Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

ISSN: 0972-6268	Vol. 12	No. 3	pp. 413-418	2013

Original Research Paper

Levels of Accumulation and Release Mechanism of Pollutants in Sediments of Lihe River as a Water Conveyance Canal

Liqin Zhu*(****), Cuiling Jiang**, Youheng Wang****, Yanmei Peng**** and Peng Zhang****

*Key Laboratory of Integrated Regulation and Resource Development on Shallow Lakes, Ministry of Education, Nanjing 210098, China

**College of Hydrology and Water Resources, Hohai University, Nanjing 210098, China

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com
Received: 14-5-2013
Accepted: 4-7-2013

Key Words:
Lihe river
Water conveyance canal
Sediments
Pollutants

ABSTRACT

Lihe River as an important water conveyance canal of diversion project from Luanhe River to Tianjin should convey 40-50 m^3/s water in each spring and autumn. With the variation of water discharge, the sediments with poor viscosity and great suspension capability were very prone to re-suspension and pollutants release easily. In order to study the effects of pollutants release in sediments on river during water diversion period and set out proper protection scheme to prevent the second pollution, experiments were done to make clear the levels of accumulation and release mechanism of pollutants in sediments. First, compared with those in Haihe River, Wulihu Lake and Xuanwuhu Lake, the average content of organic matters of sediments in Lihe River was 0.21%, lower obviously, TP with the average value of 5.18 mg/kg was much higher, while TN reaching 2.99 mg/kg, a little higher than others. Second, water diversion indeed made pollutants in sediments release quickly and threaten water quality seriously. TN was the main pollutant, a high level in both river and sediments, which kept releasing with the maximum release amount of 9.16 g/m^2 and intensity 4.2 $g/m^2/d$ and had a great negative influence. TP and Fe with the maximum release amounts were 0.248 g/m^2 and 1.7 g/m^2 with maximum release intensities of 0.248 $g/m^2/d$ and 1.7 $g/m^2/d$ respectively. They released fast and deposited also fast, and were the potential pollutants and the release amounts could not be neglected during the initial water diversion period.

INTRODUCTION

According to incomplete statistics, there are no less than 160 huge water diversion projects all over the world, which can be found in almost every major river on the earth, such as Ganges in India, Nile in Egypt, Amazon in South America, Mississippi in North America (Aubertin et al. 2006). To a certain extent, water diversion projects optimized regional water resources allocation, alleviated water shortage and accelerate economic development. However, they also brought some ecological and environmental problems at the same time.

Diversion project from Luanhe River to Tianjin, a famous comprehensive hydraulic engineering in China including inter-basin water diversion, conveyance, storage, purification and distribution systems, became the lifeline of Tianjin for providing the significant material basis for survival and development.

Lihe River as an important water conveyance canal of the famous project had special social and economic effects, which was contaminated severely because of three main ecological and environmental problems. First, its unique water conveyance function led to great changes in water quantity between water diversion period and non-water diversion period. Second, N, P and organic matters concentrations in tributaries were so high that affected the water quality seriously. Third, for its catchments were rich in iron ore, a large amount of suspended matters in mineral tailrace filled with iron (Fe) and manganese (Mn) were deposited at the bottom of the river, especially during non-water diversion period. While diversion water, silt sediments with poor viscosity were very prone to re-suspension and pollutants released which aggravated water pollution. Thus, as to the water diversion safety, the pollutants adsorbed in the sediments were potential threats.

As part of material and energy cycle in aquatic ecosystems, sediments, on the one hand, are recipients accumulating sorts of nutrients and pollutants and reducing water pollution load (Wauer et al. 2005, Hamer & Karius 2005, Li et al. 2010). On the other hand, under certain conditions such as microbial decomposition and sediments disturbance, pollutants deposit or accumulate in sediments as new pollution sources, can re-released to the overlying water (Gainswin et al. 2006, Polyak 2002, Lau & Chu 1999). Researches showed that, because of the release of sediments, the water quality of lakes did not improve as anticipated after intercepting exogenous contaminants (Trolle et al. 2009, Vicente et al. 2010). Similar to the non-point source pollution, release

