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Original Research Paper

Assessment on Sediment Pollution and Suggestions of its Disposal Method in a Reservoir used as an Urban Water Source in China

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ABSTRACT

In this study, sediment volume, heavy metals Cr, Ni, Cu, Zn, Pb, Hg, As, Cd and the nutrient substance such as TOC, TN, TP in sediment in a reservoir (an urban water source) in China were employed as the contamination index to assess the sediment pollution, using the method of index of geo-accumulation (I_{geo}). The result shows that, apart from sample 13# of Pb and 20# of Cu, the I_{geo}s of which are between 0 and 1, there is no other heavy metal pollution occurred in the reservoir. For the nutrient matters, TOC, TP and TN, the pollution levels are below the national average in this reservoir. The sediment volume is estimated as 5.6×10^7 m^3, nearly 10% of the storage capacity of the reservoir at the normal water level, implying that the situation of the sediment will affect the water supply in some way and it is essential to take measures to control this potential sediment pollution. The authors suggest that the dredging technology is the most effective way to solve sediment pollution in this reservoir, as the nutrient matters in the sediment are much abundant and could be used for resource utilization, such as building materials, fill materials and land use. Compared to the others, land use shows more potential for future development.

INTRODUCTION

Sediment, which is located at the bottom of the water, is composed of clay, sand, organic or several of mineral deposits, and formed through certain physical, chemical and biological processes (Perkins & Underwood 2001). In recent years, the formation of sediment is affected by human activities more and more in the country. The vast majority of hydrophobic organic compounds, metals, nutrients as particles were carried into the water by the particles, and then developed into contaminated sediment (Loska & Wiechua 2003). Not only the benthic habitats, sediment is also the sink of all kinds of the pollutants in water. Pollutants are purified in various ways, such as water particles' adsorption, complexation, flocculation, sedimentation and so on, by which they are finally deposited into the sediment. But on the other hand, sediment can also be an important source of secondary pollution in the water (Kim et al. 2003). When environmental conditions change, the pollutants absorbed by sediment will return to the water phase by desorption, dissolving, biological decomposition, and so on, which produce a phenomenon of secondary pollution, such as causing eutrophication of lakes and reservoirs. In addition, the excessive deposition of sediment would greatly cut the usable capacity of reservoir and lakes, reduce the reservoir benefit, and even affect the normal operation of the reservoir.

In this study, a typical reservoir (an urban water source) in northeast China was selected, in which pollution status was evaluated by field investigation, stationing monitoring, laboratory methods of chemical analysis and certain statistical analysis techniques. After that, feasible measures are proposed to control the pollution of sediment in the reservoir.

MATERIALS AND METHODS

Brief account of the reservoir: The reservoir in this study is large and has a comprehensive utilization such as supplying water to urban nearby, flood control, irrigation, etc. The drainage area of this reservoir is about 2000 km^2, and the total capacity is about 600 million m^3 at the normal water level. It not only has a nearly 90 million m^3 water supply design, but also can supply various economic species 20,000 kg per year. At the beginning of the 21st century, eutrophication with blue-green algae was outbroken in this reservoir.

Sample collection and processing: In this study, the reservoir was divided into four sampling areas, A, B, C and D, which according to the reservoir characteristics, combined with its geography, location and the distribution characteristics of sediment thickness, and with total number of 20 sampling points (Fig. 1). Sediment samples were collected using the bottom sampler (XDB0201), and sediment depth was estimated according to the mud volume and the location of the bottom sampler arrived. After packing, sealed samples were taken the laboratory for analysis.

Sample testing and analysis: After nature drying, the sediment samples were grinded through 0.15 mm sieve, and then the contamination index, contained nutrient substance such as TOC, TN, TP, and heavy metals such as Cr, Ni, Cu, Zn, Pb, Hg, As, Cd, were tested by the standard methods advised by Lu (2000). Assessment of heavy metal pollution was finished through the method of index of geo-accumulation (I_{geo}), and the TN, TP, TOC were assessed referring to the classification standard in "Pollution Survey and Evaluation of Sediment in Rivers and Lakes" (Zhou et al. 2008).

Index of geo-accumulation (I_{geo}) is also called Mull index, which is widely used to study degree of heavy metal pollution in soil and other materials (Peng et al. 2007):

$$I_{geo} = \log_2 C_n/(K*B_n) \quad ...(1)$$

Where C_n is heavy metal content of samples, B_n is the local soil background value of heavy metal; K is a constant, and the background value changes may be caused by diagenesis, so its average value is generally set as 1.5. I_{geo} is divided into 0~6 grades, indicating the pollution levels from no to extremely strong. Accumulation index value classification standard given in Tables 1 and 2 show the classification standard of organic pollution in the sediment.

