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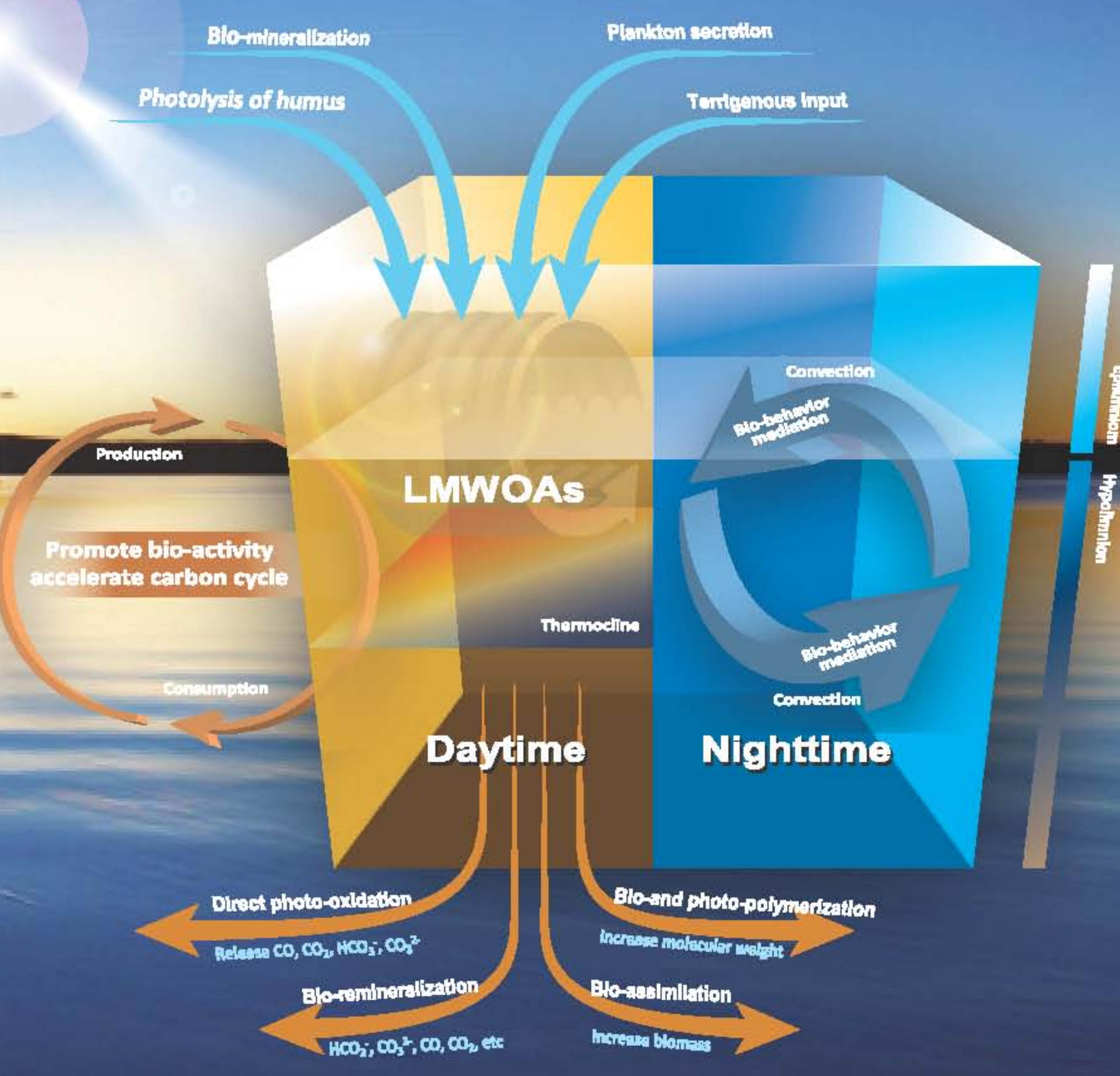

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Spatial distribution and pollution assessment of mercury in sediments of Lake Taihu, China

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Abstract

Spatial distribution patterns of total mercury (THg) in 36 surficial sediment samples representing five regions of Lake Taihu were assessed using the ArcGis geostatistical analyst module. The pollution levels of THg were also evaluated from the same five lake regions. Concentrations of THg were in a ranged of 23–168 ng/g (mean 55 ng/g) in surfical sediments, which was significantly higher than those established baseline levels of the lake. Results of THg indicated that the northern region exhibited notably higher values, the bay regions showed elevated values relative to open areas, and the lakeside regions were higher than those observed in the central area. Lake Taihu suffered moderate to high Hg pollution, and expressed clear Hg enrichment status according to monomial pollution index I_{geo} and human activity factors. The concentrations of THg in the surficial sediments of Lake Taihu showed moderate-strong variation (coefficient of variation 52%). Geostatistical analysis indicated a weak spatial self-correlation, suggesting the contamination of Hg in Lake Taihu is primarily the result of anthropogenic activities.

