SEASONAL VARIABILITY OF PARTICULATE ORGANIC CARBON (POC) IN A LARGE ASIAN TROPICAL RIVER: THE RED RIVER (CHINA/VIETNAM)

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ABSTRACT

The Red River (China/Vietnam) is one of the largest Asian tropical rivers. Based on daily water discharge and suspended particulate matter (SPM) concentrations during the 2006 - 2009 period combining with the particulate organic carbon (POC) analyse at a permanent observation station (SonTay, near Hanoi), the seasonal variability of POC concentration was determined. The results showed that the % POC is generally quite low, varied between 0.62 % and 3.92 % with a mean of 1.44 %. In addition, a relation log – log exponential decrease between the SPM concentrations and POC contents (%) was observed, suggesting the dilution of both allochthonous (plants and woody materials) and autochthonous (riverine plankton) organic matter by mineral and clay materials from rock and soil erosion in the drainage area. In contrast, the POC concentration of the Red River at SonTay showed a similar evolution with the SPM concentrations. In fact, during the dry season, the monthly POC concentrations were low (0.91 ÷ 1.25 mg/l) and increased during the rainy season (1.71 ÷ 6.24 mg/l). Finally, we quantified the annual POC flux exported by the Red River into the Delta to be $154 \times 10^3 \div 332 \times 10^3$ t/yr with the mean annual of 243×10^3 t/yr.

Keywords: Red River, Vietnam, particulate organic carbon, seasonal variability, flux.

1. INTRODUCTION

Riverine input of carbon into the ocean is an important link in the biogeochemical cycling of carbon between its two major pools: land and ocean [1, 2, 3, 4]. The quantity of carbon transported by rivers is an important component of the global carbon cycle [5, 6, 7, 8, 9, 10]. In recent years, the global carbon cycle and riverine carbon budget has been receiving more and more attention, with regards to the past, present and future linkage between river carbon atmospheric CO_2 and climate and to their coupling with other major biogeochemical cycles as nitrogen, phosphorus and sulphur [e.g. 11, 12, 13, 14, 15].

Among the total flux of carbon carried by global rivers (~1 Gt/yr), ~0.55 Gt is inorganic carbon and ~0.45 Gt is organic form, of which 45 % of POC [16, 17]. A study on fluvial carbon in tropical rivers by Probst and Ludwig [18] showed that more than 50 % of total POC flux load to the ocean by Asian rivers because of the high sediment yields. More recently, Galy et al. [19] showed that Himalayan Rivers is a significant component of the organic carbon budget of the ocean: the modern burial flux of recent carbon organic generated by Himalayan erosion was estimated at $\sim 3.1 \pm 0.3 \times 10^{11}$ mol/yr (i.e. 15 % of the global flux).

The Red River (China/Vietnam) is the one of largest rivers draining the Himalaya Mountains into South-East Asia in terms both of water discharge (3800 m^3/s) and suspended particulate matter (SPM) load (24 – 200 Mt/yr) [20]. However, little information is available on water biogeochemistry of the Red River [e.g. 21, 22]). This paper is based on daily water discharge and SPM concentrations during the 2006 - 2009 period combining with the particulate organic carbon (POC) analyse at a permanent observation station (Son Tay gauging station; data from IMHE) near Hanoi, considered to be the entry point to the Red River Delta and located at the upstream limit of the dynamic tide. The objectives of this study are to (1) describe temporal variability of POC concentrations during high frequency sampling; (2) discuss POC origins (soil, litter or autochthonous production) and (3) assess the contribution of the Red River to the POC budget into the Gulf of Tonkin in the South China Sea.

2. MATERIALS AND METHODS

2.1. Area descriptions

The Red River system has a total watershed area of 169,000 km², 50.3% of which in Vietnam, 48.8 % in China and 0.9 % in Laos and includes a fertile and densely populated delta plain (14,000 km²; Fig. 1). The Red River originates from the mountainous area of Yunnan Province in China and flows 1200 km south-eastward before entering into the Gulf of Tonkin in the South China Sea. The red laterite soils are abundant in the mountainous area and give the river its characteristic red colour [32]. The main tributaries of the Red River are the Da River, on the right bank, and the Lo River, on the left bank (Fig. 1). The Da River has its source in the Yunnan Province, near to that of the upstream Red River, at an elevation of more than 2000m.