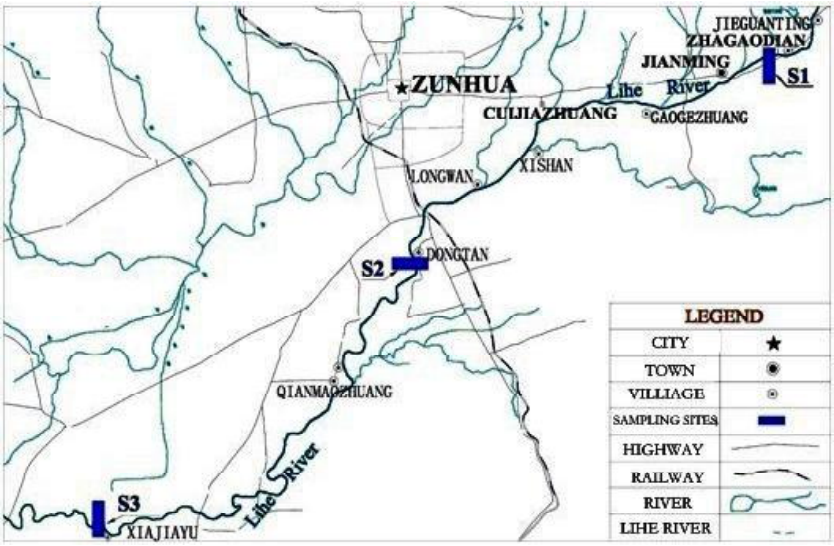

Fig.1: Three sampling sites of Lihe River.

period, space, approach and release intensity of endogenous contaminants were uncertainty (Lai & Lam 2008, Suomela et al. 2005, Cibic et al. 2008).

Nowadays, sediment in surface waters is a major environmental issue both nationally and internationally, focused by more and more researchers (EI-Sammak 2001, Diaz-Asencio et al. 2009, Atgin et al. 2000, Reczynski et al. 2010, Yi 2008). Most people paid great attention to relatively static water body such as lakes and reservoirs (Lewis et al. 2007, Kim et al. 2003, Beutel 2006, Sen 2007). Compared to them, rivers, especially the water conveyance canals with different hydraulic conditions, influenced more heavily by pollutants release in sediments (Minh et al. 2007). In order to study the effects of pollutants release in sediments in river during water diversion period and set out proper protection scheme to prevent the second pollution, experiments were done to make clear the levels of accumulation and release intensities of pollutants in sediments of Lihe River.

MATERIALS AND METHODS

Lihe River originates from Yanshan Mountain in Qianxi County, Hebei Province, flowing from northeast to southwest through Zunhua City of Hebei Province and Ji Country of Tianjin, ultimately into Yuqiao Reservoir. Sampling stations were distributed in the upper, middle and lower reaches of Lihe River respectively, named S1, S2 and S3 (Fig. 1).

On August 3rd and October 24th, 2008, sediment samples were collected from the three stations to analyse the levels of accumulation of pollutants at different stations. At each station, three layers of samples (0-5 cm, 5-20 cm, 20-40 cm) were collected to analyse pH, TN, TP, NH_3-N, NO_3^--N and organic matter.

For immersion experiments, mixture of sediments in two typical stations S2 and S3 with weigh of 7.5 kg were separately put into two water tanks with the volume of 42 × 30 × 34 cm, signed 1# and 2#. Then 20 L water taken from the upper reach of Lihe River was added to submerge the sediments in water tank 1#, while the same volume 20 L of distilled water was put into water tank 2#. Another water tank with 20 L tap water was used to calibrate water evaporation in the process of the immersion experiment. Concentrations of pH, TN, TP, COD_{Mn} and Fe in soaking water of tank 1# and 2# were monitored on the 1st, 3rd, 5th, 10th, 15th, 20th, 30th, 40th, 50th and 60th day until a relative balance emerged (50 mL soaking water one time). Air and water temperatures were recorded too.