Key words: assessment; geostatistics analysis; mercury; sediment; spatial distribution

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Introduction

The continued acceleration of industrialization and urbanization deposits large amounts of heavy metals into aquatic ecosystems (Förstner and Wittman, 1979; Frignani and Bellucci, 2004; Binelli et al., 2008). Mercury (Hg) is a highly toxic trace heavy metal with volatile, bio-accumulation, and teratogenic effects. Therefore, Hg content in foods should be strictly controlled (Torres-Escribano., 2011; Coelho et al., 2005). Natural aquatic systems generally possess low Hg concentrations, but some studies have detected elevated Hg concentrations in fish from Northern America and Northern Europe lakes far from pollution sources (Verta, 1990; Lindqvist et al., 1991). Mason et al. (1999) reported the Hg contamination burden occurs worldwide (including Hg in sediment), which is three times higher than that in pre-industrial period due to human activities.

In aquatic systems, sediments play an integral role in Hg biogeochemical cycling (Yan et al., 2008), and have been recognized as an important Hg sink and source (Shi et al., 2005), and the key microbial methylation location (Hammerschmidt and Fitzgerald, 2004, 2006). Hg contamination problems increase when contaminated sediments pollute the water column, and enrich biota and/or aquatic food chains. Contaminated fish consumption is considered the predominant human exposure to MeHg, the most toxic form of Hg (Tchounwou et al., 2003; Clarkson et al., 2003). Lake sediment Hg concentration in Northern America and Northern Europe has generally increased in recent 100 years (Ouellet and Jones, 1982; Verta et al., 1989; Swain et al., 1992; Hermanson, 1993; Lockhart et al., 1995, 1998; Lucotte et al., 1995; Gubala et al., 1995). Researchers have studied Hg enrichment in part of rivers, lakes, estuaries and reservoirs throughout China (Huang et al., 2004; Shi et al., 2005; Lin et al., 2007; Yan et al., 2008; Feng et al., 2009; Zhang et al., 2009).

The Lake Taihu is a significant drinking water resource and a typical shallow hyper-eutrophic lake in China. Heavy metals contamination has been investigated in the lake (Dai and Sun, 2001; Yuan et al., 2004, 2011; Liu et al., 2004, 2005, 2010; Zhu et al., 2005; Wang et al.,

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2008; Zhan et al., 2011). Through the research conducted investigates on Hg in the lake (Wang et al., 2002, 2011; Rose et al., 2004; Shen et al., 2005; Qu et al., 2001; Huang et al., 2005; Xiang et al., 2006), however, the spatial distribution and pollution levels of Hg in sediments need to be systematically evaluated. The aims of the present study were to: (1) determine Hg spatial distribution in the sediments of Lake Taihu; (2) quantify Hg contamination levels and anthropogenic impacts on Hg enrichment in the sediment; and (3) provide recommendations for future decision-making and watershed management.

1 Materials and methods

1.1 Study area

Lake Taihu (30°50′–32°80′N, 119°80′–121°55′E) is in the center of the Changjiang River Delta (Qin et al., 2007), and is the third largest freshwater lake in China. It is the source of drinking water for Suzhou and Wuxi in Jiangsu Province, including multi-uses of fisheries, aquaculture, farming, shipping, and flood control, etc. (Qu et al., 2001).

With rapid industrial and agricultural development since 1978, the Lake Taihu catchment was heavily polluted with nutrients and heavy metals due to the massive domestic sewage and industrial wastewater input, particularly in the north area, such as in Zhushan and Meiliang Bays adjacent to Wuxi and Changzhou Cities, respectively (Fan et al., 2002; Qu et al., 2001; Dai and Sun, 2001; Yuan et al., 2002; Lu et al., 2003). Approximate 70% of Lake Taihu contaminants originated from surrounding tributaries (Wu et al., 2007). Subsequently, the lake ecology deteriorated and water quality degenerated as a result of untreated and/or partially treated wastewater from industries. The major contributions were from high-risk companies, such as non-ferrous metal smelting, electroplating, printing and dyeing, agriculture pesticide run-off; and sewage.

