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Study on pollution and eutrophication in the Chaohu Lake

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Abstract— Effect of the pollution on the Chaohu Lake ecosystem has been described based on the results obtained by analysis of water samples and field survey. The environmental behavior of pollutants and their toxicity is discussed in relation to biological effects. Most of the chemicals identified by GC/MS are biodegradable in the water environment except for some organochlorinated hydrocarbons and PAHs. The pollution of the water body particularly cutrophication has led not only to disruption of natural scenic beauty, but also to changes of biotic communities and extinction of certain species. Deterioration of water quality, eutrophication in particular have certainly had an impact on aquatic organisms and on the human health in this region.

Keywords: lake; pollution; eutrophication.

1 Introduction

The Chaohu Lake and its lakeside area, as a land of fish and rice, is of vital importance to the people living in Hefei City of Anhui Province. Not only has it become the major source of drinking water for more than one million people, but also water in it is used for industrial production, irrigation in agriculture and inland navigation. Moreover, the lake is also important in fishery due to the fish yields of thousands of tons. Because of its scenic beauty at Mushan, the lake is a favorable sightseeing area.

At the present time, with rapid economic development in this region, human activities are causing extensive and striking trophic changes in the water and the environmental pollution has become a major problem. Further, the rapid increasing population in this area has resulted in growing quantity of fertilizers being used. Increasing nutrients from the agricultural discharge, runoff, domestic sewage and industrial wastes are causing rapid eutrophication. The undesirable consequences are a dramatic increase in algal biomass as well as changes in the dominating algal species. The destruction of the environment is becoming evident in such phenomenon so-called “water bloom”. In autumn 1987, during water bloom season, the lake surface near

Tang Xi Village was covered by 10－15 cm thick layer of blue-green algae. The drinking water was impure and foul-smelling. The water supply plant failed to supply drinking water to Hefei City for a week. It led to an economic loss of about one hundred million RMB Yuan. Toxin produced by algae may imperil the aquatic life and human health. These accidents have made people to pay greater attention on the water quality of Chaohu Lake and to the effect caused by pollution on the aquatic life. The restoration and improvement of water quality is extremely urgent.

The aim of this paper is to evaluate the water quality of Chaohu Lake based on the systematic analysis of organic pollutants and nutrients in water body, to study their fate, toxicity and eco-environmental behavior, as well as to discuss the eutrophication as a major problem in Chaohu aquatic ecosystem, in order to get a better understanding for the eco-environmental status and thus to provide a scientific basis for restoration and improvement of lake water quality and management.

2 Experimental

The water samples were collected at sampling sites 1, 2 and 4, as shown in Fig. 1. After settling of the suspended particles the water passed through a glass column of 30 cm long and 25 mm I. D. filled with resin GDX 102 and GDX 502. The resin was then extracted by methylene chloride in a Soxhlet extractor for about 8 hours. The extract was concentrated under reduced pressure to 1 ml for further analysis by GC and GC/MS.

GC analysis was performed on Hitachi 663-50 gas chromatograph equipped with FID. The experimental conditions are as follows: fused silica capillary column DB-1, 0.25 mm I. D., 25 m long; the temperature program for 70 ℃ to 250 ℃ at rate of 5℃ per minute, with carrier gas, N_2. The GC/MS analysis was carried out on JMS-D300S equipped with EI ion source. The EI-70eV mass spectra were used for the tentative identification of unknown

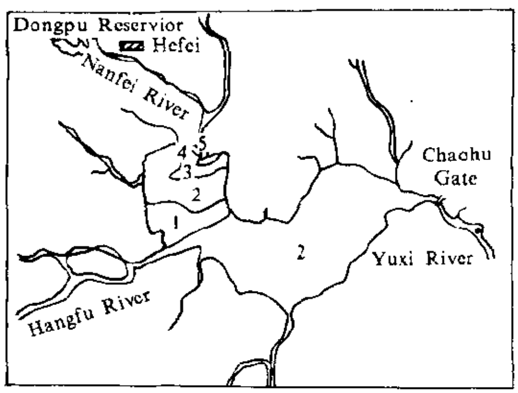

Fig. 1 The classification of water quality in Chaohu Lake

* Water quality classified according to the GB3838-83 "Environmental Criteria of the Surface Water Quality" and monitoring data performed by the Monitoring Station of Hefei City. The major pollutants: Nutrients TN and TP as well as organic compounds

1. Clearer 2. Still clear 3. Light polluted 4. Heavy polluted 5. Serious polluted

compounds.

