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Abatract: Greenhouse gas(GHG) emission from water surface nearby the small hydropower station is a rising problem of concern. This paper studied the daytime changes of GHG flux of Fujiang hydropower station (FJHPS) and Xiasi hydropower station(XSHPS) located on Qingshui river in Guizhou by the static float chamber sampling and the gas chromatography analysis method in Autumn. Data showed, the fluxes of CO_2, CH_4 and N_2O ranged from -43 to 72, -23 to 15 and -0.016 to 0.13mmol $(m^2\ d)^{-1}$, respectively. Overall, the GHG fluxes in the downstream of the station were slightly higher than the upstream, which manifested the downstream released more GHGs. The CO_2 exchange fluxes in FJHPS were higher than XSHPS, while CH_4 and N_2O fluxes showed a reverse situation. The fluxes of GHG had a positive correlation with DO and pH. Compared with other lakes and reservoirs, smaller releasing rates of GHG were existed in the small hydropower station.

Key Words: Greenhouse Gas; Small hydropower station; Water surface; Qingshui River

1 Introduction

The major greenhouse gas concentrations in the atmosphere have reached the highest point since data was recorded at 2011, with average 390.9 ppm, 1813 ppb and 324.2 ppb for CO_2, CH_4 and N_2O respectively and increased by 40%, 159% and 20% comparing with the period of Industrial Revolution based on the World Meteorological Organization[1]. The continuous increase of atmospheric greenhouse gas concentrations and the consequent global warming raises attentions to greenhouse gases produced by the running hydropower station.

Previous studies have shown that the rapid increase of greenhouse gas concentration is closely related to human activities, of which, reservoir is considered to be an important source of greenhouse gas emission. It is estimated that the CO_2 exchange flux of world's freshwater reservoirs through accounts for 4% of total anthropogenic CO_2 exchange flux[2]. For a long time, the hydropower has been considered a clean, carbon-free energy and gets extensive development[3]. However, some literatures have reported that the reservoir is likely to be an emission source of greenhouse gas[4,5], so the greenhouse gases release from the reservoir has become a controversial problem.

The GHG emissions from reservoir (CO_2, CH_4) is mainly caused due to the mineralization of organic matter[4,5]which originate from the reservoir water and sediments. The existing researches have

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showed that their exchange processes are closely related to reservoir age, soil properties of flooded area, vegetation coverage and regional climate conditions[6,7,8]. The static floating box technology was used to observe the GHG variations of Dongting Lake, Poyang Lake, Dianchi Lake and the Three Georges Reservoir by Chen et al. (2006) [9]. But the data of greenhouse gas emission in small reservoirs is lacked. In addition, as an important greenhouse gas, the warming potential of N_2O is about 310 times(Jain, 2000) [10] than that of CO_2, so it needs to be paid more attention in small reservoirs.

This paper studies the GHG variations in water surface nearby two small hydropower stations in Qingshui river, Guizhou province. Then we link the climatic conditions, water chemical parameters and GHG fluxes to discuss their potential relationships. These results will promote a better understanding of GHG exchange fluxes in the water surface areas of small hydropower stations.

2 Materials and Methods

2.1 Sampling locations

Qingshui river is located in the Guizhou province, southwest China, which is 459km long and cover 17,145 square kilometers in the watershed. Duyun and Kaili are two major cities in this watershed. In this study, GHGs were collected at the water surfaces of upstream and downstream of Fujiang hydropower station (weak human activity) and Xiasi hydropower station (strong human activity). Locations of the study site were shown in Figure 1.