1.2 Sample collection

A total number of 36 surficial sediment samples (approximately the upper 5 cm) were collected using a grab sampler in August 2010 (**Fig. 1**). Sampling sites 1–3 and 4–7 were located in the northern lake area of Zhushan and Meiliang Bays, respectively. The sites 1 and 5 were near the Baidugang and Liangxi River inlets, respectively. These sites have become eutrophic in recent decades, and suffered serious heavy metals contamination due to nonpoint and point source pollution (Qu et al., 2001). Sites 8–16 were located in the eastern lake area, which included Gonghu (sites 8–10), Manshanhu (sites 11–13), and Xukou Bay (sites14–16). Gonghu, Manshanhu, and Xukou Bay possess inflows that carry large amounts of untreated domestic sewage into Lake Taihu. Sites 17–19 were located in the southeast lake area (locally called East Taihu Lake), and approximate 97% of this area was covered at the time of the study by submerged macrophytes,

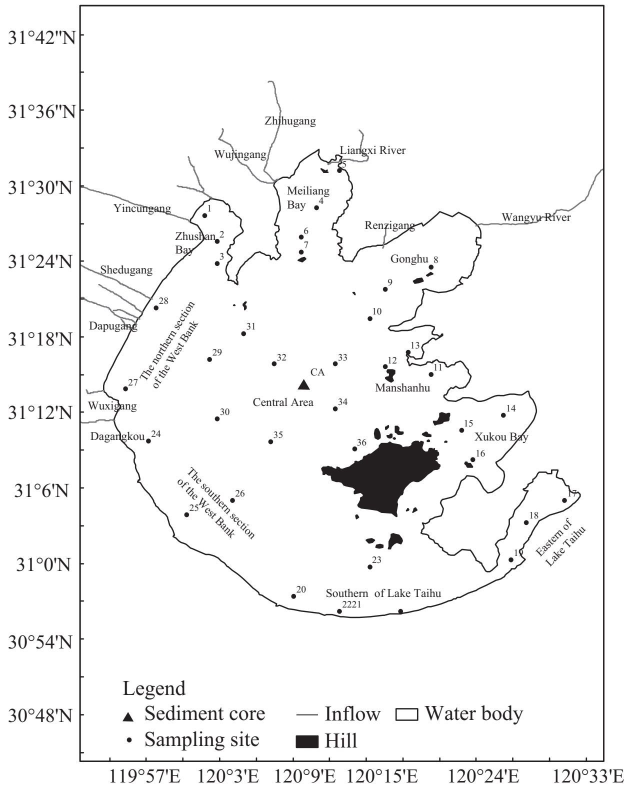

Fig. 1 Sampling site locations at Lake Taihu, China.

and floating leaves. This area has several outflows, and is referred to as a macrophyte-type basin and aquaculture region (Qu et al., 1999; Wang et al., 2011). Sites 20–23 were located in South Taihu Lake (the east and south Taihu Lake were collectively classified as the southern lake area). Sites 24–26 and 27–30 were located in the southern and northern west bank regions, respectively. Sites 31–36 were distributed in the central lake region, which is regarded as the least polluted area in Lake Taihu.

A gravity corer (CA core) (04.23 BEEKER, Eijkelkamp, NL) was used to obtain a sediment core approximately 60 cm long in the central Lake Taihu area. The bottom 6 cm of the core was sectioned into 1 cm intervals rapidly *in situ*.

Each sediment sample was placed in a 50-mL centrifuge tube, which was cleaned by acid washing, rinsed with double-deionized water to remove any organic matter, and Hg adsorbed on the vessel. All sample tubes were sealed with Parafilm to avoid cross contamination, transported in an ice-cooled container to the laboratory within 24 hr of collection, and stored in the refrigerator (4°C) until analysis.

1.3 Analytical methods

In the laboratory, lake sediment samples were lyophilized (freeze-dried), ground, and sieved to <100 mesh-sized particles. For THg analysis, lake sediment samples were subjected to acid digestion following (Li et al., 2005): 0.2 g of dry weight (dw) sample (accurate to 0.0001 g) was placed inside a 25 mL glass tube covered with a glass ball; 5 mL double-deionized water and 5 mL fresh aquaregia ($HCl+HNO_3$, V/V, 3:1) were added; digested at 95°C in water bath for 5 min. Subsequently, 1 mL BrCl solution (1.08 g of reagent grade KBr and 1.52 g reagent grade $KBrO_3$ dissolved in 100 mL of low-Hg HCl, accurate to 0.0001 g) was added to oxidation at 95°C in a water bath for 30 min, then the sample was diluted to 25 mL with double-deionized water, and reacted overnight for complete digestion after cooling.

Following oxidation, 0.2 mL $NH_2OH·HCl$ solution (25 g of reagent grade $NH_2OH·HCl$ was dissolved in 100 mL double-deionized water, accurate to 0.0001 g) was added to samples to eliminate excess halogens prior to cold vapour atomic fluorescence spectroscopy determination after $SnCl_2$ reduction (Jones et al., 1995; PS Analytical, 2001) on a PSA 10.025 Millenium Merlin System (PS Analytical, Kent), which using high purity argon (99.99%) as the carrier gas.

