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Sedimentary nutrients in the mainstream and its five tributary bays of a large subtropical reservoir (Three Gorges Reservoir, China)

Min Zhang [a,b], Yaoyang Xu [a,1], Meiling Shao [a,1], Qinghua Cai [a,*]

[a] State Key Laboratory of Freshwater Ecology and Biotechnology, Institute of Hydrobiology, Chinese Academy of Sciences, 7 Donghu South Road, Wuhan, Hubei 430072, PR China
[b] Graduate University of the Chinese Academy of Sciences, Beijing 100049, PR China

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ABSTRACT

In order to analyze the distribution pattern of the sediment nitrogen and phosphorus of the Three Gorges Reservoir (TGR), the mainstream of TGR and five tributary bays in Hubei province were observed from October 2005 to July 2006. The spatial and seasonal dynamics of the sediment total nitrogen (TN_{sed}) and total phosphorus (TP_{sed}), the relationship between the mainstream and tributary, and the sediment nutrients' effect to the surface water were analyzed. The results showed that, concentrations of TN_{sed} ranged from 0.27 to 2.04 mg/g, and TP_{sed} fluctuated between 0.17 and 1.21 mg/g. Both of the maximum of TN_{sed} and TP_{sed} appeared in the Xiangxi Bay (the longest bays studied), 1.09 and 0.90 mg/g respectively. No significant spatial differences were found among different sites in other bays ($p > 0.05$). For seasonal dynamics of TP_{sed}, only the difference in the Yuanshui Bay between spring and summer was significant ($p < 0.05$). For TN_{sed}, significant differences existed among different seasons in most bays, especially between autumn and other seasons. Cluster analysis based on the surface water nutrients and sediment nutrients indicated that the influence range of the mainstream to the surface water ranged from 10.7 to 15.1 km, while the length of the influence range to the sediment was about 5.34 km. Results of the correlation analysis showed that the internal loading in Hubei province of TGR has not caused a significant effect on the surface water in a large spatial scale, although the influence was significant in some shallow regions.

1. Introduction

Nitrogen and phosphorus are the two most important elements in the metabolism of aquatic ecosystems. At low concentrations, they could limit primary production, while in high concentrations they will accelerate the water eutrophication process (De Medina et al., 2003). In particular, low levels of nitrogen coupled with high levels of phosphorus may promote cyanobacterial blooms in lakes and reservoirs (Smith, 1983; Wang et al., 2005). In recent decades, aquatic ecosystems have received large amounts of waste water due to industrial growth. The sediments receive much nitrogen and phosphorus settling from the surface water, immobilizing them and limiting the algal growth (Nowlin et al., 2005). However, under certain conditions, sediment also could act as the internal source, releasing nutrients to the water and minimizing the effect of external nutrients reduction (Nürnberg et al., 1986; Hu et al., 2011). For example, under wind disturbance, sediment would be re-suspended, and release nutrients to the overlying water (Lopez et al., 2009). The release of the nutrients may further facilitate the water eutrophication (McCune and Caldwell, 2009; Nausch et al., 2009). Especially, phosphorus has been found to be the limiting nutrient to the trophic state in most water bodies (McCune and Caldwell, 2009). The release from the sediment would aggravate cyanobacterial blooms of lakes and reservoirs. Hence, knowledge of the chemical composition of sediment may help to elucidate the biogeochemical cycles of the main nutrients in aquatic ecosystems, and consequently may be used to design management strategies for preventing the algal blooms in lakes and reservoirs.

Three Gorges Reservoir (TGR) is the largest human-made lake in China. After the first impoundment in June 2003, lower reaches in most tributaries evolved as bays because of the backwater of the mainstream. In the confluence, a special mainstream–tributary pattern formed due to the water exchange. Usually, the influence of the mainstream on its tributaries is likely to be limited to the area that is reached by mainstream water during increased flow in the

* Corresponding author.
E-mail address: qhcai@ihb.ac.cn (Q. Cai).
[1] Present address: College of Life Science, Anhui Normal University, Wuhu 241000, PR China.

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mainstream (Beckmann et al., 2005). This area is a transitional zone. Many researchers have investigated transitional zones between lakes and rivers (Richardson and Mackay, 1991), rivers and seas (Rundle et al., 1998), rives and their floodplains (Adis and Junk, 2002). These studies showed that significant exchanges of organisms and energy occur in this area. Nevertheless, few studies focused on the size of the affected area. In the TGR region, some water environment factors in the tributary mouth appeared synchronism with those in the mainstream, e.g. suspended matter, and water chemistry (Xu et al., 2009, 2011), indicating the influence of the mainstream to the tributary. However, due to the different length of the bays, the effect caused by the mainstream might be different, and therefore, there would be different ecological patterns among bays.