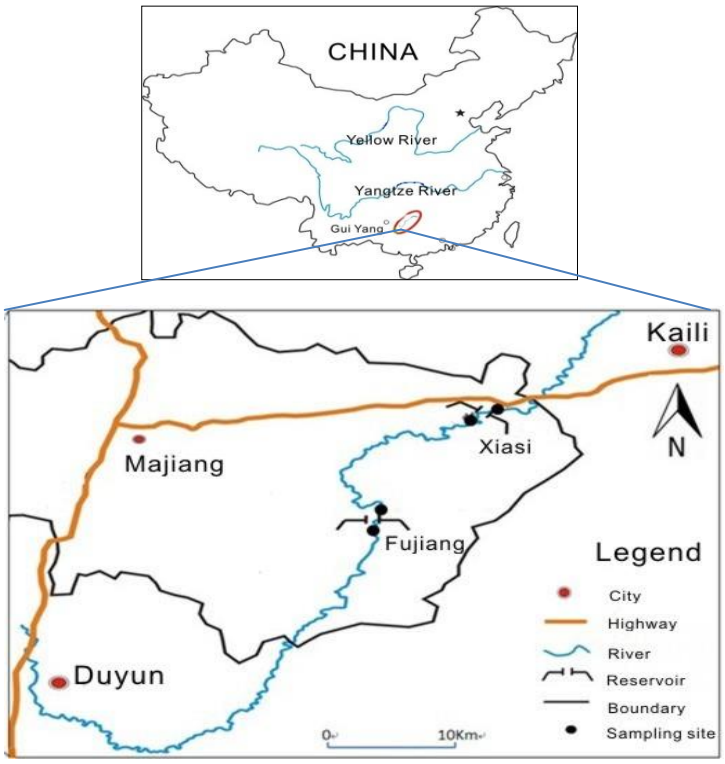

Fig. 1 Location of the sapling sites

2.2 Greenhouse gas collection and detection

GHGs were collected at water surface of two small river reservoir, in a daytime of the Autumn, with the static float chamber[11]. The collection times ranged from 09:00 am to 17:00 pm with one hour interval. The gas samples were extracted by a 30ml plastic syringe, and quickly transferred to a vacu-

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um-sealed glass vial. Four parallel samples were collected at one time. After collection, samples were quickly returned to the laboratory, and detected within 48 hours. Agilent 7890 A gas chromatograph was used for the simultaneous determination of GHGs.

2.3 Calculation of GHG exchange flux

Based on the average concentration of four samples and the background values of local atmosphere, the CO_2, CH_4 and N_2O exchange fluxes were calculated. The calculation formula was as follow:

$$F = (F1 \times F2 \times V \times \Delta c)/(F3 \times S \times \Delta t)$$

Where F represents the gas exchange flux [mg (m^2 d) $^{-1}$]. F_1 is the unit conversion factor between ppm and μg m^{-3}. F_2 is the conversion factor between min and d. V(m^3) represents the volume of air in the floating container. S is the superficial area of water surface inside the floating container. F_3 is the unit conversion factor between μg and mg. $\Delta c/\Delta t$(10^6 min^{-1}) implies the slope of the greenhouse gas concentration versus time during the observation time, which were calculated in each time period. If the exchange flux is positive, it indicates the waterbody release GHGs into the atmosphere. The negative value of exchange flux represents the waterbody absorption from the atmosphere. In this study, the gas concentration calculated by the above formula was divided by the molar mass of each gas, and the unit mg (m^2 d) $^{-1}$ was transformed into unit mmol (m^2 d)$^{-1}$.

2.4 Environmental parameters monitoring

The on-site monitoring of relevant environmental parameters were carried out at the same time of GHG collection. A SX-751 portable multi-parameter water quality monitor was used to measure water quality parameters temperature, DO and pH.

3 Results and Discussions

3.1 Variations of GHG exchange flux in FJHPS and XSHPS

3.1.1 CO_2 exchange fluxes

Monitoring results in XSHPS showed that CO_2 exchange fluxes in the downstream water surface was higher than the upstream water surface(most values>0), which indicated that XSHPS was a carbon source of CO_2. For FJHPS, CO_2 exchange fluxes appeared positive or negative values at different times. The CO_2 exchange fluxes ranged from -43.15mmol (m^2 d)$^{-1}$to 71.17mmol (m^2 d)$^{-1}$, with the range of -43.15 to 37.25mmol (m^2 d)$^{-1}$ and -39.21 to 71.17mmol (m^2 d)$^{-1}$ for the upstream water surface and downstream water surface respectively. Obviously, concentrations of CO_2 released in FJHPS were larger than XSHPS. This is because that FJHPS has run to generate electric power, which stirs water by turbines and releases the dissolved CO_2 in water[12]. A part of water without disturbance directly ran into river channel in the downstream over the rubber dam. This process can release dissolved CO_2 in water again. But XSHPS, has not yet run which doesn't disturb water to release CO_2.

3.1.2 CH_4 exchange fluxes

In the downstream water surface of FJHPS, the concentrations of CH_4 exchange flux changed slightly, which ranged from -2.43 mmol (m^2 d)$^{-1}$ to 0.94 mmol (m^2 d)$^{-1}$.The maximum concentrations of exchange fluxes in the upstream water surface and the downstream water surface were 0.94 mmol (m^2 d)$^{-1}$ and 0.72 mmol (m^2 d)$^{-1}$, respectively. In XSHPS, the changes of exchange fluxes fluctuated significantly, which ranged from -22.63 mmol (m^2 d)$^{-1}$to 14.71 mmol (m^2 d)$^{-1}$ with a maximum

in the noon. Friedl et al. have found that warm water can further promote the generation of CH_4 at the water surface [13]. It is obvious that the CH_4 exchange flux in XSHPS was greater than FJHPS. XSHPS has deeper waterbody, submerging more vegetation in the shore. When all the plants decay, they produce more CH_4[14]. Meanwhile, XSHPS is located in the center of Xiasi Town, domestic sewage can directly enter into the reservoir and led to release more methane gas in waterbody [15].