The Red River basin is characterized by two distinct seasons: the wet season from May to October and the dry season from November to April, due to the South West monsoon in summer and the North East monsoon in winter, respectively (Fig. 1). The summer season is warm and very humid with mean temperatures ranging from 27 °C to 29 °C whereas the winter season is cool and dry with mean monthly temperatures ranging from 16 °C to 21 °C (Fig. 1). The average annual rainfall in the Red River System is 1600 mm, with 85 % - 95 % of this falling during the summer season.

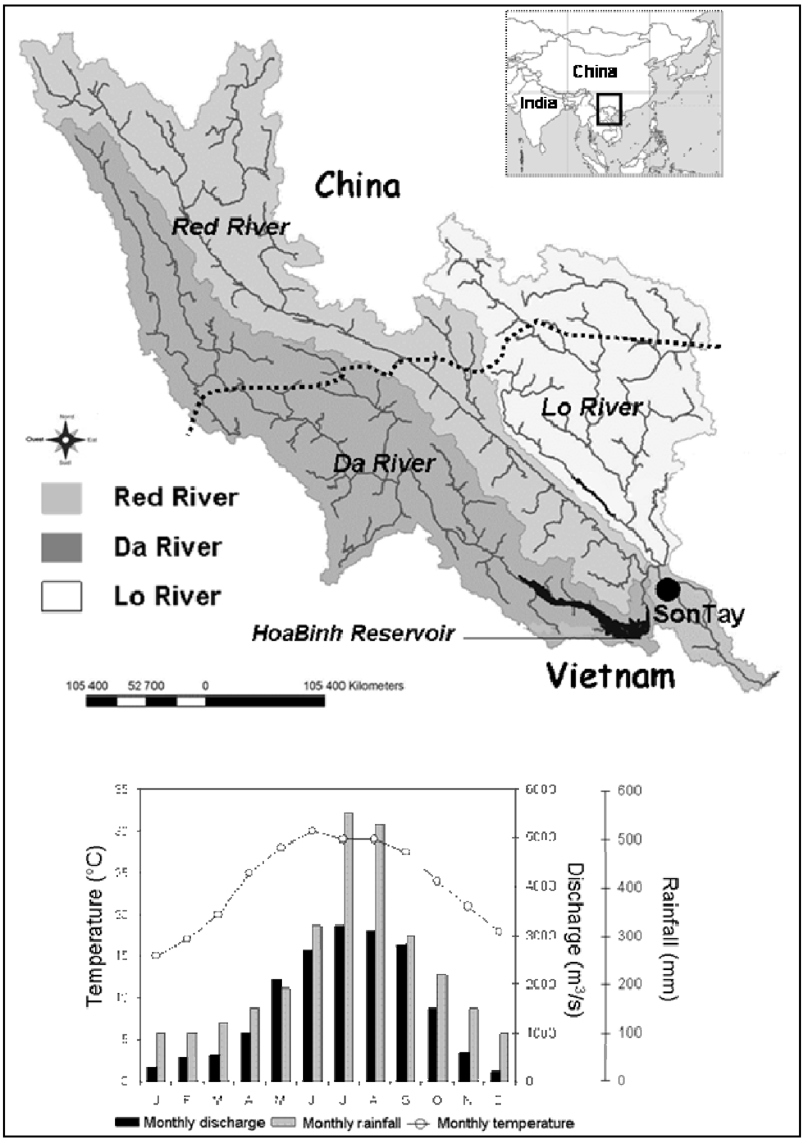

Figure 1. Map of the Red River and its tributaries and description of monthly averages of rainfall, temperature and water discharge at Son Tay site (data from [20]).

2.2. Data and methodology

2.2.1. Data collection

In this study, the available dataset is constituted by daily water discharge and SPM concentrations measurements at the Son Tay station during the 2006 - 2009 period, supplied by the Institute of Metrology, Hydrology and Environment in Vietnam (IMHE).

The annual discharge – weighted SPM concentration and POC concentration was calculated from discharges and concentrations as follows:

$$Ca = \frac{\sum (CiQi)}{\sum Qi}$$

where: Ci, Qi are carbon concentration and water discharge of day i; Ca is annual discharge-weighted of SPM or species carbon concentrations

2.2.2. Sampling frequency

During 2006 - 2009 period, different sampling frequencies were performed at the Son Tay station: weekly sampling frequency during March 2006 – September 2007 and May – September 2009 and bi-monthly sampling frequency during January – November 2008

2.2.3. Sampling and Sample analyses

Water sample were collected using 2 L glass bottle. The samples were taken 15 – 20 cm from the surface water and 2 m from the riverbank. Samples were filtered through pre-heated and pre-weighted 0.70 µm Whatman GF/F glass fiber filters for suspended particulate material weight and particulate carbon. The filters were dried in an oven at 50 °C for 24 hours and weighted to determine SPM concentrations. The filters were firstly treated with HCl 2N to remove carbonates and dried at 60 °C for 24 hours. Particulate organic carbon analyse was determined using a LECO CS 125 analyzer and carbon contents are expressed as a percentage of dry weight of SPM. Analytical accuracy was better than 5 % [23, 24, 25].