From this approach, the total nitrogen and total phosphorus of the sediment in the mainstream of the TGR and its five tributary bays in Hubei Province were studied, to: (1) describe the spatial pattern and seasonal dynamics of the sediment nitrogen and phosphorus in this system; (2) analyze the influence of the mainstream to the tributaries; (3) discuss the effect of the sediment nutrients to the surface water in TGR region.

2. Materials and methods

2.1. Study area and sample collection

The TGR is located at 29°16′–31°25′ N, 106°–110°50′ E (Fig. 1). The climate of the Three Gorges Region is subtropical monsoonal, with high inflow discharge in summer and low discharge in winter (Jiang et al., 2006). The average annual precipitation was 878 mm/a (Dai et al., 2008). Flooding normally occurs during the monsoon season from June to September, occupying 61% of the discharge all through the year (Huang et al., 2006). After the impoundment in June 2003, the water level in front of the Three Gorges Dam (TGD) increased to 135 m above sea level (a.s.l.), and fluctuated between 135 and 139 m a.s.l. (Fig. 2). TGR was operated as the mode of "storing the clear and releasing the muddy", with high and stable water level (WL) in winter, low and fluctuating WL in summer. Fig. 1 shows the water level fluctuations (WLF). The WL showed a maximum in winter (January) with low fluctuations, and began to fluctuate frequently in spring (April). In summer (July), due to the high inflow discharge from the upstream, the WL was lowered in order to make room for flood by releasing water. In autumn (October), it became high gradually due to the impoundment.

Of the five tributaries studied (Jiuwan Bay (JW bay), Xiangxi Bay (XX bay), Tongzhuang Bay (TZ bay), Qinggan Bay (QG bay), and Yuanshui Bay (YS bay)), Xiangxi Bay has the largest watershed area (3099 km^2), the longest river length (93 km) (Table 1, Fig. 1), and is one of the tributary bays studied most extensively (Zhou et al., 2009, 2011; Wang et al., 2011). After the impoundment of TGR, as the water velocity slowed and the water residence time was prolonged, algal blooms occurred frequently in many bays, especially in the XX bay. The basic information of the bays is displayed in Table 1.

According to the geomorphology of the study area, three transects were set up along the mainstream of the TGR: CJ01, CJ04 and CJ05 (Fig. 1). CJ01 was at the upstream of the dam, and CJ04 was at the confluence point of the XX bay and the mainstream. In each transect, three replicates were provided (left, middle and right) because of the broad channel. In the tributary bays, sites were selected according to the length of each bay, and distributed in the downstream (outlet), middle region and the upstream respectively.

Seasonal surveys were carried out from October 2005 to July 2006 (October – autumn, January – winter, April – spring, July –