Chemical analysis of soil samples were conducted based on procedural regulations regarding the environmental quality monitoring of soil (NY/T 395-2000), while analysis of soaking water was based on standard methodology (China Standard Press 1998).

RESULTS AND DISCUSSION

Li River as a piedmont seasonal river is usually dry, except during the flood season. From August 1983 on, chosen to be a water conveyance canal of diversion project from Luanhe River to Tianjin, it should convey 40-50 m^3/s water in each spring and autumn. The dramatic changes of inflow water conditions made it different not only in the water environment but also in the river bed. During non-water diversion period, the discharge was so small, close to none, and the

Table 1: Concentrations of nutrients in sediments of Lihe River in August and October, 2008.

Nutrients	August			October		
	S1	S2	S3	S1	S2	S3
pH	8.24	8.40	8.42	8.22	8.43	8.47
OM (g/kg)	1.81	4.27	1.19	2.17	1.50	1.47
TP (g/kg)	7.89	4.86	7.79	2.74	3.70	4.08
TN (g/kg)	4.53	2.69	3.08	2.77	2.48	2.38
NO_3-N (mg/kg)	24.48	12.22	6.86	0.98	2.17	0.65
NH_4-N (mg/kg)	5.33	11.46	9.10	14.96	8.73	9.82

Table 2: Pollutants accumulation levels of sediments in different water bodies.

Nutrients	OM (%)	TN (mg/kg)	TP (mg/kg)
Lihe River	0.21	2.99	5.18
Wulihu Lake	4.07	2.25	1.50
Xuwuhu Lake	2.30	1.93	1.02
Haihe River	6.25	2.39	0.97

concentration of pollutants in tributaries were high, leading to the poor water quality of main stream and pollutants depositing in sediments. However, when diversion water, with the variation of water discharge, the sediments with poor viscosity and great suspension capability were very prone to re-suspension and pollutants release easily (Maria et al. 2009, Liebens et al. 2007, Kotrba et al. 2009, Shin & Lam 2001, Perianez 2004).

Pollutant concentrations in sediments: Compared with the two chemical analysis results of sediments listed in Table 1, the differences were great, because there was a small water transport between August and October. Except for the NH_3-N, the concentrations of organic matters, TN, TP and NO_3^--N in August were significantly lower than those in October, demonstrating water diversion indeed made pollutants in sediments release quickly and threaten water quality seriously. Concentrations of organic matters, TP, TN, NH_3-N and NO_3^--N ranged from 0.91-9.20 g/kg, 1.74-8.64 g/kg, 0.72-5.42 g/kg, 3.15-21.42 mg/kg, and 0.31-41.16 mg/kg respectively. Furthermore, compared with those in Haihe River, Wulihu Lake (in 2002 before dredging) and Xuanwuhu Lake (in 2007 before dredging) (Table 2), the average content of organic matters of sediments in Lihe River were lower obviously, resulting form sandy gravel river bed, large gradient and high concentration of dissolved oxygen. TP was much higher than those in other water bodies. This may be because of a large amount of the unique mineral powder suspension in the water, which has a high adsorption ability to pollutants especially to P (Gainswin et al. 2006, Wauer et al. 2005, Vermaat & Bouwer 2009, Wu et al. 2009, Jiang et al. 2008, Wang et al. 2008). And this speculation was verified by the immersing experiment.

Simulation experiment of pollutants release: The soaking water in water tank 1# was taken from the upper reach of Lihe River. According to the Class of the Surface Water Quality Standards of China (GB3838-2002), concentrations of COD_{Mn}, TP, NH_3-N in the soaking water of water tank 1# were met with the standard. Meantime, concentrations of NO_3^--N and Fe met with the centralized drinking water source standards while Mn was below the detection limit.

In the process of soaking experiment, pollutant concentrations in soaking water of water tank 1# and 2# were varied constantly. The main pollutants-N, P and Fe were monitored to study the release discipline and intensities of sediments in Lihe River.