1.4 Quality control

Quality assurance and quality control of the Hg analytical process were performed using method blanks, blank spikes, matrix spikes, spike recoveries, certified reference materials (GB W07305), and blind duplicates. Method blanks and duplicates were generated regularly (>10% of samples) throughout the sampling process (Yan et al., 2005). A mean THg concentration of 100.23 ± 0.52 ng/g (n = 7) was obtained from the GB W07305 geological standard with a certified value of 100.00 ± 0.02 ng/g. The average recovery percentage on spiked samples was in the range of 90.1%–110.3% for THg analysis. The relative standard deviation on precision was < 5% for THg in sediments.

1.5 Statistical analysis

Microsoft Excel (2007) was used to data management in all experiments, and the normal distribution test was performed with Origin 8.0 software. All statistical analysis performed in this study were processed using SPSS 16.0, and spatial analyses completed by ArcGis 9.0 and Origin 8.0.

2 Results and discussion

2.1 Hg concentration in the surficial sediments of Lake Taihu

Statistical analysis results of Hg content in surficial sediments from different areas of Lake Taihu are presented in **Table 1**. The original Hg concentration date from Lake Taihu sediments resulted in a positively skewed distribution ($P < 0.05$, **Table 1, Fig. 2a**), and a normally distribution following a logarithmic transformation ($P >$ 0.05, **Table 1, Fig. 2b**). Total Hg concentration in different regions correspond to normal and log-normal distribution ($P > 0.05$, **Table 1**).

Geochronology results showed that the bottom lake catchment sample represent end of 19th century to early 20th century sediments (Wu et al., 2008) without anthropogenic contribution to heavy metal enrichment. Therefore, the mean THg concentration (22 ng/g) in the bottom 6 cm of the CA sediment core was regarded as the Lake Taihu baseline, which is consistent with other studies (Huang et al., 2005). Lakes with nonpoint source contamination have reported Hg concentrations ranging from 50 to 300 ng/g dw, while Hg concentration can reach 10 µg/kg in some Hg contaminated aquatic systems (Ram et al., 2003; Jacek and Janusz, 2003).

The mean Hg concentration (55 ng/g) (**Table 1**) in surficial sediments from Lake Taihu was significantly higher than the baseline level. The exceeding rate was 154%, with moderate Hg contamination status, and notable accumulation levels. In addition to central area, Hg content in surficial sediments of the four other regions was significantly higher than baseline levels. Industrial activities have in the past and continue to contribute substantially

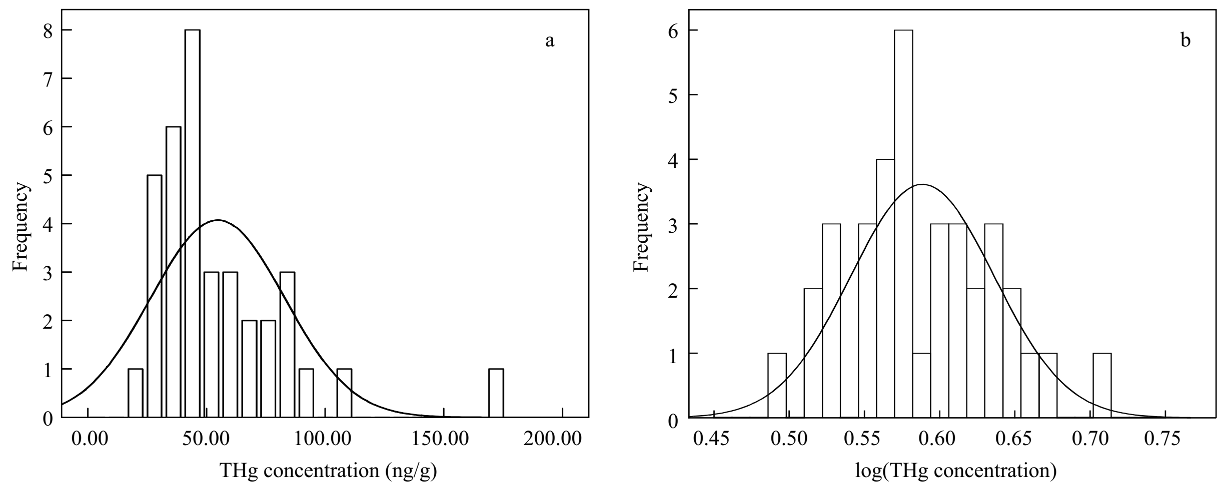

Fig. 2 Histogram of frequency of total Hg (THg) concentration in surficial sediments of Lake Taihu.