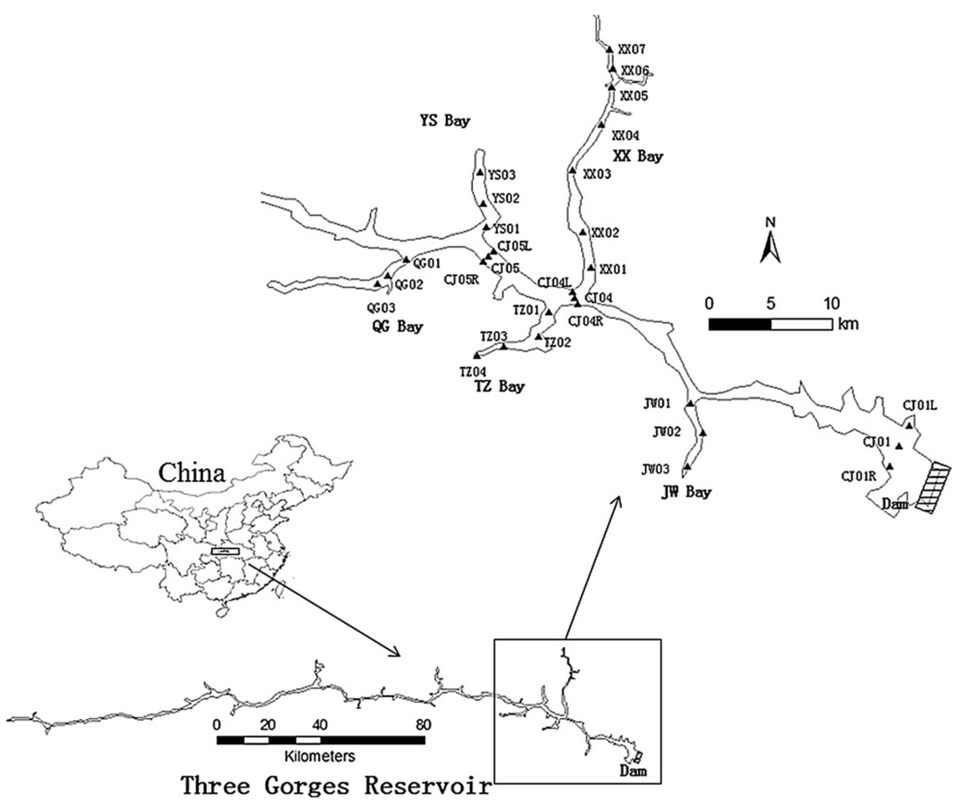

Fig. 1. Location of the study area and the distributions of the sampling sites.

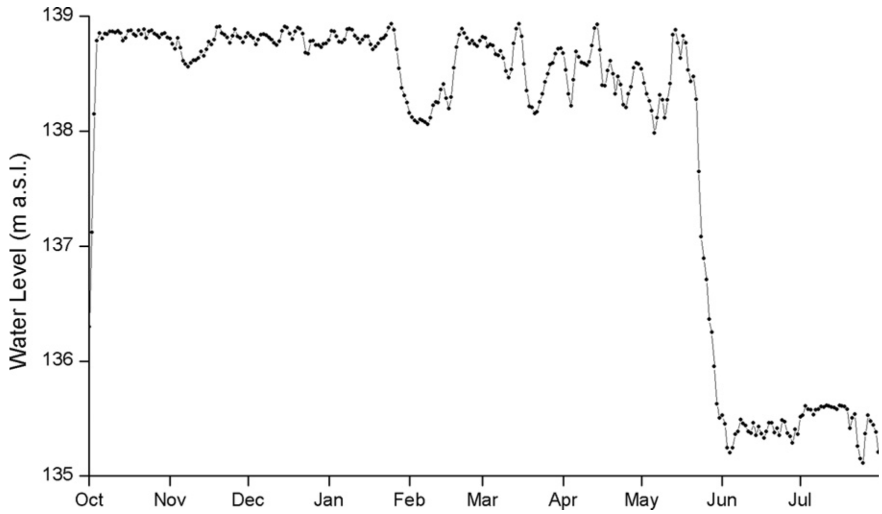

Fig. 2. Water level fluctuations in front of the Three Gorge Dam from October 2005 to July 2006.

summer). The sediment was collected using a Petersen grab, and stored at 4 °C before measurement. In the lab, sediment was digested with a mixture of concentrated sulfuric acid and hydrogen peroxide. The supernatant was used for the chemical analysis. Sediment total nitrogen (TN_{sed}) was measured with the Nesslera reagent colorimetric method, and total phosphorus (TP_{sed}) was determined by the molybdenum blue method. Surface water samples were collected with a 5-L Van Dorn sampler, for the analysis of the water chemistry (TN, NO_3-N, TP and PO_4-P) and chlorophyll *a* (Chl *a*). The samples for the water chemistry analysis were stored in a pre-cleaned plastic bottle and acidified to $pH < 2$ with sulfuric acid, and then measured with a segmented flow analyzer (Skalar San++, Holland). The water sample for Chl *a* measurement was filtered through a weighed and pre-ignited glass fiber filter (Whatman GF/C, 1.2 μm), and then determined using a spectrophotometer (Shimadzu UN 1800, Japan). Simultaneously with the water sampling, transparency (SD) was measured using a 20 cm diameter Secchi disk.

2.2. Data analysis

One-way ANOVA was used to examine the differences of sediment total nitrogen and phosphorus among different bays (SPSS 16.0). Cluster analysis was carried out based on Euclidean distance with Ward's method (Statistica 6.0), to compare the similarity among sites. Pearson Correlation analysis was used to illuminate the relationship between the sediment and surface water nutrients. All data was transformed by $\lg(x+1)$, in order to eliminate the dimension. Lengths of the bays and distances from sampling sites to the bay outlet were calculated using the "measure tool" of ArcGIS 9.2.

Table 1
Basic characteristic of the bays. Bays are arranged according to the distance from the Three Gorges Dam (watershed area and annual discharge data were cited from Huang et al. (2006)).