TN concentrations in soaking water of the two boxes, both presented steady increase (Fig. 2), higher than background value, which means TN in sediments kept releasing and had a great negative influence on river. That in tank 1# quickly rose to 5.92 mg/L on the first day and reached the highest of 13.46mg/L on the sixtieth day, as the background value was 2.95 mg/L. Among all the pollutants, its maximum release amount of 9.16 g/m^2 and intensity of 4.2 g/m^2/d were, both highest while release period was the longest too. Consistence with the experiment results, water quality of Lihe River in October 2008, the water diversion period, showed that TN concentrations kept rising from the upper reaches to the lower. In addition to the pollutants in tributaries, the high level of TN in sediments was a major factor aggravating water quality. TN was the main pollutant in Lihe River.

TP and Fe concentrations in soaking water showed a similar trend that reached the highest concentrations on the first

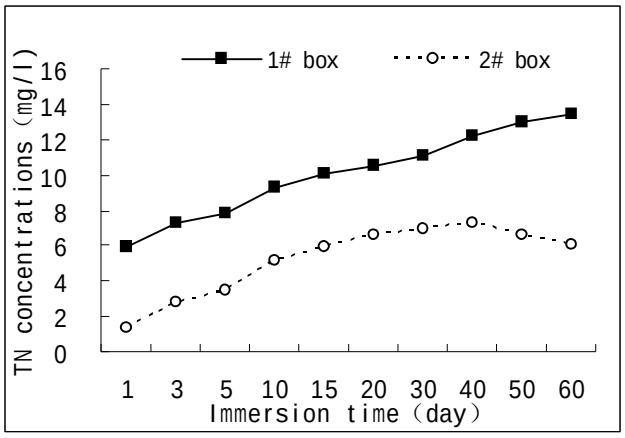

Fig.2: The variations of TN concentrations in soaking water.

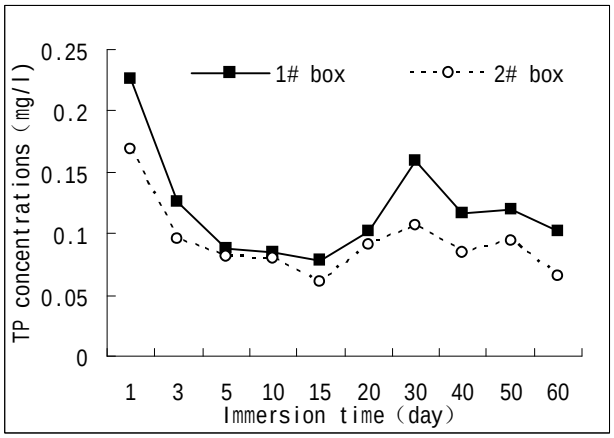

Fig. 3: The variations of TP concentrations in soaking water.

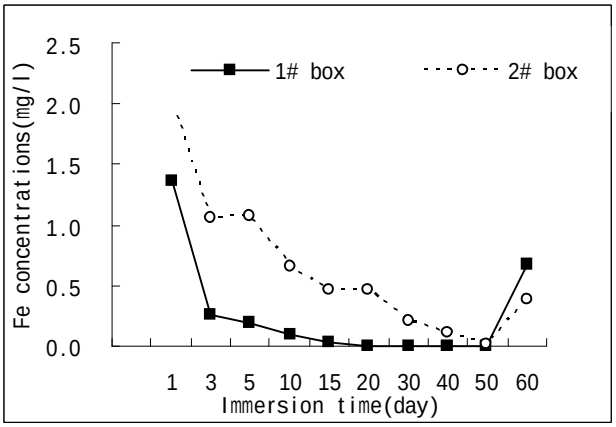

Fig.4: The variations of Fe concentrations in soaking water.

