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Organic contamination in the drinking water from Chaohu Lake

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Abstract— Chaohu Lake water body is a major drinking water source for dwellers of Hefei City and Chaohu City. The paper describes the work that concerning with the method of system analysis on the raw water and drinking water of Fourth Water Plant in Hefei City and the results on the identification of organic compounds in the water.

Keywords: organic contaminants; raw water; drinking water; system analysis.

INTRODUCTION

One of the functions of Chaohu Lake is to supply drinking water to city dwellers along the lake, such as those in Hefei City and Chaohu City.

This paper deals with the methods of systematic analysis on raw water and drinking water in the Fourth Water Plant of Hefei City, the concentration of detected organic compounds and identification of pollutants.

EXPERIMENTAL

1. Selection of sampling points

The sampling points are at the inlet of raw water before being processed and in the outlet of the water plant.

2. Sampling method

Because the contents of organic contaminants in drinking water are very low, an absorption tube loaded resin is used to reconcentrate these compounds. That nonionic resin XAD was slurry-packed in a glass tube (2 cm ID × 15 cm). The resins had been purified by consecutive 24h reflux extractor extraction with acetone, dichloromethane and ethanol. The raw water and drinking water respectively passed through (flow rate 5 ml/min) the field sampler designed by authors which is shown in Fig. 1. The water sample volume is about 40 L for the raw water and 100 L for the drinking water measured by a meter connected with a pump.

3. Sample extraction

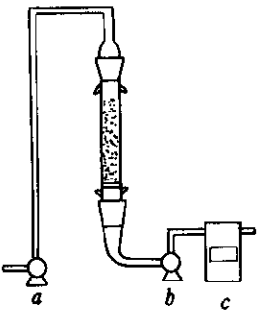

Fig. 1 Field sampler
a. pump (I) *b*. pump (II) *c*. flowmeter

An adsorption tube is mounted on an extractor. The organic contaminants absorbed by the XAD resin are extracted by the CH_2Cl_2 which has been redistilled before use. This reflux extractor (Fig. 2) helped to get the best extract resulted with minimum solvent (70 ml). The extracts were dried with sodium sulfate in order to satisfy the requirements of GC, GC/MS, HPLC analyses, the volume extracted liquid is further concentrated until the value of the volume is satisfied with the need of GC, GC/MS, HPLC. The resin extracted were analysed by GC/MS using

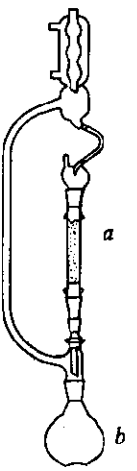

Fig. 2 Extractor-reflux extractor
a. adsorption tube loaded with XAD resin; *b*. redistilled CH_2Cl_2

a fused-silica column (SE-30, 50 × 0.25 mm) with the following temperature program: initial temperature 70 ℃ (4 min) to 265 ℃ at 5 degree/min from 30 to 40 min.

The overall analysis procedure is shown in Fig. 3.

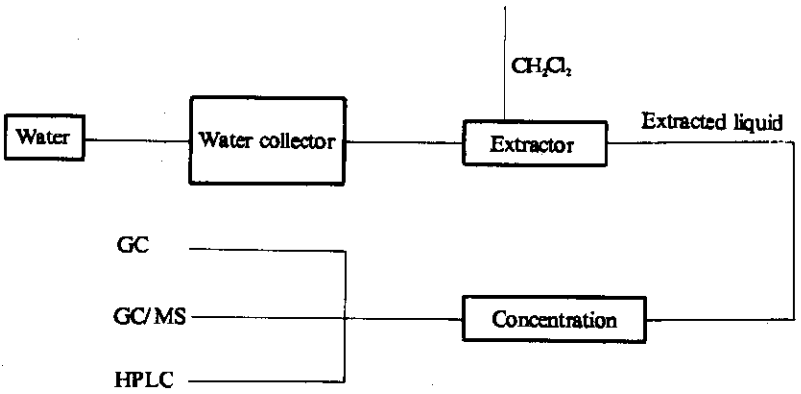

Fig. 3 The overall analysis procedure

RESULTS AND DISCUSSION

The kinds of organic pollutants detected in raw water and drinking water and the quantified concentrations of orgnaic contaminants in the raw water and drinking water are shown in Table 1 to Table 3.