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Variation of water discharge and SPM concentrations dynamics of the Red River at the Son Tay station

During 2006 - 2009, the inter-annual water discharge of the Red River at the Son Tay station was 3593 m^3/s, showing that the study period covered mean hydrological condition [4].

Concerning the SPM concentration, the daily SPM concentrations of the Red River at the Son Tay station ranged from 2.4 to 2350 mg/l (Fig. 2). We noted that the highest values were observed during the rainy season and closely linked to the variability of water discharge (Fig. 2). The inter-annual SPM discharge-weighted concentration of the Red River varied between 144 and 232 mg/l with the mean value of 189 mg/l, which are generally observed in mountainous headwaters and/or in low relief basins draining erodible rocks [3, 14].

3.1.2. Variation of Carbon concentrations of the Red River at the Son Tay station

The POC contents (expressed as percent of SPM) measured at the Son Tay station ranged from 0.62 to 3.9 % (Fig. 2) with a mean value of 1.44 %. In addition, we noticed that in high water conditions, % POC is relatively low and its values increase strongly when water level decreases (Fig. 2).

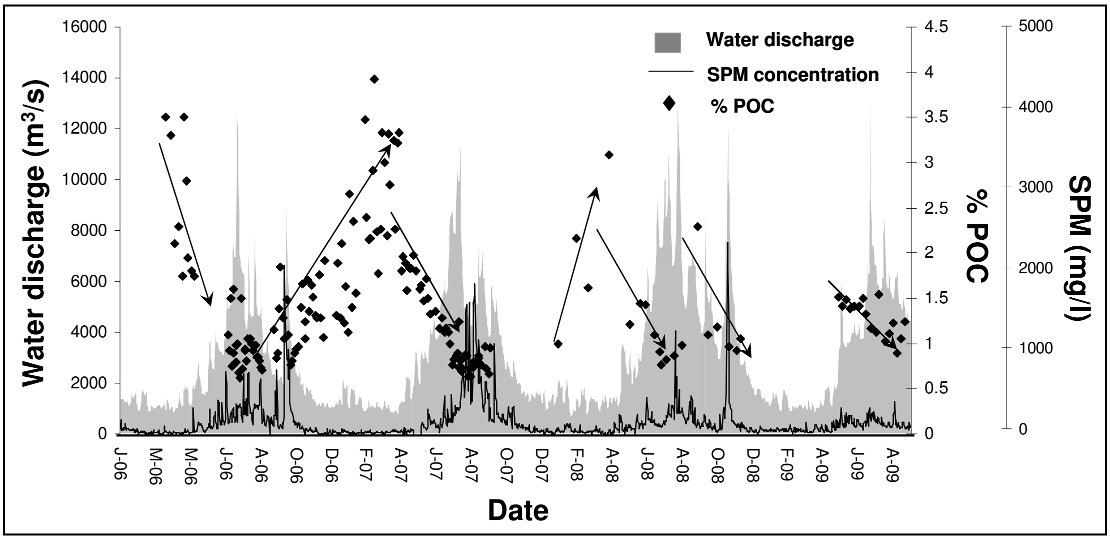

Figure 2. Evolution of water discharges, SPM concentrations and % POC of the Red River at the SonTay station during 2006 - 2009 period.

As a comparison, the %POC measured in the Red River were comparable to those observed in the other rivers located in Asia (Fig. 3): the Changjiang River (0.5 to 2.5 % with a mean of 1.26 %, [26]); the Xijiang River (0.88 % to 3.4 % with a mean of 1.22 %; [27]). They are higher than those measured in the Brahmaputra River (0.6 % to 1.34 %, with a mean of 0.50 %; [12]) or the Huanghe River (0.4 % to 1.3 % with a mean of 0.53 %; [28). As suspected, they are really lower than those of a river from a tropical wet area, like the Congo River (4.0 - 11.5 % with a mean of 6.5 %; [24]; Fig. 3).