3 Results and discussion

3.1 Identification of unknown compounds

It is necessary to analyze and identify the pollutants in Chaohu Lake in order to achieve a better understanding of the extent of water pollution and to discuss the behavior of pollutants in water environment and their effect on aquatic life. The results obtained are given in Table 1. All together 92 compounds were tentatively identified. The toxicity data of some compounds taken from registry of toxic effect of chemical substances (RTECS) are also listed. Most of those are from industrial wastes and agricultural' chemicals, such as pesticides and fertilizers. The domestic sewage containing N and P nutrients, however, are an important source of pollution due to the use of P-containing detergent in large quantities (Table 1).

Table 1 Compounds identified from the Chaohu Lake

Classification	Compounds	Composition	Biodegradability	Toxicity data
	Pentane, 2, 3, 4-trimethyl-	C_8H_{18}	1	
	Cyclohexane, 1, 3, 4-trimethyl-	C_9H_{18}	1	
	Heptane, 2, 4-dimethyl-	C_9H_{20}	1	
Aliphatic hydrocarbon	Heptane, 2,6-dimethyl-	C_9H_{20}	1	
	Heptane, ethyl-	C_9H_{20}	1	
	Heptane 3-ethyl-2-methyl-	$C_{10}H_{22}$	1	
	Decane	$C_{10}H_{22}$	1	
	Heptane, 5-ethyl-2-methyl-	$C_{10}H_{22}$	1	
	Decane, 4-methyl-	$C_{11}H_{24}$	1	
	Octane, 2,3,6-trimethyl-	$C_{11}H_{24}$	1	
	Undecane	$C_{11}H_{24}$	1	
	Dodecane	$C_{12}H_{26}$	1	
	Decane, 2,5,6-trimethy-	$C_{13}H_{28}$	1	
	Tetradecane	$C_{14}H_{30}$	1	
	Pentadecane	$C_{15}H_{32}$	1	
	Hexadecane	$C_{16}H_{34}$	1	
	Heptadecane	$C_{17}H_{36}$	1	
	Octadecane	$C_{18}H_{38}$	1	
	Undecane, 5-ethyl-5-propyl-	$C_{16}H_{34}$	1	
	Cyclohexane,1-methyl-4-(1-methylethyl)-(trans-	$C_{10}H_{16}$	1	orl-rat LD_{50}
	Nonadecane	$C_{19}H_{40}$	1	4400mg/kg

Table 1 (Continued)