Table 1 Total Hg (THg) concentrations and distribution in the surficial sediments of Lake Taihu

Sampling area		Sampling site	THg (ng/g)	Mean ± SD (ng/g)	Coefficient of variation	$P_{s\text{-}w}$*	$P_{s\text{-}w}$ (logarithmic transformation)
Northern Area	Zhushan Bay	1	168	90 ± 40	44%	0.38	0.99
		2	93				
		3	87				
		4	105				
	Meiliang Bay	5	73				
		6	61				
		7	45				
		8	66				
Eastern Area	Gonghu	9	55	43 ± 11	27%	0.32	0.73
		10	42				
		11	36				
	Manshanhu	12	38.				
		13	43				
		14	43				
	Xukou Bay	15	37				
		16	27				
		17	80				
Southern Area	Eastern area of Lake Taihu	18	75	59 ± 20	33%	0.17	0.23
		19	84				
		20	40				
	Southern area of Lake Taihu	21	38				
		22	46				
		23	53				
		24	58				
West Bank Area	Southern section of the west bank	25	51	51 ± 10	20%	0.32	0.31
		26	42				
		27	62				
	Northern section of the west bank	28	65				
		29	42				
		30	39				
		31	27				
Central Area	Central area	32	36	29 ± 4	15%	0.74	0.75
		33	29				
		34	23				
		35	30				
		36	30				
All of the areas				55 ± 28	52%	3×10^{-5}	0.83

$P_{s\text{-}w}$: level of significance for a normal distribution with S-W method; * > 0.05 indicates data exhibited normal distribution.

to Hg contamination in surficial sediments of the northern area. The region bordering the northern Lake Taihu area is highly industrialized, and results showed that the sediments exhibited the highest Hg contamination (up to 90 ng/g). Compared with the baseline value, the exceeded Hg concentration of northern, eastern, southern, and western region were 320%, 100%, 176% and 138%, respectively, which indicated that Hg contamination existed at different levels among regions, and had accumulated to varying degrees throughout the lake.

The overall concentration coefficient of variation of Hg in surficial sediments was 52% (**Table 1**). Among areas, the coefficient of variation ranged from 15% to 44%, indicating that Hg in surficial sediments exhibited moderate-strong spatial differences. The coefficient of variation of Hg contents in surficial sediments of the southern, eastern, and northern regions were 33%, 27%, and 44%, respectively. The wastewater inflow from various industrial plants, and subsequent outflows may be integral in the spatial distribution of Hg in the surficial sediments of Lake Taihu.

A comparison of Hg concentrations in surficial sediments of Lake Taihu with other lakes around the world (**Table 2**) suggested that the Hg content revealed in this study was significantly lower than that of lakes contaminated by mining and industrial activities (Hongfeng Lake (He et al., 2008), Baihua Lake (Yan et al., 2008), and Lake Jinzai (Chandrajith et al., 1995)), but higher than those of lakes, which are in the baseline level (i.e. uncontaminated) lakes. Although Hg concentrations in most regions in this study were much lower than the Grade I (150 ng/g) threshold of China's soil quality standard (GB 15618-1995), Lake Taihu has shown an accumulation degree and enrichment effects exceeding those in uncontaminated lakes worldwide.

2.2 Spatial distribution of Hg in Lake Taihu surficial sediment

The Hg spatial distribution map in surficial sediments of Lake Taihu is presented in **Fig. 3.** The map indi-

Table 2 Comparative Hg concentrations in surficial sediments collected from lakes worldwide

Study area	Hg concentration (ng/g)	Reference	Study area	THg (ng/g)	Reference
Lake Taihu, Jiangsu, China	55	This study	Lake Ontario, USA–Canada	39	Marvin et al., 2007
Lake Donghu, Wuhan Urban, China	199	Su et al., 2006	Lake Erie, USA–Canada	185	Marvin et al., 2002
Lake Liangzi, Wuhan Suburbs, China	78.3	Su et al., 2006	Lake Superior, USA–Canada	80–110	Kerfoot et al., 2004
Lake Chaohu, Anhui, China	238	Wang et al., 2003	Lake Jinzai, Shimane Prefecture, Janan	193	Chandrajith et al., 1995
Lake Dongting, Hunan, China	220	Yao et al., 2006	Lake Michigan, Michigan, USA	78	Rossman, 2002
Poyang Lake, Jiangxi, China	208	Tao, 2004	Baihua Lake, Guizhou, China	12900	Yan et al., 2008
Dianchi Lake, Yunnan, China	180	Shao, 2003	Hongfeng Lake, Guizhou, China	392	He et al., 2008
Lake Hongze, Jiangsu, China	332	Liu et al., 2005	Lake Shijian, Anhui, China	58.8	Xiao et al., 2010