RESULTS AND DISCUSSION

Sediment volume estimation: The sediment volume, wet weight and dry weight of mud area A, B, C, and D can be estimated based on wet weight, dry weight and sediment thickness of single sample, combined with the area divided, as given in Table 3. It is shown that, since its construction, the average thickness of the reservoir sediment is 93.75 cm, with a total accumulation amount of 5.6×10^7 m^3, and the total dry weight of sediment is about 2.0×10^7 t. Excessive sediment deposition will reduce the effective capacity of the reservoir, pollutants released from the sediment will cause secondary pollution in the water.

Sediment pollution status evaluation: According to the results of laboratory analysis of samples, combined with Formula (1), the I_{geo}s of heavy metals in the sediment were calculated and given in Table 4.

According to the results of laboratory analysis of samples, combined with formula (1), the I_{geo}s of heavy metals in the sediment was calculated and given in Table 4. It can be seen from Table 4 that heavy metals in the reservoir sediment studied, the sample 13#, I_{geo} of Pb is 0.02, meaning the contents of Pb in the sediment is lightly contaminated, and the others are all negative. For Cu, only the I_{geo} of sample 20# is higher than zero, the others are all negative. It may be due to that the sampling point was located in the estuary; certain exogenous matter has contribution to the deposit of its value. The I_{geo} of the remaining six heavy metals are all negative, pollution level described as no pollution. Thus, it can be seen as the water source, basically there is no heavy metal pollution situation in the reservoir.

In terms of the nutrients, TOC content in sediment less than 2.60% as the level I accounting for 85% of the total number of samples, and the account of level II (2.60%~3.90%) is 15%; for TP, content less than 730 mg/kg as level I is account for 5% of the total number of samples, and the level II (730 mg/kg~1100 mg/kg) is 95%. TN content of less than 1100 mg/kg as level I account for 15% of the total samples, the account of level II (1100 mg/kg~1600 mg/kg) is 75%, the level III (1600 mg/kg~2000 mg/kg) and the level IV (>2000 mg/kg) is 5%, respectively. Compared to "Pollution Survey and Evaluation of Sediment in Rivers and Lakes", the reservoir nutrient pollution levels are below the national average, however, in view of the reservoir had burst accident of water eutrophication, the control of nutrients as N, P in sediment should not be ignored.

Sediment pollution control measures: The main purpose of controlling sediment pollution in lakes and reservoirs is to make it harmless to ecology and environment, especially to urban water source. Mainly there are three measures as following: (1) Covering technology, in the case of water depth deep enough, it can be used that the sediment was covered with a layer of clean sediment (such as sand material) to make the sediment non-contaminated from the water, but the cost is higher; (2) In situ purification or curing techniques, namely decomposing or immobilizing pollutants in the sediment by biological, physical or chemical methods, thus reducing its impact on water. This method is not yet fully mature, and there are less application examples; (3) Dredging technology, in most cases the desilting is the only effective

Table 1: Geo-accumulation index (I_{geo}) and standards of the grade evaluation.

I_{geo}	<0	0-1	1-2	2-3	3-4	4-5	>5
Grading Pollution level	0 No	1 No-medium	2 Medium	3 Medium-strong	4 Strong	5 Strong-extremely strong	6 Extremely strong

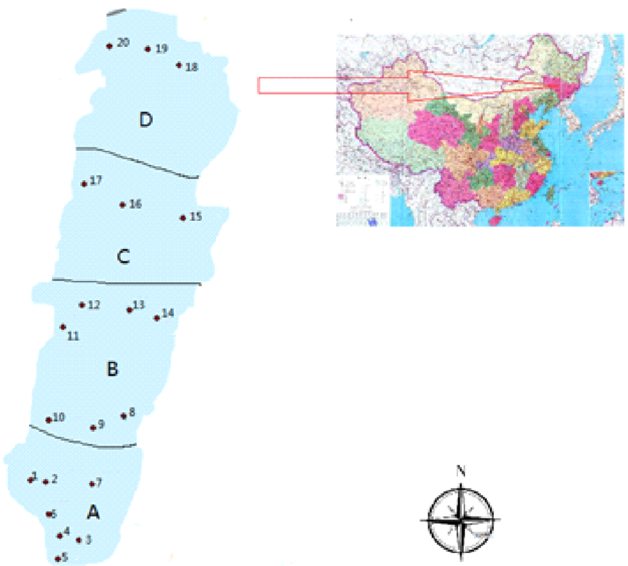

Fig. 1: Schematic diagram of sampling points in the reservoir.

way to solve any river course or lake sediment pollution.