	Watershed area (km^2)	Annual discharge (m^3/s)	Length of bay (km)	Distance from dam (km)
JW bay	514	17.5	6.00	20
XX bay	3099	47.4	22.0	32
TZ bay	248	6.40	5.70	42
QG bay	523	19.6	5.80	48
YS bay	194	8.30	5.90	34

3. Results

3.1. Water environment

The basic information about the water quality of each bay was displayed in Table 2. Chl *a* in the mainstream (CJ), JW bay, and QG bay were relatively lower than those in other bays. It showed the highest value in XX bay, followed by YS bay. TN content in XX bay was significantly higher than that in the mainstream, JW bay and QG bay, with the *p* value 0.005, 0.017 and 0.043, respectively. TP concentration was also higher in XX bay compared to those in other bays ($p < 0.01$), with an annual average of 0.196 mg/L.

TN in most bays displayed a pattern of "high in the upstream and low in the outlet", with NO_3-N as the main form. Nevertheless, in XX bay, TN increased from the inlet to the outlet. TP, displayed a pattern of "high in the upstream, and low in the outlet" in XX bay (just opposite with the pattern of TN), and did not show an obvious spatial pattern in other bays.

3.2. Spatial distributions of sediment nitrogen and phosphorus

Concentrations of TN_{sed} ranged from 0.27 to 2.04 mg/g (Fig. 3). The average concentration showed the maximum in XX bay (1.09 mg/g), while the lowest value appeared in TZ and QG bays (0.71 mg/g). One-way ANOVA indicated that, TN_{sed} in XX bay was significantly different with that in the mainstream and TZ bay, with *p* value 0.044 and 0.000, respectively. Significant difference also existed between the mainstream and TZ bay ($p < 0.05$), but did not exist among other bays. In most bays, TN_{sed} showed the maximum in the upstream, except in XX and TZ bays. The highest value of TN_{sed} in XX bay appeared in the middle reach, while in TZ bay, the difference among sites was not observable.

Contents of TP_{sed} fluctuated between 0.17 and 1.21 mg/g. There are significant differences between XX and JW, XX and TZ, with *p* values 0.034 and 0.039, respectively. No significant difference was found among other bays. The maximum of TP_{sed} appeared in XX bay (0.90 mg/g); and the lowest value appeared in JW bay (0.68 mg/g). Within all bays, the lowest value usually was found in the inlet, and the highest was always in the outlet except XX bay (maximum of XX bay appeared in the middle reach).

3.3. Seasonal dynamics of TN_{sed} and TP_{sed}

Obvious seasonal fluctuations were found for TN_{sed}, compared to TP_{sed} (Fig. 4). One-way ANOVA of TP_{sed} of all bays indicated that,

Table 2
Comparisons of the water environmental factors in each bay (seasonal average value ± Std. D).