Classification	Compounds	Composition	Biodegradability	Toxicity data
	Cyclohexane, 1-methyl-4-(1-methylethyl)-(R)-	$C_{10}H_{16}$	1	
	4-Carene (1S,3S,6R)-(-)-	$C_{10}H_{16}$	1	
	Bicyclo (3,1,1,) heptane, 6,6-dimethyl -0-2-methyl-(1S)-	$C_{10}H_{16}$	1	
	Bicyclo (3,1,1) hepta-2-ene, 2,6,6-trimethyl-	$C_{10}H_{16}$	1	
	Tricyclo (2,2,1,02,6) heptane, 1,7,7-trimethyl-	$C_{10}H_{16}$	1	
Aromatic hydrocarbons	Benzene, methyl-	C_7H_8	1	orl-rat
	Benzene, ethyl	C_8H_{10}	1	LD_{50}:5000mg/kg
	Benzene, 1,4,-dimethyl-	C_8H_{10}	1	
	Benzene, 1,3,-dimethyl-	C_8H_{10}	1	orl-rat LD_{50}
	Benzene, 1-ethyl-3-methyl-	C_9H_{12}	1	4300mg/kg
	Benzene, 1,2,4-trimethyl-	C_9H_{12}	1	ipr-rat
	Benzene, 2-ethyl,1,3,dimethyl	$C_{10}H_{14}$	1	LDLo: 1752mg/kg
	Benzene, 1-ethyl-3, 5,dimethyl	$C_{10}H_{14}$	1	orl-rat LD_{50}
	Benzene, 1,2,3,5-tetramethyl-	$C_{10}H_{14}$	1	5000mg/kg
Carboxylic acid	Nonanoic acid	$C_9H_{18}O_2$	1	orl-rat LD_{50} 6980mg/kg
	Hexandecanoic acid	$C_{16}H_{32}O_2$	1	
	9-octadecenoic acid (Z)	$C_{18}H_{34}O_2$	1	
	9,12-octadecadienoic acid (Z, Z)	$C_{18}H_{32}O_2$	1	
	Benzene dicarboxylic acid, dibtyl-	$C_{16}H_{22}O_4$	1	
Carboxylic acid ester	Benzene, dicarboxylic acid, diisooctyl ester	$C_{24}H_{38}O_4$	1	
	Hexadecanoic acid methyl ester	$C_{17}H_{34}O_2$	1	orl-rat LD_{50}: 17300mg/kg
	Hexadecanoic acid 16-methyl ethyl ester	$C_{19}H_{38}O_2$	1	
	1,2-benzenedicarboxylic acid butyl 2-methylpropyl ester	$C_{16}H_{22}O_4$	1	
Ketone	2-cyclohexane-1-one	C_6H_8O	1	
	2-pentanone, 4-hydoxy-4-methyl	$C_6H_{12}O_2$	1	orl-rat LD_{50}
	3-pentanone, 2,4-dimethyl-	$C_7H_{14}O$	1	220mg/kg
	2-heptanone, 6-methyl-	$C_8H_{16}O$	1	orl-rat LD_{50}
	2-cyclopenten-1-one, 2,3,5-trimethyl 4- methylene	$C_9H_{12}O$	1	4000mg/kg
	Ethanone, 1-phenyl-	C_8H_8O	1	LD_{50} 900mg/kg

Table 1 (Continued)

Classification	Compounds	Composition	Biodegradability	Toxicity data
Alcohol phenol	1,2,3-propanetriol triactate	$C_{19}H_{14}O$	1	
	Phenol 2,5-dimethyl-	$C_8H_{10}O$	1	
	Phenol, 2-(1-methylethyl)-	$C_9H_{12}O$	1	
	Phenol,2,4,6-trimethyl-	$C_9H_{12}O$	1	orl-mus
	Phenol,2,3,5-trimethyl-	$C_9H_{12}O$	1	LD_{50}:10g/kg
Aldehydes	Benzaldehyde ethyl	$C_9H_{10}O$	1	
	Benzaldehyde, 2,5-dimethyl	$C_9H_{10}O$	1	
Halogenated	2-propanone, 1,3-dichloro-	$C_3H_4OCl_2$	1	orl rat
	2-propanol, 1,3-dichloro-	$C_3H_6OCl_2$	1	LD_{50} 110mg/kg
	Ethane, 1,1,2-trochloro-	$C_2H_3Cl_3$	3	
	DDT	$C_{14}H_9Cl_5$	2	LD_{50} 177mg/kg
	BHC	$C_6H_6Cl_6$	2	LD_{50} 76 mg/kg
	Ethane, hexychloro-	C_2Cl_4	1	
	Ethanol, 2,2,2-trichloro-	$C_3H_3OCl_3$	1	
	Ethelene, tetrachloror-	C_2Cl_4	1	
Nitrogen containing	pyridine, 4-methyl	C_6H_7N	1	orl-rat LD_{50}
	Pylidine, 2,6-dimethyl-	C_7H_9N	1	1290mg/kg
	Isoquinoline, methyl-	$C_{10}H_9N$	1	orl rat LD_{50}
	Quinoline, methyl-	$C_{10}H_9N$	1	656mg/kg
	1-Naphthalenecarbonitrile	C_7H_9N	1	orl-rat LD_{50}
	Quinoline, 2,7-dimethyl-	$C_{11}H_{11}N$	1	1260mg/kg
	Quinoline, 2,3-dimethyl-	$C_{11}H_{11}N$·	1	
	Phenol, 3-(1-methyl)- methylcarbonate	$C_{11}H_{15}O_2N$	1	
	Benzo (F) quinoline	$C_{13}H_9N$	1	
	Benzothiazole	C_7H_5NS	1	orl-rat LD_{50}
	Phenol, 2-nitro-	$C_6H_5O_3N$	1	900mg/kg
	Phenol, 4-methyl-2-nitro-	$C_6H_7O_3N$	4	orl-rat LD_{50} 2828mg/kg
Sulphur-containing	Disulfide, dimethyl-	$(CH_3)_2S_2$	4	ihl-rat LC_{50} 805ppm
	Accticacid, mercapto- phenylmethyl ester	$C_9H_{10}O_2S$	4	
	Methane, sulfonylbis-	$C_2H_6O_2S$	4	