cates moderate Hg contamination in Lake Taihu, and Hg concentrationst in surficial sediments with visible spatial alterations. Concentrations of THg concentration in lake bays were significantly higher than those observed in open regions, suggesting a major source from inflows contaminated with Hg (Yuan et al., 2004). Mean Hg levels of 116, 71, and 54 ng/g were detected in Zhushan, Meiliang Bay and Gonghu Bay, which were 5.4, 3.3, and 2.5 times higher than the baseline value, respectively. Results also indicated that Hg concentration decreased with distance from the bay, and bay sediments showed an increase trend due to deposition of particulate Hg, the major form of Hg in water. This distribution feature conforms to contaminants' transportation law. The velocity of inflow become lower after it enters into lake from river. Particulates and its absorbed heavy metals settle at estuary firstly. With the distance increasing, the impact of inflows decreases and the content of heavy metals in sediment reduce as well.

Qu et al. (2001) also observed significantly higher Hg concentrations in the Liangxi River and Zhihugang bay compared to other sites due to untreated domestic sewage deposition, and reported that the Hg concentration in Meiliang Bay (130 ng/g) was higher than Wuli Lake (80 and 110 ng/g, respectively), which is the route for the Liangxi River into Lake Taihu. In addition, Hg concentration in the northern lake region was substantially higher (nearly twice) than the average concentration of Wuli Lake (**Fig. 3** and **Table 1**), suggesting the northern region has experienced more serious Hg contamination due to industrialization. Wang et al. (2002) and Gu and Wu (2005) also found that the northern Taihu Lake region exhibited the highest Hg pollution in surfical lake sediments, which congruent with Qu et al. (2001). The Hg content in central area was significantly lower than that in any other region of the lake, indicating that the effects of anthropogenic Hg deposition on central Taihu Lake have been reduced due to gradual pollutant deposition during water flow transportation.

Previous research (Yan et al., 2008; He and Feng, 2010; Bai et al., 2007) reported that Hg concentrations in outflows were much lower than in reservoirs as the result of deposition. East Lake Taihu is impacted by aquaculture effluent and has several outflows, and as a result showed the relatively high Hg content in sediments. Sediment re-suspension and macroalgae blinding were likely respon-

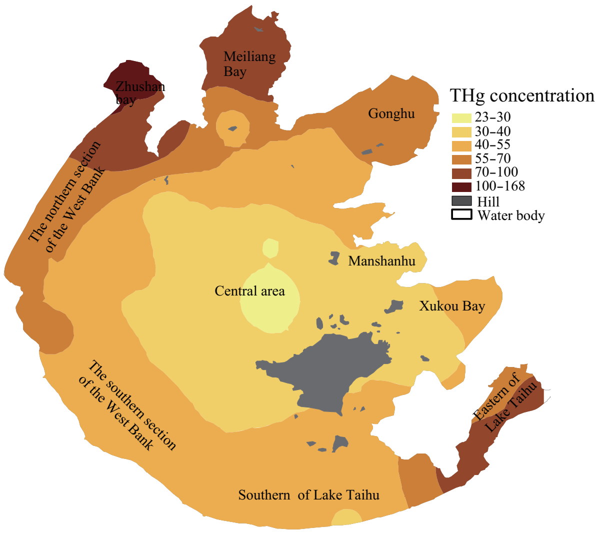

Fig. 3 Spatial distribution of THg concentrations in surficial sediments.

sible for increased Hg levels in this area. Compared with other reservoirs, Lake Taihu is shallow with a mean depth of only 1.9 m. Sediments readily re-suspend, and suspended particulates can blind large amount of heavy metals (Chi and Zhu, 2005, 2006). In addition, field sampling was conducted in August during the highest of algal blooms. Pardal et al. (2004) reported that as eutrophication processes occur worldwide, freshwater bays shift from stable, macrophyte makes systems to highly dynamic macroalgae based systems. In such systems, macroalgae may represent a substantial Hg pool, as a result of its reported capacity to bind trace metals (Radway et al., 2001; Vasconcelos and Leal, 2001), and rapid growth rate. When macroalgae (as sub-suspension sediments) move with the water current and/or settle as sediment, the Hg distribution can be altered in aquatic systems (He et al., 2008; Zhu et al., 2005).