The mean annual POC discharge-weighted concentrations for the 2006 - 2009 period of the Red River at the Son Tay station ranged between 0.4 and 24 mg/l, with the mean value of 3.2 mg/l. We noted that this value is slightly lower than the average POC concentration of Asian rivers estimated by Meybeck at al. [3] (4.5 mg/l).

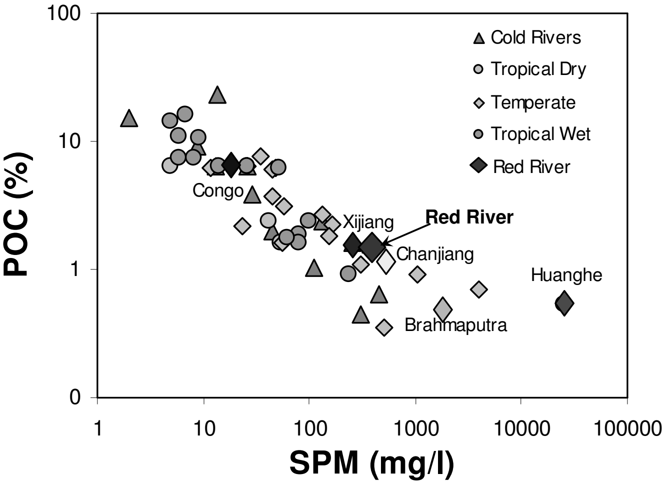

Figure 3. Distribution of mean annual POC contents in SPM of the world's rivers clustered by climate type (Source: [2, 3, 24, 26, 27, 28]).

3.2. Discussion

3.2.1. Temporal variation of carbon concentrations

Monthly variation of POC concentration of the Red River at the Son Tay station

Based on the whole POC concentration analysis from high resolution sampling frequency (weekly to bi-monthly) of the Red River at the Son Tay station, the monthly concentration of POC concentration was calculated for the 2006-2009 period (table 1). We observed that the monthly POC concentrations were low in dry season (from November to April) and its values increased firstly in rainy season (from May to October). In fact, the POC concentrations varied between 0.91 mg/l (observed in April) and 6.24 mg/l (observed in August) (table 1). These results suggested that the POC concentrations evolution was closely linked to the hydrological conditions, due to the soil erosion.

Table 1. Average monthly concentration (mg/l) of water discharge, SPM and POC during the study period. n denotes number of samples.

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Q (m^3/s)	1499	1439	1243	1515	3023	4037	7668	6404	4407	3295	2825	1506
SPM (mg/l)	87.6	53.8	43.6	36.3	118	169	329	762	620	477	262	73.4
POC	1.25	1.05	1.09	0.91	1.71	2.40	2.56	6.24	5.38	5.28	2.79	1.04
n	*9*	*6*	*12*	*16*	*21*	*13*	*56*	*38*	*17*	*13*	*16*	*7*

In addition, the relationships between POC concentrations and water discharge showed a counterclockwise loop (Fig. 4): at a similar discharge, POC values on the falling limb were greater than the ones on the rising limb. This phenomenon have observed in many rivers in the word and two processes can explain this loop type: (i) a relatively long travel time of the flood wave and the POC flux between the flood source and the measuring station; (ii) a high soil erodibility in conjunction with prolonged erosion during the flood [26]. This counterclockwise pattern also has been observed for SPM in the Red River, showing a similar evolution of POC concentrations with SPM concentrations (Fig. 4).

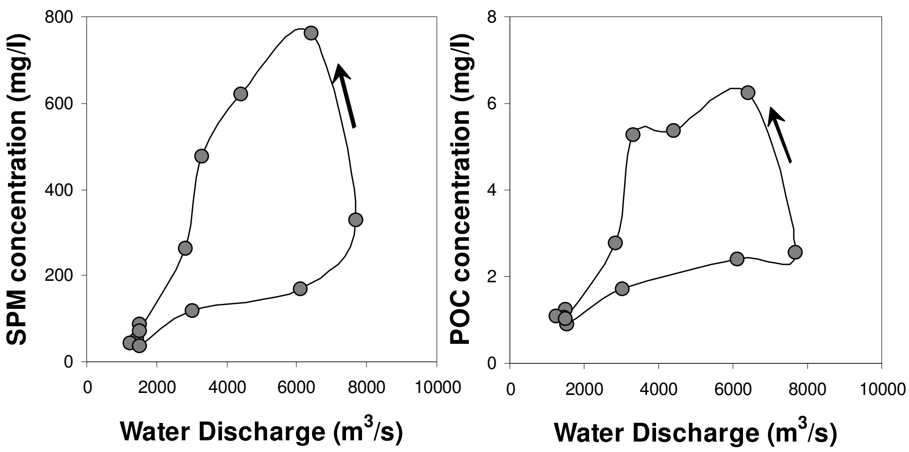

Figure 4. Behaviors of monthly SPM and POC concentrations with monthly water discharge of the Red River at Son Tay during 2006 - 2009 period.