Under the conditions mentioned above in the experimental of gas chromatography analysis, hundreds of organic compounds in water samples can be separated by a capillary column but it is difficult to make a quantitative determination simultaneously for all the separated organic compounds. An available method adopted is that the total peak area value of chromatography will be used as the basis for comparing the total amount of each organic compounds.

Table 3 shows the total area value detected by GC in raw water and drinking water. It can be seen that the contents of organic compounds in raw water and drinking water have significant difference.

In this study, nineteen standard organic compounds of different types were selected for quantitative analysis. The calculation result obtained from the analysis shows that the total concentration of quantified compounds in raw water is 19 times as much as that in the drinking water, indicating that the quality of water has been improved after the treatment process.

From Table 1 and Table 2, it can be seen that in the water of the eutrophic Chaohu Lake, the number of oxygen-containing compounds is 50% of the total number of detected compounds, whereas it is about 60% in the drinking water. Oxygen-containing compounds include aldehyde, alcohol, ketone, acid, ester and phenol and so on. The detail of the detected com-

pounds is shown in Table 4.

Table 1 The classification of organic compounds in raw water

Name	The numbers of cpd detected	Weight percentage, %
a Oxidous compounds		
a_1 Aldehyde	5	5.5
a_2 Ketone	12	13.2
a_3 Alcohol	9	9.9
a_4 Phenol	7	7.7
a_5 Ester	5	5.5
a_6 Acid	5	5.5
a_7 Ether	1	1.1
	44	48.5
b Hydrocarbon compounds	14	15.4
c Aromatic compounds	6	6.6
d Polyaromatic compounds	7	7.7
e Nitrogenous compounds	10	11
f Contain N.P.S compounds	1	1
g Sulfocompounds	5	5.5
h Chlorine compounds	4	4.4
All total amounts	91	100

The number of hydrocarbon compounds in raw water is 15% of the total number of detected organic compounds and it is more than 20% in drinking water.

There are many compounds in the raw water which contain N, P, S, Cl in the detected compound, such as purine, pyridine, amine-compounds benzothiazole, quinoline etc..

The natural organic compounds detected in the water body are highest cholest stigmast, carbazole and peppermint camphor and so on.

The number of detected organic compounds in drinking water is less than that in the raw water in the GC spectrum within the retention times less than 35 minutes. If more than 35 minutes, there is larger number of detected compounds in the drinking water.

The carcinogenic agent 3, 4 benzopyrene was once detected by HPLC in raw water and drinking water.

Nanfei River and Shiwuli River located in the northern part of the Fourth Water Plant are the main sources of organic effecting the drinking water quality. Such a large number of organic compounds and high concentration fund in the raw water and in the drinking water is a threaten to the health of people in Hefei City.

It is evident and important that in-depth research on the relationship between eutrophication

Table 2 The classification of organic compounds in drinking water

Name	The numbers of cpd detected	Weight percentage, %
a Oxidous compounds		
a_1 Ester	3	3.9
a_2 Aldehyde	3	3.9
a_3 Alcohol	18	23
a_4 Ketone	5	6.4
a_5 Phenol	4	5.1
a_6 Acid	13	16.7
	46	58.5
b Hydrocarbon compounds	16	20.5
c Nitrogenous compounds	6	7.1
d Chlorine compounds	5	6.4
e Sulfocompounds	3	3.9
f Aromatic hydrocarbon	1	1.3
g Polyaromatic hydrocarbon	1	1.3
All total amounts	78	100

Table 3 The comparison of organic compounds in the raw water and drinking water of the Fourth Water Plant

Item	Source water	Drinking water	S/d
Total peak area value of chromatography	2710219	96126	28/1
The kinds of quantified compounds	18	9	2/1
The total concentration of organic compounds in water samples	9.3 (mg/L)	0.5 (mg/L)	19/1

Quantified compounds by GC: S is the total amount of organic compounds in source water; d is the total amount of organic compounds in drinking water

and organic compounds and water quality must be continued. A series of methods to remove organic pollutants in the treatment process must be used in order to improve the quality of drinking water.