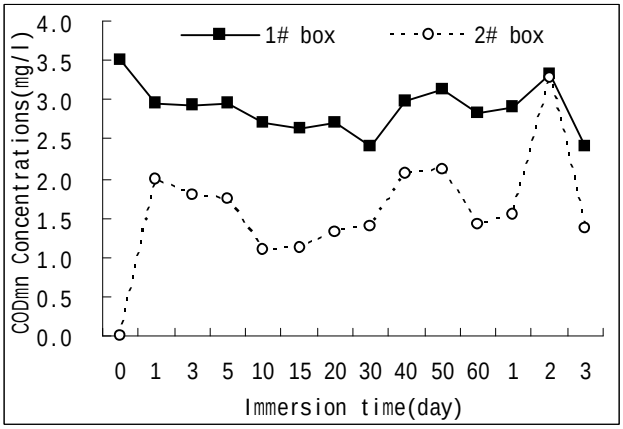

Fig. 5: The variations of COD_{Mn} concentrations in soaking water.

day and then decreased gradually (Figs. 3 and 4). TP concentrations rose from 0.051 mg/L to 0.226 mg/L on the first day and then dropped to a relative balance, meeting Class of the Surface Water Quality Standards of China (GB3838-2002). Fe concentrations increased from background value of 0.18 mg/L to 1.37 mg/L on the first day and then declined to 0.26 on the third day, lower than detection line after the fifth day. TP and Fe released fast and subsidence was also fast, with the maximum release amounts of 0.248 g/m^2 and 1.7 g/m^2, and maximum release intensities of 0.248 g/m^2/d and 1.7 g/m^2/d respectively, which can not threaten water safety seriously in a long term. Whereas they were still the potential pollutants and the release amounts could not be neglected during the initial water diversion period.

Special among pollutants, COD_{Mn} concentrations in soaking water were lower than the background value and changed slightly, ranging from 2.40 mg/L to 3.14 mg/L, which stated that COD_{Mn} could be absorbed by sediments, with a maximum adsorption capacity of 2.29 g/m^2 (Fig. 5). It could be seen that organic matters concentrations would decrease continuously if there was no pollution discharge along Lihe River.

CONCLUSIONS AND SUGGESTIONS

1. With the variation of water discharge, the sediments with poor viscosity and great suspension capability were very prone to re-suspension and pollutants release easily.
2. Compared with the two chemical analysis results of sediments, expect for the NH_3-N, the concentrations of organic matters, TN, TP and NO_3^--N in August were significantly lower than those in October, showing that water diversion indeed made pollutants in sediments release quickly and threaten water quality seriously.
3. Concentrations of organic matters, TP, TN, NH_3-N and NO_3^--N in sediments ranged from 0.91-9.20 g/kg, 1.74-8.64 g/kg, 0.72-5.42 g/kg, 3.15-21.42 mg/kg, and 0.31-41.16 mg/kg respectively. Compared with those in different water bodies, the average content of organic

matters of sediments in Lihe River were lower obviously, resulting from sandy gravel river bed, large gradient and high concentrations of dissolved oxygen. TP was much higher than those in other water bodies. That may be because of a large amount of the unique mineral powder suspension in the water, which has a high adsorption ability to pollutants especially to P.

4. TN in sediments kept releasing and had a great negative influence on river. Among all the pollutants, its maximum release amount of 9.16 g/m^2 and intensity of 4.2 $g/m^2/d$ were the highest while release period was the longest. TN concentrations in river and sediments were both in a high level, which was the main pollutant.

5. TP and Fe released fast and subsidence also fast, with the maximum release amounts of 0.248 g/m^2 and 1.7 g/m^2, and maximum release intensities of 0.248 $g/m^2/d$ and 1.7 $g/m^2/d$ respectively, which can not threaten water safety seriously in a long term, but still the potential pollutants and the release amounts could not be neglected during the initial water diversion period.

6. COD_{Mn} could be absorbed by sediments, with a maximum adsorption capacity of 2.29 g/m^2. It could be seen that organic matters concentration would decrease continuously if there was no pollution discharge along Lihe River.

7. In order to improve the water quality of Lihe River and ensure water supply safety, proper measures should be taken: (a) Control non-point source pollutions; (b) Local sediments dredging; (c) Ecological treatment in the tributary.