POC contents and SPM concentrations relationship

A relation log – log exponential decrease between the SPM concentrations and POC contents (%) was established based on the whole data (Fig. 5). This relation is observed on many streams and rivers of the world at individual measurements at a given station; on yearly or long-term averages and on different basins comparison [2, 15, 29]. The trend of decreasing organic carbon content with increasing SPM concentration can explain by the dilution of both allochthonous (plants and woody materials) and autochthonous (riverine plankton) organic matter by mineral and clay materials from rock and soil erosion in the drainage areas and by the reduction of autochthonous POC, resulting reduced light penetration because of high turbidity [30]. Ittekkot [5] reported that suspended particles in less turbid rivers contain more labile fraction (30 – 45 %) in the total POC than particles in high turbid rivers (< 20 %). In addition, Meybeck et al. [3] reported that highly turbid rivers (> 1000 mg/l) may carry an appreciable amount of fossil POC.

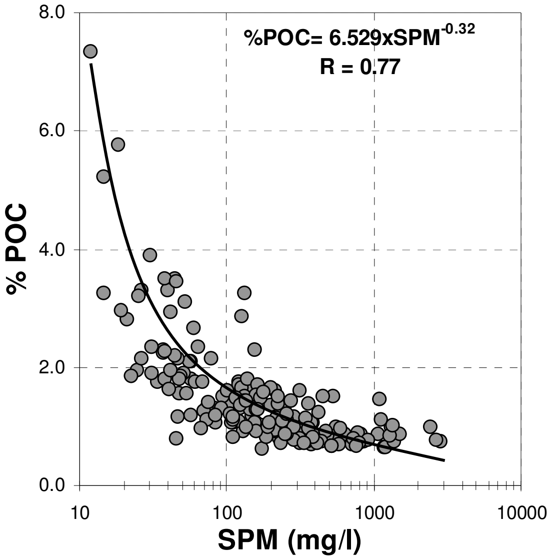

Figure 5. Relationship between % POC and SPM concentrations of the Red River at Son Tay during the 2006 - 2009 period.

In order to calculate the distribution of difference POC pools, we devised three distinguished classes (Fig. 5): at low SPM concentrations (< 100 mg/l), the organic fraction in SPM is largest (~2.5 %), indicating the important distribution of autochthonous POC by riverine primary production [3]; at medium SPM concentrations (100 - 1000 mg/l), the organic fraction is less abundant (~1.14 %) and essentially litter/riparian POC dominating; while at high SPM concentrations (> 1000 mg/l), the organic fraction is relative constant about of 0.5 %, showing that the soil and sedimentary rock are a major source of organic carbon in these sample [9]. The same threshold values of POC content in SPM concentration (0.6 ± 0.2 %) were observed on the Lanyang-His River in Taiwan when SPM concentration ranged from 1000 mg/l to 30 000 mg/l [6]. Furthermore, by 14C analyse, Kao and Liu [6] demonstrated the fossil POC of such particle, which presents 70 % of total organic carbon load by this river. This observation is used to calculate the different carbon organic pools of the Red River.

Finally, we noted that when we subtract the part of POC due to soil/rock material, autochthonous material is about ~1.2 % of SPM. This value is relatively lower than other world river of 4 % [31] and can explain by a small fraction of phytoplankton biomass on the particulate organic carbon of the Red River [32].

*** Carbon Budget of the Red River System**

POC fluxes transported by the Red River were calculated from the daily water discharges and SPM concentrations during 2006 - 2009 period based on the % POC-SPM relationship [e.g. 3, 14, 24, 33].