Table 4 The total identified organic compounds in raw water and drinking water

	Raw water		Drinking water	
Oxidous compounds				
Alcohol	$C_{10}H_{14}O_2$	2-Butanediol, 1-phenyl	$C_{27}H_{46}O$	Cholestan-3-ol (3 Alpha)
	$C_8H_{16}O$	Cyclohexanol, 2, 6-dimethyl	$C_{29}H_{50}O$	Stigmast-5-en-3-ol
	$C_{10}H_{18}O$	Bicyclo-2, 2, 1, heptan 2-ol, 1, 3, 3, trimethyl	$C_8H_{12}O$	Bicyclo 2, 2, 2 oct-5-en-2-ol
			$C_{10}H_{20}O$	Cyclo hexanol, 4-sec-butyl
	$C_{15}H_{26}O$	3-Cyclohexene-1-methanol, Alpha, 4-dimethyl-Alpha-	$C_{15}H_{26}O$	2, 6, 10-Dodecatrien-1-ol 3, 7, 11-trimethyl
			$C_{18}H_{38}O$	1-Octadecanol
	$C_{15}H_{24}O$	1H-3A, 7-methanoazulen-5-ol, octahydro, 3, 8, 8-trimethyl-	$C_{15}H_{32}O$	1-Dodecanol 3, 7, 11-trimethyl
			$C_{18}H_{36}O$	9-Octadecen-1-ol
	C_8H_9OF	Benzenethanol, 3-fluor-	$C_{27}H_{48}O_2$	Ethanol, 2, 19, 12-octadecadiethyloxy-
	$C_{10}H_{20}O$	Cyclohexane ethanol, Beta, 4-dimethyl, trans-	$C_{36}H_{60}O_2$	Cholesta-4, 6-dien-3-ol, benzoate
	$C_7H_{16}O$	Cyclohexanemethanol, 4-dimethyl-trans	$C_{29}H_{48}O_2$	Cholest-5-en-3-ol (3Beta)
			$C_{33}H_{48}O_2$	26, 27, Dinorergost-5-en-3-ol benzate
			$C_{38}H_{70}O_2$	Cholest-5en-3-ol (3-beta) -propanoate
	$C_{10}H_{20}O$	3-Cyclohexene-1-methanol, alpha, 4-dimethyl-alpha	$C_{27}H_{46}O$	Cholest-5-en-3-ol (3-beta)
			$C_{27}H_{48}O$	Cholest-3-ol (3-beta-5-alpha)
			$C_{31}H_{52}O_2$	Cholest-5-en-3ol (3beta)
			$C_{29}H_{48}O$	Stigmasta-5, 22-dien-3-ol
Ester	$C_{15}H_{14}O_2$	Benzoic acid, 2-phenyl-ethyl ester	$C_{24}H_{38}O_4$	1, 2, Benzendicarboxylic acid diisooctyl ester
	$C_{14}H_{18}O_4$	1, 2-Benzenedicarboxylic acid, dipropyl ester	$C_{19}H_{38}O_2$	Hexadecanoic acid 1-methylethyl ester
	$C_{20}H_{30}O_4$	1, 2-Benzenedicarboxylic acid, butyl-2-ethylhexyl ester	$C_{24}H_{38}O_4$	1, 2-Benzenedicarboxylic acid, diisooctyl ester
	$C_8H_{14}O_4$	Butanedioic acid, 2, 2 dimethyl ester		
	$C_{24}H_{38}O_4$	1, 2-Benzedicarboxylic acid diisooctyl ester		
Acid	$C_{15}H_{30}O_2$	Tetradecanoic acid	$C_6H_{22}O_4$	1, 2-Benzenedicarboxylic acid, butyl-2-methylpropy
	$C_{13}H_{26}O_2$	Tridecanoic acid		
	$C_{18}H_{36}O_2$	Octadecanoic acid		
	$C_{30}H_{28}O_2$	1-Phenanthiene carboxylic acid 1, 2, 3, 4, 4A, 9, 10, 10A octalty	$C_{16}H_{32}O_2$	Hexadecanoic acid
			$C_6H_6O_3S$	Benzenensulfonic acid
			$C_8H_8O_2$	Benzenacetic acid

Table 4 (Continued)

