

*Original Research*

# Volatile and Semi-Volatile Organic Compounds in the Lower Yangtze River and Surface Waters of Three Chinese Provinces

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## Abstract

Water samples were collected from the drinking water source of 21 urban areas from the lower Yangtze River at Jiangsu province and various surface drinking water sources of Jiangsu, Zhejiang, and Shandong provinces of China. They were tested for 25 VOCs and 38 SVOCs using purge and trap (P&T) and gas chromatography – mass spectrometry (GC-MS). The results show there were 19 VOCs and 10 SVOCs detected several times in at least one drinking water source. One hundred and twenty-six samples from 21 sampling sites were found to have organic compound pollutants in the range of less than MDL to 27.79 µg/L, including volatile chlorinated hydrocarbons, BTEX, chlorinated benzenes, phenols, nitrobenzene, phthalate esters, pesticides, et al. – in total 21 types of organic compounds considered to be priority water pollutants by the Chinese Department of Water Resources. However, the concentrations of VOCs and SVOCs in samples from the lower Yangtze River were markedly different from those in surface drinking water sources in Jiangsu, Zhejiang, and Shandong provinces. PAEs were detected in all water samples, but PCP and Rogor were only detected in samples from the lower Yangtze River. It should be noted that the majority of water samples with detected atrazine were from Jiangsu and Shandong provinces. The main SVOCs detected in the Yangtze River included PCP, Rogor, nitrobenzene, and PAEs. More pollutants were detected in the surface waters of Jiangsu than those of Zhejiang and Shandong. Among the surface water sources in Zhejiang, there were more species of VOCs and SVOCs in the Shanhusa Reservoir than the other reservoirs, which may have resulted from pollutants in Qiantang River water. Though the types and levels of water pollutants varied from one region to another in Jiangsu, Zhejiang, and Shandong provinces, our report added new evidence that the Yangtze River and other urban surface water sources have been universally polluted, and we recommend that all potential sources should be traced and mediated. In addition, because these persistent pollutants may be a health risk if transferred to drinking water, drinking water quality must be controlled specifically for certain VOC's and installation of a monitoring program/quality control for drinking water resources is needed.

**Keywords:** surface drinking water sources, volatile organic compounds, priority water pollutants, monitoring, Yangtze River

## Introduction

In recent years, Jiangsu, Zhejiang and Shandong provinces, situated in eastern China with 228,879,932 population, have grown and developed. Central to the economic and social development of these provinces are the Yangtze and Huai river systems, the Qiantangjiang and Oujiang River systems, and the Yellow River system, which respectively cover Jiangsu, Zhejiang, and Shandong provinces. However, economic growth has also introduced diverse water pollutants, including heavy metals, volatile organic compounds (VOCs), and semi-volatile organic compounds (SVOCs). These pollutants may lead to genotoxicity of surface drinking water sources, which can be assessed using the Ames test [1, 2].

But while many studies have been conducted in China over the past decade to assess the potential ecological and human health effects (especially carcinogenesis) by genotoxicity testing of concentrated water samples [3, 4], less of a focus has been placed on comprehensive monitoring and assessment of the actual occurrences and levels of aquatic pollutants. VOCs and SVOCs are used as pesticides, herbicides, fumigants, or solvents for lipid-soluble chemicals [5]. Some VOCs also can be produced biologically by marine algae, phytoplankton, and forest soil [6]. Although VOCs often occur in trace concentrations in surface drinking water sources, they can pose great human health risks because even very low concentrations are toxic in the human body. In addition, although this is a subject of some controversy, VOCs and SVOCs may function as carcinogens, mutagens, and endocrine disruptors in humans [7, 8].

Historically, much effort has been made to improve the quality of drinking water and to offer safe drinking water in mainland China. The Ministry of Health of China issued the Hygienic Criteria for Drinking Water in 1976, thus issuing

only 23 items to be met for drinking water safety. With the development of the economy comes an increase of pollutants in water and additional requirements for water safety: the number of items required to be routinely monitored was increased to 106 items in 2006. In recent years, due to the rapid development of chemical industries and the resultant water pollution, especially some VOCs and SVOCs appeared in drinking water sources. In particular, limited data are available for the occurrences of VOCs and SVOCs in surface water sources in economically developed areas. This hinders the development of environmental regulation policies for water and the establishment of maximum allowable levels of VOCs and SVOCs in surface and drinking water.

We report here on the occurrence and characteristics of VOCs and SVOCs in surface water and provide an overview of VOC and SVOC levels in the Yangtze River (we refer to Yangtze River Jiangsu Segment in the paper) and surface water sources in Jiangsu, Zhejiang, and Shandong provinces. This report might be beneficial for ascertaining potential causes of water pollution and allowing the development of practical water regulation policies through comparing VOC and SVOC levels in the surface waters of urban, suburban, and rural areas in these provinces.