During 2006 - 2009 period, POC fluxes transported by the Red River to its delta varied between 154×10^3 and 332×10^3 t/yr with the mean annual of 243×10^3 t/yr. Comparatively to some other world rivers, the calculation of the specific POC fluxes (i.e. normalized annual POC fluxes by the watershed areas to obtain specific POC fluxes (t/km^2/yr), which allow comparing the differ watersheds) show that the contribution of the Red River to the organic carbon flux to the sea must be take into account. The specific POC flux is in the same order or higher than the ones of the Asian Rivers (e.g. Yellow, Changjiang and Brahmaputra, Fig. 6).

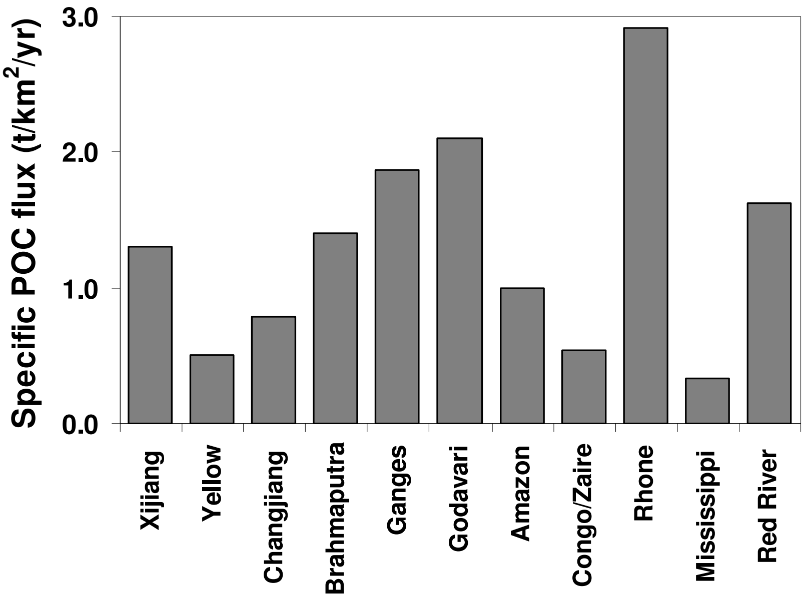

Figure 6. Comparison of specific POC flux in the Red River with some other world rivers. [Data sources: 3, 23, 24, 31, 34, 35, 36].

4. CONCLUSIONS AND PERSPECTIVES

The four years (2006 - 2009) high-resolution dataset of water discharge, SPM concentration combined with the carbon analyse (POC) of the Red River at the Son Tay station, show that the POC concentration dynamics in the Red River was closely linked to water discharges and SPM concentrations. However, the common inverse relationship between % POC and SPM concentrations was observed. Even if the % POC of the Red River remains moderate, the specific POC flux transported by the Red River is comparable to other rivers located in Asia (e.g. Ganges, Brahmaputra, Yellow and Changjiang Rivers), due to the high erosion rates of this area. Future carbon studies should at the upstream part of the Red River watershed (e.g. at Lao Cai) and at the both tributaries Da and Lo Rivers to better understand carbon source but also carbon transport dynamic in the Red River system.

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REFERENCES

1. Kemper S. - Carbon in the freshwater cycle. In The Global Carbon Cycle, edited by B. Bolin et al., Scope **13** (1979) 317-342.
2. Meybeck M., Cauwet G., Dessery S., Somville M., Gouleau D., Billen G. - Nutrients (Organic C, P, N, Si) in the eutrophic river Loire (France) and its estuary, Estuarine, Coastal and Shelf Science **27** (1988) 595-624.
3. Meybeck M., Roussennac S., Dürr H., Vogler J. - Lateral carbon transport in freshwaters. Concerted Action CarboEurope-GHG, CarboEurope Cluster Report, 55pp (2005).
4. Raymond P. A., Bauerb J. E., Caracoc N. F., Colec J. J., Longworthd B. and Petschd S. T. - Controls on the variability of organic matter and dissolved inorganic carbon ages in northeast US rivers, Marine Chemistry **92** (2004) 353-366.
5. Ittekkot V. - Global trands in the nature of organic matter in river suspensions, Nature **332** (1988) 436-438.
6. Kao S. J., Liu K. K. - Fluxes of dissolved and nonfossil particulate organic carbon from an Oceania small river (Lanyang His) in Taiwan, Biogeochemistry **39** (1997) 255-269.
7. Kao S. J., Liu K. K. - Particulate organic carbon export from a subtropical mountainous river (Lanyang His) in Taiwan, Limnol. Oceanogr. **41** (1996)1749-1757.
8. Lobbes J. M., Fitznar H. P., Kattner G. - Biogeochemical characteristics of dissolved and particulate organic matter in Russian rivers entering the Arctic Ocean., Geochimica et Cosmochimica Acta **64** (2000) 2973-2983.
9. Meybeck M., Laroche L., Durr H. H., Syvitski J. P. M. - Global variability of daily total suspended solids and their fluxes in river, Glob. Planet Change **39** (2003) 65-93.
10. Sempéré R., Charrière, B., Van Wambeke, F., Cauwet, G. - Carbon inputs of the Rhone River to the Mediterranean Sea: Biogeochemical implications, Global Biogeochemical Cycles **14** (2000) 669-681.
11. Bouillon S., Abril G., Borges A. V., Dehairs F., Govers G., Hughes H. J., Merckx R., Middelburg J. J. - Distribution, origin and cycling of carbon in the Tana River (Kenya): a dry season basin-scale survey from headwaters to the delta, Biogeosciences **6** (2009) 2475-2493.
12. Galy V., France-Lanord C., Lartiges B. - Loading and fate of particulate organic carbon from the Himalaya to the Ganga-Brahmaputra delta, Geochimica et Cosmochimica Acta **72** (2008) 1767-1787.
13. Gupta L. P., Subramanian V., Ittekkot V. - Biogeochemistry of particulate organic matter transported by the Godavari River, India. Biogeochemistry **38** (1997) 103-128.