	$C_8H_{10}O_4$	Benzeneacetic acid, alpha 3, 4 trans (trimethyl silyl)	$C_{12}H_{24}O_2$	Dodecanoic acid
			$C_{13}H_{26}O_2$	Tridecanoic acid
			$C_{18}H_{34}O_2$	9-Octadecanoic acid
			$C_{14}H_{28}O_2$	Tetradecanoic acid
			$C_{10}H_{22}O_5$	1, 2-Benzenedicarboxylic acid, 2-butoxyethylbutyl
			$C_{16}H_{22}O_4$	1, 2-Benzenedicarboxylic acid, butyl, 2-methylphenyl
			$C_{15}H_{30}O_2$	Pentadecanoic acid
			$C_{17}H_{32}O_2$	Heptadecanoic acid
			$C_{17}H_{34}O_2$	Heptadecanoic acid
Ketone	$C_{10}H_{16}O$	Bicyclo 4, 1, 0 heptan-3-one 4, 7, 7, trimethyl1R-(1-alpha)	$C_5H_7NO_2$	1H-Pyole, 2, 5-dione 3-ethy 1-4-methyl
			$C_{10}H_{12}O$	Ethanone, 1, (4-ethyl-phenyl)
	$C_{10}H_{12}O$	Ethanone, 1-(4-ethyl-phenyl)	$C_{19}H_{30}O$	1-Octanone, 1-(2-octyl-cyclo propyl)
	$C_{11}H_{14}O_2$	Ethanone 1-4-(1-hydro-1-methylethyl) phenyl	$C_{16}H_{28}O_2$	Oxacycloheptadec-8-en-2-one
	$C_{14}H_{18}O$	1(2H)-Naphthalenone, 2-(1, 1-dimethylethyl)-3, 4-di-hydro	$C_{27}H_{42}O$	Cholesta-3, 5-dien-7-one
	C_5H_5NOS	2(1H)-Pyridinethione, 3, hydroxy		
	$C_{11}H_8O_{4/T}$	1, 4-Naphthalenedione, 8-hydroxy-2-methoxy		
	$C_{20}H_{26}O_2$	Podocarpa-1, 8, 11, 13-tetra-en-3-one, 12-hydroxy-13-iso-pro-		
	$C_{22}H_{22}O$	Nathaone, 1, 4-dimethyl-7-(1-methylethyl)2-azalenyl		
	$C_{13}H_8O_5$	SH-Xanthen-9-One, 1, 3, 8-tri-hydroxy		
	$C_{17}H_{11}N_3O$	Naphtho, 2, 3, D, 1, 2, 3-triazin-4(3H)-one-3-phenyl		
	$C_{19}H_{18}O_6$	4H-1-Benzopyran-4-one, 3(3, 4-dimethylphenyl)		
Aldehyde	C_7H_6O	Benzaldehyde	$C_5H_{10}O$	Pivalaldehyde
	$C_9H_{10}O$	Benzaldehyde, ethyl	$C_{17}H_{34}O$	Hexadecanal, 2-methyl
	$C_{10}H_{16}O$	1-Cyclohexene-1-carbo-xaldehyde, 2, 6, 6-tri-methyl	$C_{18}H_{32}O$	9, 17-Octadecadienal

Table 4 (Continued)

	$C_{20}H_{40}O_2$	2-Cyclo pentanene-1-acetaldehyde, 2-formyl-alpha, 3-dimethyl		
	$C_{18}H_{36}O$	9-Octadecanal		
Phenol	C_7H_8O	Phenol, 4-methyl	C_7H_8O	Phenol, 4-methyl
	$C_9H_{12}O$	Phenol, 3, 4, 5-trimethyl	C_6H_6O	Phenol
	$C_{11}H_{16}O_2$	Phenol, (1, 1-dimethyl-ethyl)-4methoxy	$C_9H_{12}O$	Phenol, 4-(1-methyl-ethyl)
	$C_{15}H_{24}O$	Phenyl, 2, 6 bis (1, 1-di-methylethyl)-4-methyl	$C_{12}H_{15}NO_2$	Phenol, 3-(1-methyl-ethyl), methylcarbomate
	$C_9H_{12}O$	Phenol, 4, 11-methylethyl		
	$C_{14}H_{12}$	Phenol, 4-(2-phenylethyl)		
	$C_{16}H_{10}N_2O$	Phenol, 2-(2-ouinoxalinyl)		
Ether	$C_{12}H_{30}OSi_4$	Disiloxane, hexaethyl		
Nitrogen containing	C_5NCl_5	Pyridine, pentachloro	$C_9H_{17}NO$	1-Azethridienecarboal dehyde, 2, 2, 4, 4, -tetra-methyl
	$C_9H_{10}N_2S$	2-Benzothiazolamine		
	C_5HNF_4	Pyridine, 2, 3, 5, 6-tetrafluoro-	$C_5H_6N_2$	Pyrimidine-5-methyl
			$C_{10}H_9N$	2-Naphthaleneamine
	$C_{10}H_{11}N_3S$	Delta 2-1, 3, 4-oxadiazo-lin-5-one, 2-iso-butyl-4-(p-nitro)	$C_{10}H_9N$	Isoquidoline, 1-methyl
			C_9H_9N	4-Quinoline, 4-methyl
	$C_{12}H_{13}N_3O_4$	Delta 2-1, 3, 4-oxadia-zolin-5-one, 2-iso-butyl -4-nitro	$C_{18}H_{27}NO$	2-Naphthalenetran-amine, N-(1-methyl-ethyl)-beta
	$C_{16}H_{13}N$	2-Naphthalenamine, N-phenyl		
	$C_{16}H_{12}NCl$	Cyclopropane carboni-tile-1- (chlorophenyl)-2-phenyl		
	$C_{16}H_{12}N_2O$	Pyridazine, 3, 6-diphenyl-1-oxide		
	$C_{18}H_{13}N$	9H-carbozole, 9-phenyl		
	$C_{12}H_{10}N_3F$	1H-Pyrine-6-amine, (2-fluorophenyl) methyl		
Aromatic compounds	C_9H_{12}	Benzene, 1-ethyl-3-methyl		
	$C_{10}H_{14}$	Benzene, methyl (1-methylethyl)		
	$C_{10}H_{14}$	Benzene, (1, 1-dimethylethyl) 4-ethyl		
	$C_{14}H_{22}$	Benzene, 1-ethyl, 3, 5-diiso-		