Table 1 (Continued)

Classifi-cation	Compounds	Composi-tion	Biodegra-dability	Toxicity data
PAH	Naphthalene	$C_{10}H_8$	1	LD_{50} 130mg/kg
	Naphthalene, 1,2,3,5,6,7,8,8A-octahydro-1, 8A-dimethyl-7-(1-methylethyl)- 1S.(1, alpha, 7, alpha, BA alpha)-	$C_{15}H_{24}$	1	
	Acenaphthene	$C_{12}H_{10}$	1	
	Phenanthrene	$C_{14}H_{10}$	1	LD_{50} 700mg/kg
	Fluoranthene	$C_{16}H_{10}$	2	orl-rat LD_{50}
	Pyrene	$C_{16}H_{10}$	2	2000mg/kg
	1,4-methanonaphthalen-9-ol-1,4-dihydro-	$C_{11}H_{10}O$	4	orl-rat LD_{50}: 2700mg/kg
	9,10-Anthracenedione	$C_{14}H_8O_2$	4	ipr-rat LD_{50}:3500mg/kg
	1H-Indene, 5-butyl-hexyoctahydro-	$C_{19}H_{36}$	4	
Others	Cyclohexanone-6-furfurylidene-2,2-dimethyl	$C_{13}H_{16}O_2$	4	
	Azulene	$C_{10}H_8$	4	
	Alpha-pinene	$C_{10}H_{16}$	4	

1. biodegradable; 2. no biodegradable; 3. moderately biodegradable; 4. unknown

3.2 Eco-environmental behavior of the pollutants

Different classes of the chemicals have different environmental behavior and biological effects on the aquatic ecosystem. Most of the detected compounds, such as aliphatic hydrocarbons, aromatic hydrocarbons, phenol and phenolic compounds, carboxylic acids, carboxylic acid esters, ketones, alcohol phenol, aldehydes, nitrogen-containing compounds are considered to be degradable by microorganisms in the environment (Qian, 1987). The chlorinated compounds, such as DDT and BHC, are persistent compounds to biodegradation. The biodegradability of these compounds depends on the number of hydrogen atoms replaced with chlorine atoms. Compounds with more chlorine atoms are more persistent to biodegradation. PAH compounds were identified. Some are known as carcinogenic chemicals. PAH with more than two condensed rings are very persistent to biodegradation. In general, DDT and BHC are considered to be harmful chemicals due to their bioaccumulation in aquatic organisms. The characteristics of DDT and BHC are their high solubility in lipid. This property combined with their extreme stability is a principal explanation for the accumulation of these compounds in the fat of many aquatic animals through food-chain. The total DDT and BHC residues in the carps caught in Chaohu Lake based on monitoring data in 1984 were 0.0818 and 0.0482 ppm, respectively.