	Chl *a* (μg/L)	SD (cm)	NO_3-N (mg/L)	TN (mg/L)	PO_4-P (mg/L)	TP (mg/L)
CJ01	1.66 ± 3.04	212 ± 191	1.41 ± 0.31	1.72 ± 0.39	0.045 ± 0.011	0.070 ± 0.019
CJ04	0.69 ± 0.40	189 ± 174	1.35 ± 0.24	1.72 ± 0.36	0.047 ± 0.015	0.082 ± 0.015
CJ05	0.67 ± 0.85	198 ± 188	1.37 ± 0.25	1.71 ± 0.40	0.065 ± 0.036	0.097 ± 0.031
JW01	1.12 ± 1.03	203 ± 197	1.26 ± 0.43	1.99 ± 0.99	0.057 ± 0.018	0.069 ± 0.016
JW02	1.41 ± 1.07	256 ± 255	1.26 ± 0.34	1.75 ± 0.49	0.058 ± 0.0140	0.067 ± 0.020
JW03	3.09 ± 3.06	198 ± 184	1.05 ± 0.54	1.65 ± 0.32	0.044 ± 0.022	0.056 ± 0.018
XX01	2.07 ± 2.17	175 ± 156	1.21 ± 0.30	1.74 ± 0.54	0.089 ± 0.057	0.116 ± 0.050
XX02	6.75 ± 9.22	184 ± 119	1.19 ± 0.31	1.73 ± 0.42	0.087 ± 0.071	0.116 ± 0.080
XX03	7.48 ± 11.84	191 ± 135	1.09 ± 0.25	1.61 ± 0.54	0.098 ± 0.057	0.126 ± 0.076
XX04	9.87 ± 12.38	171 ± 101	1.04 ± 0.26	1.42 ± 0.40	0.085 ± 0.064	0.125 ± 0.069
XX05	13.98 ± 10.05	151 ± 94	0.86 ± 0.29	1.26 ± 0.40	0.070 ± 0.072	0.140 ± 0.067
XX06	35.06 ± 36.35	119 ± 61	0.80 ± 0.36	1.39 ± 0.30	0.105 ± 0.044	0.185 ± 0.090
XX07	19.82 ± 16.58	133 ± 38	0.79 ± 0.31	1.24 ± 0.35	0.113 ± 0.071	0.177 ± 0.064
XX08	1.75 ± 1.22	393 ± 14	0.78 ± 0.16	1.12 ± 0.43	0.413 ± 0.381	0.708 ± 0.493
TZ01	4.88 ± 5.03	146 ± 142	1.10 ± 0.30	1.62 ± 0.33	0.046 ± 0.028	0.068 ± 0.030
TZ02	7.30 ± 8.28	128 ± 107	1.13 ± 0.20	1.69 ± 0.42	0.053 ± 0.030	0.053 ± 0.027
TZ03	11.07 ± 9.89	120 ± 85	1.14 ± 0.26	1.67 ± 0.36	0.041 ± 0.022	0.049 ± 0.018
TZ04	6.14 ± 6.97	139 ± 111	1.15 ± 0.16	1.74 ± 0.24	0.048 ± 0.031	0.054 ± 0.025
QG01	1.36 ± 0.67	205 ± 197	1.18 ± 0.37	1.66 ± 0.34	0.059 ± 0.026	0.068 ± 0.018
QG02	1.24 ± 1.17	248 ± 226	1.07 ± 0.38	1.82 ± 0.72	0.064 ± 0.015	0.062 ± 0.016
QG03	1.30 ± 1.16	262 ± 254	1.11 ± 0.35	1.68 ± 0.72	0.065 ± 0.021	0.067 ± 0.024
YS01	9.11 ± 12.65	153 ± 157	1.11 ± 0.20	1.67 ± 0.32	0.053 ± 0.037	0.056 ± 0.024
YS02	12.14 ± 17.60	118 ± 92	1.05 ± 0.27	1.64 ± 0.29	0.058 ± 0.029	0.058 ± 0.029
YS03	14.91 ± 21.47	110 ± 80	1.06 ± 0.24	1.54 ± 0.30	0.051 ± 0.025	0.050 ± 0.027

significant difference of seasonal dynamic was only found between summer and spring of YS bay ($p < 0.05$). For TN_{sed}, significant seasonal changes were found in most bays (one-way ANOVA, Fig. 4). Differences were always significant between autumn and other seasons in the mainstream. However, no significant difference was found among other seasons. For the other bays, there usually appeared to be significant differences between autumn and other seasons, except in JW bay. Pronounced difference sometimes also appeared between summer and other seasons in XX and YS bays.

3.4. Cluster analysis

Cluster analysis was carried out based on the content of TN_{sed} and TP_{sed} (Fig. 5). All sites studied could be divided into four groups. The sites in the mainstream and those located in the outlet of the bay belonged to Group 1; sites in the middle reach of the shorter bays belonged to Group 2; sites in the inlet of the shorter bays were in Group 3; and sites in the middle reach of the longer bay (XX bay) belonged to Group 4. The concentrations of TN_{sed} and TP_{sed} of each group are displayed in Fig. 6. For TN_{sed}, significant differences existed between Groups 1 and 2, Groups 1 and 4, with *p* value 0.032 and 0.002 respectively. There was also a pronounced difference between Groups 2 and 4 ($p < 0.05$). For TP_{sed}, the content in Group 3 was significantly lower than those in other groups, with *p* value less than 0.05. Marked differences were also found between Group 4 and other groups ($p < 0.05$). However, cluster analysis based on the water total nitrogen and total phosphorus divided all sites into 2 groups: site in the middle reach of XX bay (XX04–XX07) belonged to one group, and the remaining sites were one group (Fig. 7).

3.5. Relationship of the nutrients between sediment and surface water

Correlation analysis was performed between TN_{sed}, TP_{sed} and water TN, TP and Chl *a*. The results (Table 3) showed that, for TN_{sed}, no significant effect was found to the parameters of the surface water in Groups 1 and 2. The correlation coefficients (*R*) of Group 3 were relatively higher but not significant, with the *p* values close to