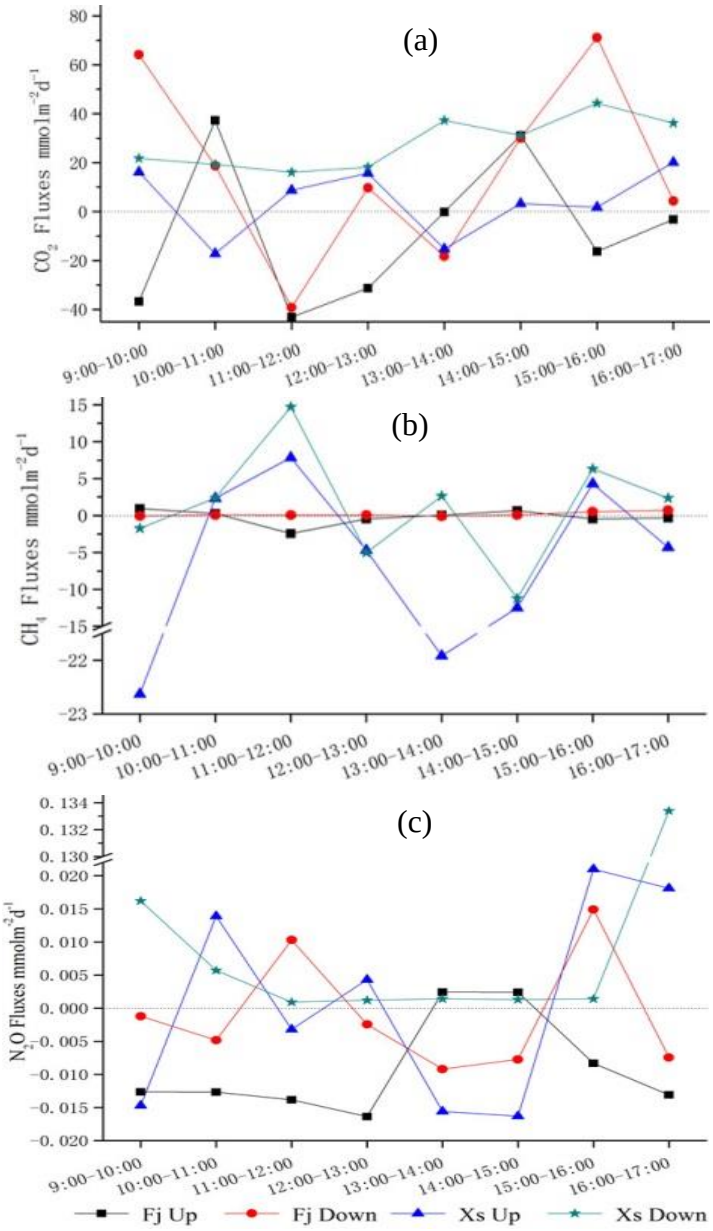

Fig. 2 Day time variations of CO_2, CH_4 and N_2O flux in FJHPS and XSHPS (a) Variations of CO_2 emission fluxes (b) Variations of CH_4 emission fluxes (c) Variations of N_2O emission fluxes.

3.1.3 N_2O exchange fluxes

The N_2O exchange fluxes in both hydropower stations were small, which ranged from -0.016 to 0.133mmol $(m^2\ d)^{-1}$. In FJHPS, the N_2O exchange fluxes ranged from 0.016 to 0.015mmol $(m^2\ d)^{-1}$, which were obviously smaller than those in XSHPS. The main cause is that XSHPS is located in Xiasi Town, where waterbody receives domestic sewage with high nitrogen. And the amount of N_2O is closely related to TN[16] in the waterbody.

3.2 Correlation analysis between water chemical parameters and GHG fluxes

Water temperature, dissolved oxygen and pH were selected as three water chemical parameters to study their correlations with GHG fluxes.