14. Meybeck M., Dürr H. H., Vörösmarty C. J. - Global coastal segmentation and its river catchment contributors: A new look at land-ocean linkage. Global biogeochemical cycles 20, GB1S90, 15pp., 2006; doi:10.1029/2005GB002540 (2006).
15. Meybeck M., Vörösmarty C. J. - Global transfer of carbon by rivers, Global Change Newsl. **37** (1999) 12-14.
16. Ludwig W., Probst J. L., Kempe S. - Predicting the oceanic input of organic carbon by continental erosion, Global Biogechem, Cycle **10** (1996) 23-41.
17. Meybeck M. - Riverine transport of atmospheric carbon: sources, global typology and budget. Water, Air, and Soil Pollution **70** (1993) 443-463.
18. Ludwig W, Probst J. L. - River sediment discharge to the oceans: present-day controls and global budgets, American Journal of Science **298** (1998) 265-295.
19. Galy V., Bouchez J., France-Lanord C. - Determination of Total Organic Carbon content and δ13 in Carbonate-Rich detrital sediments, Geostandards and geoanalytical research **31** (2007) 199-207.
20. Dang T.H., Coynel A., Orange D., Blanc G., Etcheber H., Le L.A. - Long-term monitoring (1960-2008) of the river-sediment transport in the Red River Watershed (Vietnam): temporal variability and dam-reservoir impact, Science of the Total Environment **408** (2010) 4654-4664.
21. Le T. P. Q., Garnier J., Billen G., Thery S. and Chau V. M. -The changing flow regime and sediment load of the Red River, Viet Nam, Journal of Hydrology **334** (2007) 199-214.
22. Vu H. H., Le T. P. Q., Garnier J., Henri E., Duong T. T., Ho T. C. - Preliminary observation of particulate organic carbon (POC) contents in water environment of the downstream of Red River system, Tạp chí các Khoa học về Trái đất **34**(1) (2010) 65-69.
23. Coynel A., Etcheber H., Abril G., Dumas J., Hurtrez J. E.- Contribution of small mountainous rivers to particulate organic carbon input in the Bay of Biscay, Biogeochemistry **74** (2005a) 151-171.
24. Coynel A., Seyler P., Etcheber H., Meybeck M., Orange D. - Spatial and seasonal dynamics of total suspended sediment and organic carbon species in the Congo River , Global Biogeochemical Cycles 1**9** (2005b) 1-17.
25. Etcheber H., Relexans J. C., Beliard M., Weber O., Buscail R., Heussner S. - Distribution and quality of sedimentary organic matter on the Aquitanian margin (Bay of Biscay), Deep-Sea Research Part II: Topical Studies in Oceanography **46** (2009) 2249-2288.
26. Wu Y., Zhang J., Liu S. M., Zhang Z. F., Yao Q. Z., Hong G. H. and Cooper L. - Sources and distribution of carbon within the Yangtze River system, Estuarine, Coastal and Shelf Science **71** (2007) 13-25.
27. Dianjun, G., Longjun, Z., Liqing J. - The effects of estuarine processes on the fluxes of inorganic and organic carbon in the Yellow River estuary', Journal of Ocean University of China **8** (2009) 352-358.
28. Ittekkot V., Laane R. W. P. M. - Fate of riverine particulate organic matter, in Biogechemistry of major World Rivers, edited by E. T. Degens, S. Kempe and J. E. Richey, Scope **42** (1991) 233-242.
29. Ittekkot V., Arain R. - Nature of particulate organic matter in the river Indus, Pakistan, Geochimica et Cosmochimica Acta **50** (1986) 1643-1653.