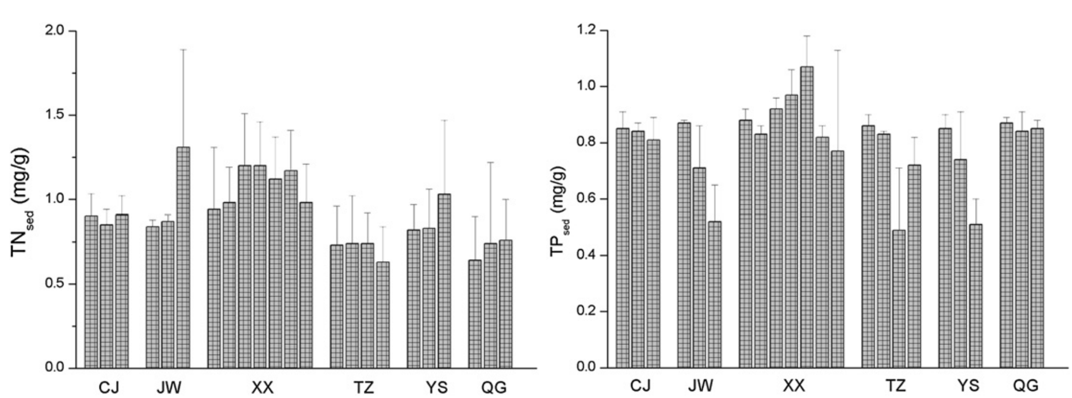

Fig. 3. Spatial distributions of the TN_{sed} and TP_{sed} in the mainstream (CJ) of the Three Gorges Reservoir and the tributary bays in from October 2005 to July 2006.

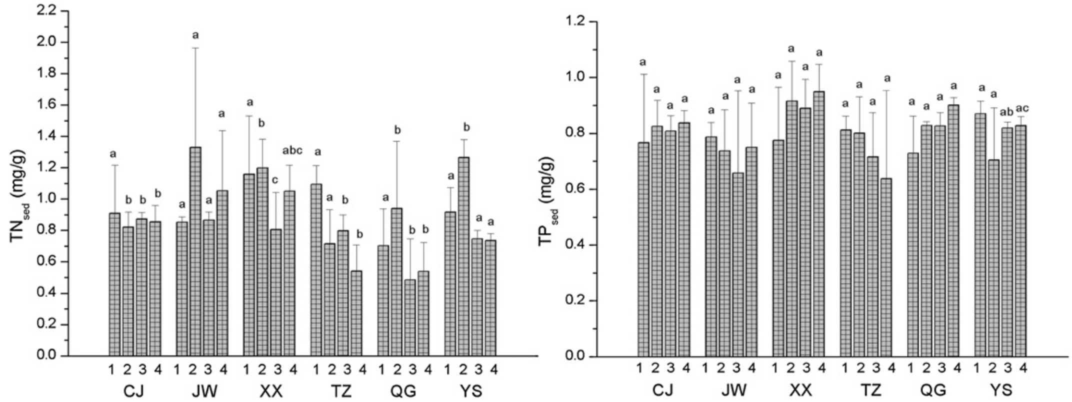

Fig. 4. Seasonal dynamics of the TN_{sed} and TP_{sed} in the sediment in the mainstream (CJ) of the Three Gorges Reservoir and the tributary bays from October 2005 to July 2006 (1: Autumn; 2: Winter; 3: Spring; 4: Summer) (the same letter indicated no significant difference ($p > 0.05$); the different letters indicated significant differences ($p < 0.05$)).

the significance level. A negative correlation was found between TN_{sed} and water total phosphorus in Group 4. For TP_{sed}, no significant influence was found on any surface water parameters.

4. Discussion

For the content of TN_{sed}, most bays displayed a pattern of "high in the outlet and low in the inlet", except the XX bay. This spatial pattern was opposite of that of water total nitrogen. TP_{sed} increased from the inlet to the outlet, similar pattern with the water nitrogen. However, in the XX bay, both TN_{sed} and TP_{sed} displayed a pattern of "high in the middle and low in the two ends", which has been discussed by Zhang et al. (2009). The concentrations of TN_{sed} or TP_{sed} in the XX bay were significantly higher than those in the mainstream (CJ) of the TGR. In the mainstream, due to the short residence time (Xu et al., 2009), the similarity of water dynamics among sites was very high. This could be the reason why no significant difference was found among sites and seasons. For the XX bay, the sedimentation rate also displayed a pattern of "high in the middle and low in the two ends" (Shao, 2008). Usually sediment nitrogen and phosphorus were the results of the sedimentation of the suspended matter in the surface water (Nowlin et al., 2005). Therefore, the pattern of the sedimentation could be the main reason why the sediment nitrogen and phosphorus displayed such a spatial distribution.