Table 4 (Continued)

		propyl		
	$C_{14}H_{14}$	Benzene, 1-1'-ethlidene bis-		
	$C_8H_{10}O$	Benzene, ethylphenoxy		
Polyaro-	$C_{10}H_8$	Naphthalene	$C_{12}H_{14}$	Naphthalene, 1, 5, -
matic	$C_{12}H_{16}$	Naphthalene, 1, 2, 3, 4-tetra-		dimethyl
		hydro 1, 5-dimethyl		
	$C_{11}H_{10}$	Naphthalene 2-methyl		
	$C_{14}H_{10}$	9H-Fluorene, 9-methylene		
	$C_{16}H_{10}$	Fluoranthene		
	$C_{17}H_{14}$	Naphthalene, 2-(phenyl-		
		methyl)		
Hydrocar-	$C_8H_{16}O_2$	3, 10-Dioxatricyclo, 4, 3, 1, -	$C_{21}H_{44}$	Heptadecane, 2, 6, 10,
bon com-		0, 2, 4-dec-7-ene		15-tetramethyl
pounds	$C_{10}H_{16}$	1, 5-Cyclooctadiene, 1, 5-di-		
		methyl		
	C_9H_{12}	Cyclohexane, 1, 2, 4-tri-meth-	$C_{15}H_{24}$	1, 4-Methanoazulene
		ylene		decahydro-4, 8, 8-
	$C_{10}H_{20}$	Cyclohexane, (1, 1-dimethyl-		trimethyl-9-M
		ethyl)	$C_{20}H_{40}$	5-Eicosene
	$C_{20}H_{20}$	2, 4-Diheptane, 1-phenyl-5-	$C_{16}H_{32}$	Cyclohexadecane
		(phenylmethylene)	$C_{21}H_{44}$	Heptadecane, 2, 6, 10.
	$C_{15}H_{24}$	1, 2, 4-Methenoazolene deca-		15 tetramethyl
		hydro-1, 5, 5, 8, A-tetramethyl	$C_{18}H_{38}$	Octadecane
	$C_{13}H_{16}$	Benzene, 1-methyl-3-(1-methyl	$C_{20}H_{38}$	9-Eicosyne
		ethylidene) cyclopropyl	$C_{18}H_{36}$	1-Octadecane
	$C_{15}H_{26}$	1*H*-3A, 7-methanoazulene	$C_{22}H_{46}$	Docosane
		octahydro-1, 4, 9, 9-tetrame-	$C_{21}H_{44}$	Heptadecene, 2, 6, 10,
		thyl		15-tetramethyl
	$C_{15}H_{32}$	Tetradecene, 3-methyl	$C_{35}H_{72}$	Pentatriacontane
	$C_{12}H_{20}$	1, 5-Cyclododecadiene	$C_{27}H_{44}$	Cholesta-3, 5-diene
	$C_{12}H_{18}$	1, 4, 8-Dodecatriene		
	$C_{13}H_{28}$	Undecane, 3, 8-dimethyl		
	$C_{15}H_{24}$	Tricyclo, 5, 4, 0, 0, 2, 8-unde-		
		9-ene, 2, 6, 6, 9-tetramethyl		

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