REFERENCES

Aubertin, M. , Cifuentes, E., Martin, V., Apithy, S., Bussiere, B., Molson, J., Chapuis, R.P. and Maqsoud, A. 2006. An investigation of factors that influence the water diversion capacity of inclined covers with capillary barrier effects. Proceedings of the Fourth International Conference on Unsaturated Soils, pp. 613-624.

Atgin, R.S., El-Agha, O., Zararsýz, A., Kocatas, A., Parlak, H. and Tuncel, G. 2000. Investigation of the sediment pollution in Izmir Bay: Trace elements. Spectrochim. Acta B, 55: 1151-1164.

Beutel, M.W. 2006. Inhibition of ammonia release from anoxic profound sediments in lakes using hypolimnetic oxygenation. Ecol. Eng., 28: 271-279.

Cibic, T., Acquavita, A., Aleffi, F., Bettoso, N., Blasutto, O., De Vittor, C., Falconi, C., Falomo, J., Faresi, L., Predonzani, S., Tamberlich, F. and Fonda Umani, S. 2008. Integrated approach to sediment pollution: A case study in the Gulf of Trieste. Mar. Pollut. Bull., 56: 1650-1667.

Diaz-Asencio, M., Alonso-Hernandez, C.M., Bolanos-Alvarez, Y., Gomez-Batista, M., Pinto, V., Morabito, R., Hernandez-Albernas, J. I., Eriksson, M. and Sanchez-Cabeza, J.A. 2009. One century sedimentary record of Hg and Pb pollution in the Sagua estuary (Cuba) derived from 210Pb and 137Cs chronology. Mar. Pollut. Bull., 59: 108-115.

EI-Sammak, A. 2001. Heavy metal pollution in bottom sediment, Dubai, United Arab Emirates. Bull. Environ. Contam. Toxicol., 67: 295-302.

Gainswin, B.E., House, W.A., Leadbeater, B.S.C., Armitage, P.D. and Patten, J. 2006. The effects of sediment size fraction and associated algal biofilms on the kinetics of phosphorus release. Sci. Total Environ., 360: 142-157.

Haggard, B.E. and Soerens, T.S. 2006. Sediment phosphorus release at a small impoundment on the Illinois River, Arkansas and Oklahoma, USA. Ecol. Engg., 28: 280-287.

Hlavay, J. and Polyak, K. 2002. Investigation on the pollution sources of bottom sediments in the Lake Balaton. Microchem. J., 73: 65-78.

Hamer, K. and Karius, V. 2005. Tributyltin release from harbour sediments-Modelling the influence of sedimentation, bio-irrigation and diffusion using data from Bremerhaven. Mar. Pollut. Bull., 50: 980-992.

Jiang, X., Jin, X., Yao, Y., Li, L. and Wu F. 2008. Effects of biological activity, light, temperature and oxygen on phosphorus release processes at the sediment and water interface of Taihu Lake, China. Water Res., 42: 2251-2259.

Kim, L.H., Choi, E. and Stenstrom, M.K. 2003. Sediment characteristics, phosphorus types and phosphorus release rates between river and lake sediments. Chemosphere, 50: 53-61.

Kotrba, P., Najmanova, J., Macek, T., Ruml, T. and Mackova, M. 2009. Genetically modified plants in phytoremediation of heavy metal and metalloid soil and sediment pollution. Biotechnol. Adv., 27: 799-810.

Lai, D.Y.F. and Lam, K.C. 2008. Phosphorus retention and release by sediments in the eutrophic Mai Po Marshes, Hong Kong. Mar. Pollut. Bull., 57: 349-356.

Lewis, G.N., Auer, M.T., Xiang, X. and Penn, M.R. 2007. Modeling phosphorus flux in the sediments of Onondaga Lake: Insights on the timing of lake response and recovery. Ecol. Model., 209: 121-135.

Liebens, J., Mohrherr, C.J. and Rao, K.R. 2007. Sediment pollution pathways of trace metals and petroleum hydrocarbons in a small industrialized estuary: Bayou Chico, Pensacola, FL. Mar. Pollut. Bull., 54: 1523-1558.