30. Meybeck M. - Carbon, nitrogen, and phosphorus transport by World Rivers, American Journal of Science **282** (1982) 401-450.
31. Le T. P. Q., Billen J., Garnier J., Sylvain T., Denis R., Nghiem XA. and Chau V. M. - Nutrient (N, P, Si) transfers in the subtropical Red River system (China and Vietnam) Modelling and budget of nutrient sources and sinks, Journal of Asian Earth Sciences **37** (2010) 259-274.
32. Kao S. J., Liu K. K. - Estimating the Suspended Sediment Load by using the historical hydrometric record from the Lanyang-His watershed, TAO **12** (2001) 401-414.
33. Sun H. G., Han J., Lu X. X, Zhang S. R., Li D. (2010) - An assessment of the riverine carbon flux of the Xijiang River during the past 50 years, Quaternary International, doi:10.1016/j.quaint.2010.03.002.
34. van Maren D. S. - Water and sediment dynamics in the Red River mouth and adjacent coastal zone, Journal of Asian Earth Sciences **29** (2007) 508-522.
35. Vessy E., Etcheber H., Lin R. G., Buat-Menard P., Maneux E. - Seasonal variation and origin of Particulate Organic Carbon in the lower Garonne River at la Reole (southwestern France), Hydrobiologia **391** (1999) 113-126.
36. Williams, G. P. - Sediment concentrations versus matter discharge during hydrologic events in rivers, Journal of Hydrology **111** (1989) 89-106.

TÓM TẮT

NGHIÊN CỨU SỰ BIẾN ĐỔI HÀM LƯỢNG CACBON HỮU CƠ LƠ LỬNG (POC) THEO MÙA TRONG NƯỚC SÔNG NHIỆT ĐỚI CHÂU Á: VÍ DỤ TẠI SÔNG HỒNG (TRUNG QUỐC/VIỆT NAM)

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Sông Hồng có nguồn gốc từ Trung Quốc chảy qua Việt Nam trước khi đổ ra biển Đông là một trong những sông nhiệt đới lớn ở Châu Á. Dựa trên các số liệu hàng ngày từ 2006 đến 2009 lưu lượng nước (Q) và hàm lượng chất rắn lơ lửng (SPM) kết hợp với số liệu phân tích hàm lượng các-bon lơ lửng (POC) trong nước sông Hồng tại Sơn Tây, nghiên cứu đã đánh giá diễn biến hàm lượng POC trong nước sông Hồng theo thời gian. Các kết quả thu được đã chỉ ra rằng hàm lượng POC trong chất rắn lơ lửng (% POC) tương đối thấp, dao động từ 0,62 % đến 3,92 % với hàm lượng trung bình là 1,44 %. Hơn thế, mối tương quan tỉ lệ nghịch giữa hàm lượng SPM và % POC đã chỉ ra rằng hiện tượng pha loãng các chất hữu cơ trong nước (các chất hữu cơ dạng allochthonous và autochthonous) bởi các khoáng và sét đến từ quá trình xói mòn đất đá. Ngược lại, sự biến đổi hàm lượng POC (mg/l) trong nước sông Hồng lại tỉ lệ thuận với hàm lượng SPM.

Cụ thể là trong mùa khô, hàm lượng POC (mg/l) thấp (0,91 ÷ 1,25 mg/l) và hàm lượng này tăng đáng kể trong mùa mưa (1,71 ÷ 6,24 mg/l). Cuối cùng, nghiên cứu cũng chỉ ra rằng hàng năm, sông Hồng chuyển tải từ $154\times10^3 \div 332\times10^3$ tấn/năm các-bon hữu cơ lơ lửng với tải lượng trung bình là 243×10^3 tấn/năm.

Từ khóa: Sông Hồng, Việt Nam, các-bon hữu cơ lơ lửng, biến đổi theo mùa, tải lượng.