In the lake environment, there are many physico-chemical and biological processes including adsorption, chemical oxidation, photodecomposition, microbial degradation. The biodegradation is a more important mechanism for environmental loss of organic contaminants, considering most of those to be biodegradable. Microorganisms play a major role in the fate and transport of hydrophobic organic compounds and for nutrients, the plankton function is more important because of their large biomass in Chaohu Lake.

Degradation of organic compounds by microorganisms can have a significant effect on their distribution in the sediment. PAH as well as pesticides often associate with particles in the aquatic ecosystem and can deposit to the sediment. In contrast with other large lakes in China, the sediment-water interface in Chaohu Lake is always unstable. The water is always turbid. It is considered to be unfavorable to the biodegradation of hydrophobic compounds.

Many types of organic matter are not stable when associated with the sediment and contaminants may be released or bound when organic matter is altered. Linear aliphatic and simple aromatic structure are readily biodegraded, as shown in Table 1, resulting in branched and cyclic aliphatic and substituted aromatic structures accumulating in partially degraded humic substances (Leenbeer, 1990).

Many chemicals identified in water samples belong to the priority pollutants listed by US EPA. It has been shown that Chaohu Lake was, in some degree, contaminated by organic compounds, in particular, in the area of Nanfei River mouth.

3.3 Eutrophication in water body

Chaohu Lake is characterized by lack of aquatic macrophytes. The phytoplankton is a major producer. At the present time, the eutrophication in Chaohu Lake is a serious problem due to heavy load of nutrients and other pollutants from the catchment every year. Annual total nitrogen and phosphorus load to Chaohu Lake was estimated to be 1050 tons and 18370 tons respectively based on the research conducted in 1987. Seven rivers carry the majority of the nutrients to the lake and it was 68.50% for TP and 76.9% for TN. The external nutrient loads of TP and TN were 1.46 g/m^2 and 22.78 g/m^2 exceeding the dangerous load limit 10 times (Tu, 1990).

Many environmental factors can affect the occurrence of water bloom besides the nutrients The monitoring results of water quality at Tangxi Village in 1987 are shown in Fig. 2. The variation of concentrations of N and P was not significant from month to month. The chl-a, however, varied significantly and reached a peak value. It is obvious that certain cell constituent is highly dependent on environmental conditions. The effects of some physico-chemical factors, such as light intensity, pH, CO_2 concentration, O_2 concentration, temperature, as well as turbulence on the growth of algae are of great importance (Carmichael, 1981). It has been investigated that the temperature between 28.8 ℃ to 30.5 ℃ is most suitable for the growing of *Macrocystis* (Krüger, 1981). During water bloom season the dominant species of plankton algae were almost entirely blue-green algae, especially *Microcystis* and *Anabaena*. The frequency was up to 100% and abundance 99.7% (Meng, 1988). The water was covered by a layer of plankton.

The fish died in large quantities, emphasizing the uncomfortable effect on the health of people. The impact of eutrophication on Chaohu Lake ecosystem is more serious than pollution caused by organic chemicals because certain algae can produce substances toxic to aquatic organisms and also to man through drinking water and food chain (He, 1989). Toxins of *Mycrocystis aeruginaosa* have been isolated and identified to be a peptides of small molecular weight ranging in size from 500 to 1700 daltons (Carham, 1979). The chemical structures and toxicity to animals for most of substances excreted by phytoplankton are still unknown.

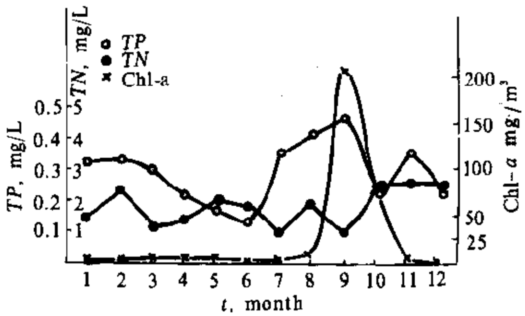

Fig. 2 Monthly TN, TP and chl-a concentrations in 1987

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