Water temperature can not only directly affect the gas exchange flux by changing the speed of gas molecule diffusion and solubility in water, but also indirectly affect geochemical process of GHG by changing the metabolic activity of microorganisms in water[17]. In addition, the water temperature can affect photosynthesis and respiration of aquatic plants, resulting in variations of CO_2 exchange flux[18]. The average temperature in both areas respectively was 17.75℃ and 18.5℃. No correlations between the water temperature and greenhouse gas exchange flux were showed in the studied area (Table 1). It was indicated the water temperature was not a major affecting factor in Autumn.

The concentration of DO determines the ways and products of organic matter degradation in water. In the cycle of carbon, organic matters mainly generate CO_2 in aerobic environment and CH_4 in anaerobic condition. In the nitrogen cycle, organic matters exercise the aerobic nitrification and anaerobic denitrification[19]. Correlation analyses showed the DO had a good positive correlation with three parameters, which implied high DO can promote the release of GHGs in waterbody.

The pH value is another important chemical parameter of waterbody, which can affect the release of CO_2 in the reservoir by changing the carbonate balance. It is a significant factor affecting the produce and release of CO_2 and CH_4, which has close relationships with the decomposition of organic matter, microbial activity and biological metabolic activity in waterbody[20]. Results indicated that correlations between pH and GHGs in FJHPS had better positive correlation than in XSHPS(Table 1). It can be explained that the pH value of waterbody in XSHPS is disturbed by organic matter from sewage.

Table 1 Correlation coefficients between the fluxes of CO_2, CH_4, N_2O and the environmental factor Temperature, DO and pH in waterbody of small hydropower stations in Qingshui River.

Item	Fujiang hydropower station			Xiasi hydropower station		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Temperature	-0.078	0.057	0.192	-0.173	-0.076	-0.010
DO	0.428	0.414	0.557*	0.331	0.307	0.377
pH	0.506*	0.274	0.495	0.257	0.162	0.102

*.Significant correlation at the 0.05 level (bilateral); **. Significant correlation at the 0.01 level (bilateral)

Table 2 Range of greenhouse gas fluxes from the studied area and other areas. ($mmol/m^{-2}d^{-1}$)

Name	Temperature Zone	CO_2	CH_4	N_2O	References
Lokka Lake	Frigid zone	11.23-73.44	0.328-7.430	-0. 500-5.797	21
Kevätön Lake	Frigid zone	-1.81-25.06	0.276-12.096	-1.702-0. 440	22
Arrow Lake	Temperate	13.82-25.92	0.216-0.665	-0. 023-0.079	20
Cabonga Lake	Temperate	5.01-78.62	0.190-3.370	-0. 390-6.099	6

Maotiao River	Subtropics	-9-77	nd	nd	23
Donghu Lake	Subtropics	-31.97-87.26	0.086-8.294	nd	16
Qingshui River	Subtropics	-43-72	-23-15	-0.016-0.13	This study
Curua-Una Lake	Tropical	7.5-227.27	0.125-42.5	nd	24
Petit Saut Lake	Tropical	13.18-238.64	0.313-237.5	nd	25

Note: nd is not detected

3.3 Comparisons of GHGs in the study area and other areas

The GHG flux data summarized in Table 2 were obtained from literatures of different areas. We found that GHG fluxes of tropical lakes or reservoirs of were significantly higher than the other temperature Zone. CO_2 fluxes of frigid zone and temperate were relatively lower. And the CO_2 flux ranges in our studied hydropower stations changed from -43 to 72 mmol $(m^2 d)^{-1}$, which was similar with those of frigid and temperate reservoirs. The values of CH_4 flux ranged from -23 to 15 mmol $(m^2 d)^{-1}$, significantly larger than the those of other lakes or reservoirs. But the N_2O fluxes ranged from -16 to 130 μmol·$(m^2 d)^{-1}$, which were significantly lower than those of other lakes or reservoirs. Therefore, we can conclude the running of small hydropower station only promote the rising of CH_4 flux, but slightly affect the CO_2 and N_2O fluxes.

4 Conclusions

The fluxes of greenhouse gas(CO_2,CH_4 and N_2O) fluctuate at the water surface of small hydropower stations Qingshui river of Guizhou province in Autumn, during a daytime continuous monitoring. On the whole, the GHG fluxes at the downstream water surface of hydropower station are slightly higher than the upstream water surface, manifesting the more GHG releases at downstream waterbody. The turbine rotating can significantly influence the CO_2 exchange fluxes of waterbody nearby hydropower stations. The domestic sewage and submerged plants can result in decomposition of organic matter to release more CH_4 and N_2O. Through the correlation analysis, the dissolved oxygen and pH influences apparently the GHG in Autumn. The running of small hydropower station only influences obviously the CH_4 fluxes, and therefore can be considered as an effective way to clean energy utilization.

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