Due to the subtropical monsoon climate in TGR region and the special operation mode "storing clear and releasing muddy" of TGR, both the inflow discharge from upstream and the water residence time displayed remarkable seasonal fluctuations (Zhang et al., 2010). However, TP_{sed} was not influenced observably, with little seasonal fluctuations in most bays, while TN_{sed} was influenced. Most bays (JW, TZ, QG, YS) showed the maximum of TN_{sed} in winter, when the WL of the TGR was stable. The stable water environment is not favorable to the sediment nitrogen release. In other seasons, the sediment could be re-suspended because of the water disturbance caused by WLF. Both the re-suspension and the increase of dissolved oxygen could intensify the nitrogen release from sediment to the overlying water (De Medina et al., 2003; Nausch et al., 2009), and finally led to the low content of the sediment nutrients.

However, in the TGR, the contribution of the internal load release to the surface water was very low, probably due to the deep water. Only in the sites located in the inlet region of the shorter bays (shallow regions), TN_{sed} showed negative correlations with water nitrogen and Chl *a*, which implied that, the absorption of the sediment to nitrogen reduced the nitrogen content in surface water. This reduced the eutrophication risk of this region. Current studies about the effect of internal loading to surface water indicated that, the contribution of the internal nutrients is very high to water eutrophication in most shallow lakes and reservoirs (Søndergaard et al., 1992; Xu et al., 2003). In deep reservoirs (e.g. TGR), the internal nutrient release has not caused significant effect to water

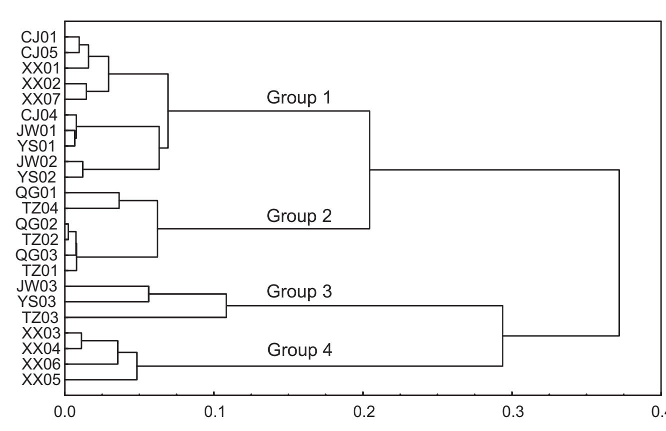

Fig. 5. Cluster analysis based on the TN_{sed} and TP_{sed}.

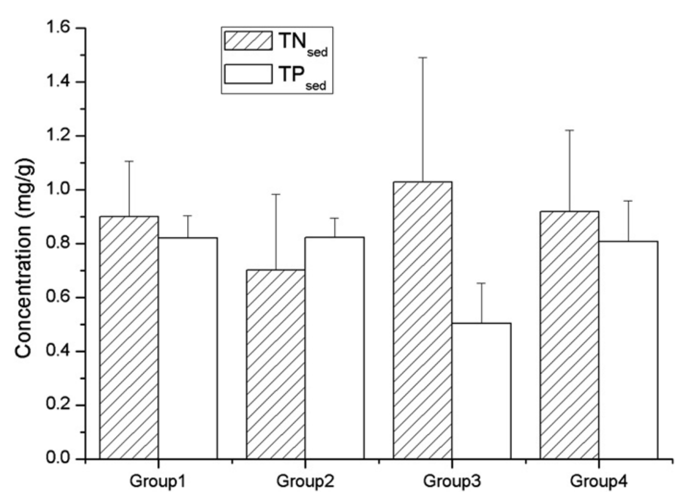

Fig. 6. Comparisons of the sediment nitrogen and phosphorus among groups divided by the cluster analysis.

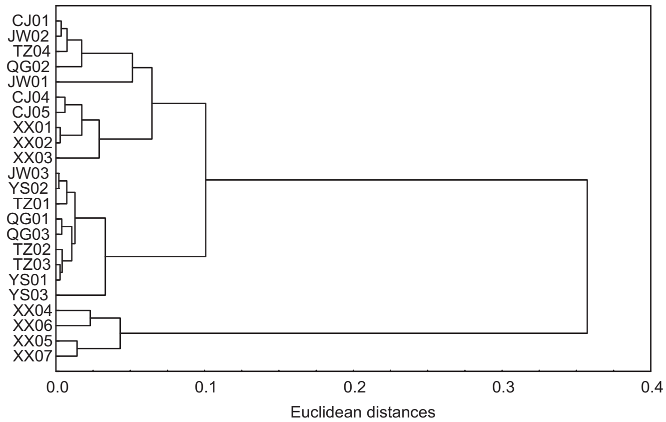

Fig. 7. Cluster analysis based on the total nitrogen and total phosphorus in the surface water.

eutrophication at a large scale, but in some regions, especially the shallow regions, the effect has been remarkable.