Dredging engineering can effectively restore the capacity of the reservoir and improve the question of endogenous pollution, which is technically feasible and has a relatively low cost. Desilting can improve water quality of the reservoir, the alluvial sediment cleared can be used for production of organic fertilizer and soil improvement, and it can also be used as materials of brick or construction sand, which realized resource utilization of alluvial silt, and reduce the cost of desilting indirectly.

Sediment management and disposal: The resource utilization of alluvial silt can be classified as: fill material (Dubois et al. 2009), building materials, and land use (Sabat et al. 2002).

The dredged sediment can be used as fill material under appropriate conditions after certain pretreatment. First, it should come into being suitable for the engineering requirement through improving the properties of high water content and low strength, and then used for backfill construction. The pretreatment of dredged sediment usually include physical method (drying, dehydrating), chemical methods (curing processing) and heat treatment method (burning-out processing). In the view of the engineering applications, the dredged sediment can be used for the following projects: Embankment or reinforced embankment engineering, roadbed filling engineering (Siham et al. 2008) and so on. Dredged sediment can also be used as material of the wall, light aggregate concrete and silicate gelling material (Hamer & Karius 2002). Using dredged sediment as alternative clay will reduce the use of agricultural soil for building materials manufacturing, and it is another way of dredged sediment resource utilization, which has a wide development prospect in our country.

Land use is that dredged sediment which can be applied in farmland (Comoss et al. 2002), woodland, grassland, wetland, municipal greening, land restoration and reconstruction (Yozzo et al. 2004). Scientific and reasonable land use, can not only reduce the negative effect, but also make the dredged sediment back into the natural environment of matter and energy cycle. Because of low energy consumption, land use is safe and suitable to the situation of this country.

Land use of dredged sediment requires an important precondition, that is, the contents of harmful ingredients in it must be not more than the capacity range that environment can withstand; it must meet the national "Standard of Pollutant Control in Agricultural Sludge" (GB4284-84) and "Environmental Quality Standard for Soils" (GB15618-1995). Non-toxic harmless handling (generally adopts high temperature compost, processing cost is 180-200 Yuan/t dry sludge) is indispensable before the land disposal of sediment. In this study, heavy metal contents in the sediment are lower than the background value, fully meet the standard requirements, and the mud contains a certain amount of organic matter and nutrients the plants needed, and it has the organic fertilizer which chemical fertilizers do not have, with large amount and relatively balanced fertilizer ingredients. It can make the soil granular structure formation and keep nutrient effect by the humus colloidal in it. Above all, dredged sediment is a valuable resource. Dredged sediment can also be used for construction of the wetland, and further as the animal habitats. Such land as saline and alkaline land generally has lost the good qualities of the soil, which can not directly plant trees and grasses. Ploughing dredged sediment can increase soil nutrient, improve soil characteristics, and promote the growth of the plants. Dredged sediment used to repair saline and alkaline land also avoid the food chain, with a small potential threats to human life, and in this way it can not only dispose the dredged sediment, but also recover the ecological environment, which is a kind of valuable utilization way.

CONCLUSION

In this study, the reservoir sediment volume is estimated to about 5.6×10^7 m^3, exist a certain phenomenon of excessive deposition. The index of geo-accumulation method used for analysis of sediment samples shows that, among eight heavy metals, only index of sample point 13# of Pb and 20# of Cu is greater than zero, indicating the presence of light pollution;

Table 2: Classification standard of organic pollution in sediment.

	I	II	III	IV
TOC (%)	<2.60	2.60~3.90	3.90~5.20	>5.20
TN (mg/kg)	<1100	1100~1600	1600~2000	>2000
TP (mg/kg)	<730	730~1100	1100~1500	>1500

Table 3: Estimation of sediment thickness, volume and total wet and dry weight distribution.

Areas	A	B	C	D	Total
Thickness/cm	115	100	90	70	
Area/10^5 m^2	140	140	140	140	560
Volume/10^5 m^3	161	140	126	98	525
Wet weight/10^5 t	199	170	151	92	612
Dry weight/10^5 t	65	56	49	30	200

Table 4: The index of geo-accumulation (I_{geo}) of heavy metals in sediments.