2.3 Hg contamination assessment in the surficial sediments of Lake Taihu

Human activity factors (AFs) were used to evaluate the Hg contamination conditions in the surficial sediments of Lake Taihu (**Fig. 4**). Results for the entire lake showed 50% of the AFs values ranged from 1.0 to 2.0, with a mean of 2.5, indicating a moderate pollution status. The Hg pollution levels in sediments from different lake regions based on AFs from highest to lowest were as follows: northern area

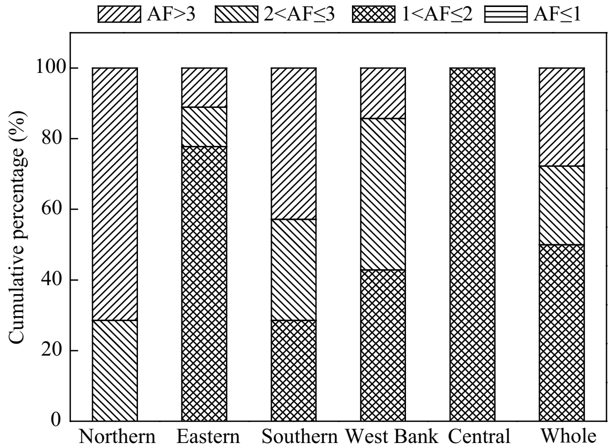

Fig. 4 Activity factors (AFs) accumulative frequencies for THg in the surficial sediment from different regions.

(4.2) > southern area (2.8) > west bank area (2.4) > eastern area (2.0) > central area (1.4). All AFs for the northern lake region investigated were in levels of AFs > 2 and exhibited huge impacts of anthropogenic activies. Industrial enterprises and factories are densely distributed in the northern region, and it is a heavily populated area. Large amounts of industrial wastewater and domestic sewage flow from the Baidugang, Shatanggang, Wujingang and Liangxi Rivers into the lake. Results showed moderate-serious Hg contamination in the southern area (43% of AFs > 3), and a slight-moderate Hg pollution in both the west bank area and eastern region (14% and 11% of AFs > 3, respectively). These two regions exhibited similar Hg contamination due to similar sewage disposal and industry types. The mean AFs level (1.1) in the central area indicated decreased particulate Hg deposition, reflecting the lower incidence of human activities affecting the central part of the lake. AFs from all central region-sampling sites range from 1.0 to 2.0.

Atmospheric Hg deposition can also contribute to sediment Hg enrichment (i.e. Hg escapes from electrolytic Cl_2 production, and fossil fuel combustion), and untreated industrial effluents from electroplating, printing and dyeing, smelting and machine manufacturing, pollution from urbanization in decorating materials, debris or powder mixed with garbage, and sewer deposited in the lake through inflows. According to the Annual Statistical Information of Jiangsu Province in 1998, the emissions of mercury and its inorganic compounds reached 710 kg in 1997. In addition to inflows that carry large Hg amounts from industry waste, damaged high pressure mercury lamp, fluorescent tubes, lead-battery discarded from vehicle repair, mercurochrome and thermometer frequently used in hospitals, which are not disposed properly all become significant sources of Hg pollution. Furthermore, in the last few decades the rapid development of shipping has increased pollution on the rivers systems that inflow into Lake Taihu, likely resulting in Hg contamination particular in central area.

Overall, the results of our study clearly demonstrated the entire Lake Taihu sampled in this study suffers from Hg contamination, and the spatial distribution of Hg pollution in surficial sediments was closely related to industrial production, anthropogenic activities, and input and output channels. Hg concentration exhibited the following levels from highest to lowest concentration areas: northern > southern > west bank > eastern > central. These results are inconsistent with those reported by Wang et al. (2011), where the Hg content of surficial sediments in Lake Taihu exhibited the following levels from highest to lowest concentration: north > east > central > west. However, Wang et al. (2011) had a much smaller sample size (only 1–2 sediment core in each region), therefore could not accurately reflect the mean Hg content and spatial distribution characteristics. However, Hg content in present study was lower than that detected by Xiang et al. (2006) and Gu and Wu (2005). The reason maybe that our sampling was in summer (August) during to algal blooms, and surfical sediment resuspension caused by seasonally increased wave action in the shallow freshwater lake. Algal and suspension particulate matter can blind substantial Hg from sediments. In summary, the results of this study provide evidence for urgent restoration efforts of Lake Taihu to prevent further ecological damage from pollution and eutrophication, and being restoration, especially in the northern lake region. In recent years, land use changes, increased urbanization, and industrialization production processes in areas adjacent to the lake have been modified leading to more complex pollution in lake sediments.

2.4 Effectiveness of spatial interpolation prediction tests

Kriging is a moderately quick interpolator that can be exact or smoothed depending on the measurement error model. It is a flexible means to evaluate graphs of spatial autocorrelation. Kriging uses statistical models that generate a variety of map outputs, e.g., predictions, prediction standard errors, and probability. However, Kriging flexibility often require decision-making. Kriging assumes the data are derived from a stationary stochastic process, and some methods assume normally distributed data.