Li, K., Liu, Z. and Gu, B. 2010. The fate of cyanobacterial blooms in vegetated and unvegetated sediments of a shallow eutrophic lake: A stable isotope tracer study. Water Res., 44: 1591-1597.

Lau, S.S.S. and Chu, L.M. 1999. Contaminant release from sediments in a coastal wetland. Water Res., 33(4): 909-918.

Markou, D.A., Sylaios, G.K., Tsihrintzis, V.A., Gikasa, G.D. and Haralambidou K. 2007. Water quality of Vistonis lagoon, Northern Greece: Seasonal variation and impact of bottom sediments. Desalination, 210: 83-97.

Maria, E.J.S., Siringan, F.P. and Sombrito, E.Z. 2009. Estimating sediment accumulation rates in Manila Bay, a marine pollution hot spot in the Seas of East Asia. Mar. Pollut. Bull., 59: 164-174.

Minh, N.H., Minh, T.B., Kajiwara, N., Kunisue, T., Iwata, H., Viet, P.H., Tu, N.P.C., Tuyen, B.C. and Tanabe, S. 2007. Pollution sources and occurrences of selected persistent organic pollutants (POPs) in sediments of the Mekong River delta, South Vietnam. Chemosphere, 67: 1794-1801.

Perianez, R. 2004. Testing the behaviour of different kinetic models for uptake/release of radionuclides between water and sediments when implemented in a marine dispersion model. J Environ. Radioactiv., 71: 243-259.

Reczynski, W., Jakubowska, M., Golas, J., Parker, A. and Kubica, B. 2010. Chemistry of sediments from the Dobczyce Reservoir, Poland, and the environmental implications. Int. J. Sediment Res., 25: 28-38.

Shin, P.K.S. and Lam, W.K.C. 2001. Development of a marine sediment pollution index. Environ. Pollut., 113: 281-291.

Suomela, J., Gran, V., Helminen, H., Lagus, A., Lehtoranta, J. and Sipura, J. 2005. Effects of sediment and nutrient enrichment on water quality in the Archipelago Sea, northern Baltic: An enclosure experiment in shallow water. Estuar. Coast. Shelf S., 65: 337-350.

Sen, S., Haggard, B.E., Chaubey, I., Brye, K.R., Costello, T.A. and Matlock, M.D. 2007. Sediment phosphorus release at Beaver Reservoir, North-

west Arkansas, USA, 2002-2003: A preliminary investigation. Water Air Soil Poll., 179: 67-77.

Trolle, D., Zhu, G., Hamilton, D., Luo, L., McBride, C. and Zhang, L. 2009. The influence of water quality and sediment geochemistry on the horizontal and vertical distribution of phosphorus and nitrogen in sediments of a large, shallow lake. Hydrobiologia, 627: 31-44.

Vermaat, J.E. and Bouwer, L.M. 2009. Less ice on the Baltic reduces the extent of hypoxic bottom waters and sedimentary phosphorus release. Estuar. Coast. Shelf S., 82: 689-691.

Vicente, I., Cruz-Pizarro, L. and Rueda, F.J. 2010. Sediment resuspension in two adjacent shallow coastal lakes: Controlling factors and consequences on phosphate dynamics. Aquat. Sci., 72: 21-31.

Wauer, G., Gonsiorczyk, T., Kretschmer, K., Casper, P. and Koschel, R. 2005. Sediment treatment with a nitrate-storing compound to reduce phosphorus release. Water Res., 39: 494-500.

Wang, P., Song, J., Guo, Z. and Li, P. 2008. The release behavior of inorganic nitrogen and phosphorus in sediment during disturbance. Chinese Journal of Oceanology and Limnology, 26(2): 197-202. (In Chinese)

Wu, X., Yang, X. and Zed, R. 2009. Phytoremediation facilitates removal of nitrogen and phosphorus from eutrophicated water and release from sediment. Environ. Monit. Assess., 157: 277-285.

Yi, Y., Wang, Z., Zhang, K., Yu, G. and Duan, X. 2008. Sediment pollution and its effect on fish through food chain in the Yangtze River. Int. J. Sediment Res., 23: 338-347.