Samples	Cr	Ni	Cu	Zn	Pb	Hg	As	Cd
1	-1.09	-1.00	-0.75	-0.91	-0.36	-1.56	-1.68	-2.73
2	-0.52	-0.39	-0.26	-0.44	0.07	-1.36	-1.17	-2.69
3	-0.51	-0.36	-0.28	-0.44	0.00	-2.09	-1.12	-2.86
4	-0.43	-0.30	-0.19	-0.39	-0.07	-1.19	-1.14	-2.87
5	-0.46	-0.33	-0.23	-0.44	-0.15	-0.89	-1.24	-3.16
6	-0.54	-0.42	-0.31	-0.52	-0.22	-0.87	-1.39	-3.41
7	-0.68	-0.61	-0.54	-0.75	-0.42	-0.45	-1.63	-5.16
8	-0.94	-0.88	-0.74	-0.93	-0.41	-2.38	-2.49	-5.93
9	-0.63	-0.52	-0.35	-0.70	-0.26	-1.48	-1.83	-5.10
10	-0.78	-0.63	-0.37	-0.90	-0.50	-2.08	-1.95	-4.91
11	-0.48	-0.31	-0.38	-0.60	-0.19	-1.47	-1.88	-5.40
12	-0.33	-0.21	-0.15	-0.43	-0.01	-2.29	-1.87	-4.09
13	-0.36	-0.24	-0.14	-0.47	0.02	-2.03	-1.64	-3.60
14	-0.81	-0.74	-0.83	-1.20	-0.32	-2.83	-1.61	-5.16
15	-0.67	-0.56	-0.32	-0.79	-0.44	-1.82	-1.50	-5.40
16	-0.75	-0.66	-0.53	-0.82	-0.17	-2.03	-1.51	-4.40
17	-0.30	-0.18	-0.15	-0.50	-0.21	-1.71	-1.44	-3.95
18	-1.25	-1.29	-1.25	-1.43	-0.32	-3.04	-1.78	-4.78
19	-0.57	-0.46	-0.31	-0.52	-0.09	-1.70	-1.47	-4.07
20	-0.39	-0.21	0.03	-0.12	-0.01	-1.52	-1.53	-4.03

the contents of the rest of heavy metals are all lower than the background value. The contents of total organic matter, total nitrogen and total phosphorus are below the national average. Sediment dredging can improve the endogenous pollution problem, with economy and technology feasibility; the resource utilization of dredged sediment, including used as building materials, fill materials and land use. Among them, the land use by which dredged sediment can be treated, and the ecological environment can be improved, shows that land use is a very valuable way with a vast potential for future development.

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REFERENCES

Comoss, E. J., Kelly, D. A. and Leslie, H. Z. 2002. Innovative erosion control involving the beneficial use of dredge material, indigenous vegetation and landscaping along the Lake Erie shoreline. Ecological Engineering, 19(3): 203-210.

Dubois, V., Abriak, N. E., Zentar, R. and Ballivy, G. 2009. The use of marine sediments as a pavement base material. Waste Management, 29(2): 774-782.

Hamer, K. and Karius, V. 2002. Brick production with dredged harbour sediments: An industrial-scale experiment. Waste Management, 22(5): 521-530.

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(1): 53-61.

Loska, K. and Wiechula, D. 2003. Application of principal component analysis for the estimation of source of heavy metal contamination in surface sediments from the Rybnik Reservoir. Chemosphere, 51(8): 723-733.

Lu, R. K. 2000. Methods for Agricultural Chemical Analysis of Soils. First edition, Agricultural Science and Technology Press, Beijing.

Perkins, R. G. and Underwood, G. J. C. 2001. The potential for phosphorus release across the sediment-water interface in a eutrophic reservoir dosed with ferric sulphate. Water Research, 35(6): 1399-1406.

Peng, J., Li, Z. and Hou, J. 2007. Application of the index of geo-accumulation index and ecological risk index to assess heavy metal pollution in soils. Guangdong Trace Elements Science, 14(8): 13-15.

Siham, K., Fabrice, B., Edine, A.N. and Patrick, D. 2008. Marine dredged sediments as new materials resource for road construction. Waste Management, 28(5): 919-928.

Sabat, L.J., Vogt, C. and Holliday, B. 2002. Promoting dredged material as a resource. Sea Technology, 43(8): 47-52.

Yozzo, D. J., Wilber, P. and Will, R.J. 2004. Beneficial use of dredged material for habitat creation, enhancement and restoration in New York-New Jersey Harbor. Journal of Environmental Management, 73(1): 39-52.

Zhou, H. D., Hao, H., Wang, Y. C., Wu, P. R. and Wu, S. L. 2008. Pollution Survey and Evaluation of Sediment in Rivers and Lakes. Available at: http://wenku.baidu.com/view/ f02699b465ce050876321367.html