Results of the cluster analysis also implied that length of the bays caused some influence on the spatial pattern of the sediment nutrients. The two sites near the outlet had higher similarity with the mainstream. For the shorter bays (e.g. JW, YS, TZ), the sites located in the inlet (a little far from the mainstream) had higher TN_{sed} and lower TP_{sed}. Usually, nitrogen comes from diffused pollution (Jia et al., 2007). Therefore, the dense population around these regions contributed to the high nitrogen content. For TP_{sed}, in shallow reservoirs, wind turbulence re-suspends particulate P, returns interstitial P to the water column and maintains aerobic conditions within the water column and at the sediment surface (Watts, 2000; Brand et al., 2010). Although the increase of DO caused by wind disturbance would decrease the sediment particle's absorption ability to phosphorus, the aerobic conditions were beneficial to the activities of the benthic organisms and bacteria (Dinsmore et al., 1999), and accelerated the degradation of the organic phosphorus (Swan et al., 2007; Hupfer and Lewandowski, 2008), which finally led to the release of the sediment phosphorus.

The shorter bays could be more easily influenced by the mainstream, especially the surface water. In the shorter bays, the surface water of the whole bay could be influenced by the mainstream. However, in the XX bay, from the middle reach (from XX04), the similarity of the water chemistry with the mainstream became very low. This implied that, the longest distance which could be influenced by the mainstream was less than 15.1 km (distance from XX04 to the outlet) but more than 10.7 km (distance from XX03 to the outlet). The study of the synchronous of the suspended matter (SM) of the mainstream and the XX bay showed that sites located near the outlet (XX01, XX02, XX03) were more synchronous with the mainstream, and the SM contents were significantly affected by the inflow discharge of TGR (Xu et al., 2009). As the main source of the sediment, the spatial pattern of SM must have some influence on the sediment nutrient contents. However, the difference between the sediment and the suspended matter pattern lies in the length of the range which could be influenced by the mainstream. The region for sediment which was influenced was relatively shorter, XX01 and XX02 (5.34 km, distance of XX02 from the outlet). This was similar with the zoobenthos zonation studied by Shao et al. (2010). For other bays, the similarities of the sediment nutrients between the sites near the inlet of the bays and the mainstream were also very low. According to the distance of the sites which were influenced by the mainstream, the influence of the mainstream of the TGR to the surface water and the sediment of tributary bays are different, with larger influence range (IR) to the surface water ($10.7 < IR < 15.1$), while the IR to the sediment was about 5.34 km.

In summary, TN_{sed} fluctuated between 0.27 and 2.04 mg/g and TP_{sed} ranged from 0.17 to 1.21 mg/g in the mainstream of the TGR and its five tributaries in Hubei Province. TN_{sed} in most bays decreased from the inlet to the outlet, and TP_{sed} increased from the inlet to the outlet, except in XX bay, where both TN_{sed} and TP_{sed} displayed a pattern of "high in the middle reach and low in the two ends". Seasonally, TN_{sed} showed significant difference between autumn and other seasons, but TP_{sed} did not. Sediment nitrogen and phosphorus in the tributaries were affected by the mainstream. This effect was closely related to the length of the bays. The maximum of influence range of the mainstream to the tributary sediment was about 5.34 km.

Table 3
Correlations between the sediment nutrients and the water nutrients in each group divided by the cluster analysis.

Group	Variables in surface water	TN_{sed}		TP_{sed}	
		R	*p*	*R*	*p*
Group 1	Chl *a*	0.001	0.995	−0.061	0.691
	TN_{water}	−0.153	0.315	−0.02	0.896
	TP_{water}	0.023	0.879	0.158	0.3
Group 2	Chl *a*	0.066	0.784	−0.32	0.169
	TN_{water}	−0.188	0.427	−0.146	0.54
	TP_{water}	−0.022	0.927	−0.047	0.843
Group 3	Chl *a*	−0.619	0.056	−0.205	0.57
	TN_{water}	−0.608	0.062	−0.059	0.871
	TP_{water}	0.605	0.064	−0.046	0.899
Group 4	Chl *a*	−0.444	0.085	0.09	0.739
	TN_{water}	0.098	0.719	−0.104	0.701
	TP_{water}	−0.56	0.024	−0.055	0.841

Acknowledgements

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