The spatial distribution of Hg in Lake Taihu based on geostatistics analysis using Kriging interpolation is depicted in **Fig. 5**. I_{geo} results for Hg distribution in surficial sediment detected an I_{geo} mean value of 1.4 for the norther area of Lake Taihu, indicating high contamination levels. These results remain consistent with the other analyses conducted in our study. The Hg enrichment of central area is low ($I_{geo} < 0$). In addition, the Hg levels in sediment of eastern region were higher than those of the west bank area, and the results are congruent with the AFs analysis. However, compare with I_{geo} and AFs assessments applying I_{geo} analysis alone to evaluate Hg contamination or enrichment levels might lead to underestimates.

The semivariogram equation parameters for the Hg

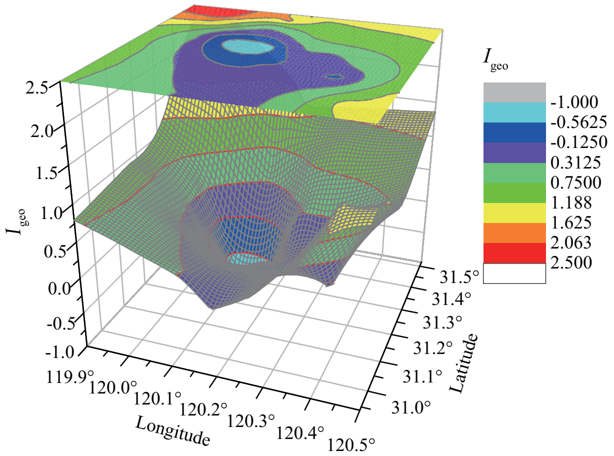

Fig. 5 Distribution of THg concentration I_{geo} in the surficial sediments.

content in surficial sediments of Lakef Taihu (Spherical model) were as follows: C_0 0.033239, C_0+C 0.0430096, $C_0/(C_0+C)$ 77.28%, and range 1801.72 m. Nugget (C_0) depicted random variation was derived from measurement error and sampling scales which are smaller than the smallest variation caused by non-continuous variance. The partial sill (C_0+C) was expressed as the total variance within the system, and typically indicated structural and random variation. The ratio $C_0/(C_0+C)$ was the response to spatial heterogeneity of regional variables, and revealed any spatial correlation among regional variables. In general, the ratio < 25% indicates a strong spatial correlation, a ratio in the 25% to 75% range showed a moderate correlation, and a ratio > 75%, a weak spatial correlation (Spijker et al., 2005).

At present study, Semivariogram was determined and the results were a ration of 77%. Therefore Hg in surficial sediments of Lake Taihu exhibited a weak spatial self-correlation, suggesting the natural environment (local topography, climate, and bedrock, among other factors) had little influenced on the spatial variability of Hg in Lake Taihu. The primary factors responsible for high Hg levels in the lake are anthropogenic effects, and include industrial emissions, coal-fired process, and other anthropogenic disturbance factors, consistent with those report by Liu et al. (2004).

Kriging interpolation accuracy can be evaluated according to several cross-validation indicators as follows: the absolute value of the average standard error (MSE) should be close to 0; minimize the root mean square prediction error (RMSE), which should be close to the mean standard error (AME); and the standard root mean square (RMSS) should be close to 1. Meeting the conditions above can lead to better spatial interpolation accuracy. The cross-validation errors of Kriging interpolation are as following: ME 0.030, RMSE 0.34, ASE 0.33, MSE 0.080 and RMSSE 1.0, indicating that the ordinary Kriging spatial interpolation method performed more reliability for Hg prediction.

3 Conclusions

The Hg concentrations of Lake Taihu were in the range of 23–168 ng/g with a mean value of 55 ng/g, which were significantly higher than baseline values (exceeding rate was 154%). The Hg content in the surfical sediments of Lake Taihu showed the following levels from higher to lower concentrations: northern > southern > western bank > eastern > central regions; the exceeding rate were 320%, 176%, 138%, 100% and 36%, respectively.

The coefficient of variation for overall Hg content in surfical sediments was 52%. Geostatistical analysis indicated that Hg concentration expressed weak spiral self-correlation, which suggested that the natural environment had little impact on Hg levels, and Hg contamination was primarily the result of anthropogenic causes, such as industrial activities, urbanization, shipping, domestic waste, and other impacts.

Kriging interpolation analysis on the single Hg pollution index in the surfical sediments of Lake Taihu showed that lake sediments possess moderate to high Hg contamination, with high contamination in the northern and lakeside regions, and critical management should be given before further degradation of the freshwater ecosystem occurs.

Acknowledgments

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