling started at 8: 00 a.m., and the order of sampling site was kept consistent.

2.4 Sampling method

In this study, the sampling site was located at the midstream of channel, and the static closed chamber was used to observe CO_2 emission at the water-gas interface.

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

Sample concentration = (peak area of gas sample/peak area of standard gas) × standard gas concentration

Finally, regression analysis was performed for gas concentration and duration of the sample. The slope S of the curve was recorded when the regression coefficient of the curve reached 0.95.

The gas flux was calculated by 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 diagram, $mg•kg^{-1}•min^{-1}$; F_1 is the conversion coefficient between $mg·kg^{-1}$ and $μg·m^{-3}$ (CO_2：1798.45); F_2 is the conversion coefficient between minutes and days (1440); V is the volume of air into the buoyancy tank, m^3; S is the surface area of floating box above water, m^2; F_3 is the conversion coefficient betweenμg and mg (1000). Among them, a positive value indicates that the gas is discharged from the water body to the atmosphere while a negative value indicates that the water body absorbs the gas in the atmosphere.

In the sampling process, 100 ml of gas was extracted from the static closed chamber every 5 min for consecutive 5 times, which was then sent back to the laboratory for analysis as soon as possible. The concentration of CO_2 in gas samples was linearly analyzed by gas chromatograph, and the slope was calculated as the change rate of CO_2 in the water body.

3 Result and analysis

In the investigation, the variation rate of CO_2 averaged 0.66-2.05 ppm/Min in Caotang River, and the number was 1.02 ppm/Min and 2.67 ppm/Min respectively in Yangtze River. There were drastic differences among monitoring points in terms of the standard deviation of CO_2 variation rate, indicating that the CO_2 variation rate of water body fluctuated greatly in each month during the first year of investigation.

The variation rate of CO_2 in water body changed with time, which peaked in November. CO_2 was released from water to the atmosphere at all sections. The highest release rate occurred at CT02 section in the midstream of Caotang River, with a release rate of up to 42.58ppm/min. The release rates of two sections in the Yangtze River mainstream, 16.43 ppm/min and 12.34 ppm/min respectively, were higher than two other sections in Caotang River, which stood at 4.75 ppm/min and 11.84 ppm/min respectively. In December, other sections also released CO_2 in addition to CT02 section in the middle reaches of Caotang river, though the release rate was significantly lower than that in November. From July to October, most sections absorbed CO_2 without a fixed pattern in space. From January to March of 2018, the absorption and release rate of CO_2 slowed down, with an absolute value between 0.20-2.28 ppm/min. From April to June, the release or absorption rate of CO_2 was slightly higher than that from January to March.

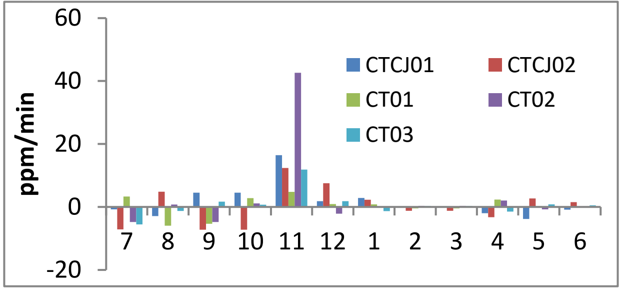

Fig.1. Water CO_2 variation rate-time diagram during investigation

The release and absorption rate of CO_2 followed no fixed pattern in space, probably due to the narrow basin of Caotang River, insignificant climate differences in the basin during the same monitoring period and complex water body hydrodynamic force. Therefore, there was no obvious difference in CO_2 release or absorption in space. However, it showed distinct characteristics in time, that is, the release or absorption rate in the second half of the year was significantly higher than that in the first half of the year. From July to September of 2017, algal bloomed in the Three Gorges Reservoir, with a large number of phytoplankton engaging in CO_2 absorption for photosynthesis to facilitate reproduction and the formation of dominant species. After October, the biological community in the water body was basically established, and a large number of plankton had formed dominant species, giving priority to growth and development instead of reproduction. Therefore, respiration outweighed photosynthesis, with some communities going extinct. The proteins and amino acids in phytoplankton were degraded into CO_2 and released into the atmosphere, featuring a massive amount of release in November.

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