## Materials and Methods

### Sampling

The sampling locations were chosen from those sources serving as raw water sources for drinking water treatment plants in Jiangsu, Zhejiang, and Shandong, from which more than two hundred million people obtain their daily

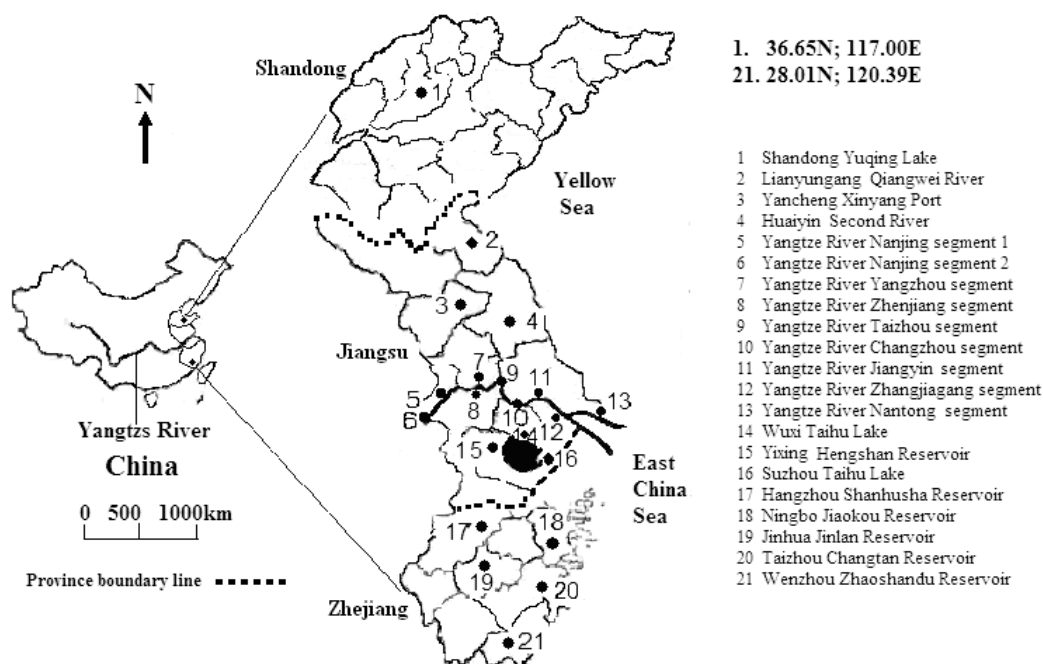


Fig. 1. Locations of Jiangsu, Zhejiang, and Shandong provinces in China and distribution of sampling sites along the lower Yangtze River at Jiangsu, and the surface waters in Jiangsu, Zhejiang and Shandong provinces.

water. A map of Jiangsu, Zhejiang, and Shandong provinces showing the sampling sites is given in Fig. 1.

Samples from each location were collected in triplicate and also had a travel blank control sample. The samples were immediately transferred to dark brown 1L amber glass bottles, which were filled completely to avoid any headspace. All samples were acidified with 1:1 HCl, stored at 4°C, and analyzed within 7 days of collection. All samples were collected at selected sites from April to May 2008.

### Choosing Compounds

A total of 25 VOCs and 38 SVOCs were selected from the "black list" of priority organic water pollutants jointly developed by China's Ministry of Environmental Protection.

### Analytical Protocol

After water samples were extracted with an OI Eclipse 4660 purge-and-trap sample concentrator (Owens Illinois, United States), the selected VOCs and SVOCs were determined by HP 6890/5973 GC-MS, i.e. an HP 5973 mass spectrometer (MS) interfaced with an HP 6890 gas chromatograph (GC) (Hewlett Packard, United States).

The analytical methodology followed the description given in Environmental Quality Standards for Surface Water of the P. R. China (GB3838-2002). Briefly, 25 ml water samples were taken for analysis and 5 µg of fluorobenzene, purchased from Supelco (Bellefonte, PA, United States), was added as an internal standard. Five µg of 4-bromofluorobenzene (4-BFB), available from Chem Service (West Chester, PA, United States) was added as a recovery rate indicator. The sample was purged with ultra-pure nitrogen (99.999%, v/v) at 25°C in the OI Eclipse 4660 for 10 min at a flow rate of 40 ml/min. The VOCs to be tested were trapped at room temperature in a multi-bed sorbent trap, which consisted of activated charcoal, silica and a TENAX mixture (Supelco, United States). The trap was then thermally desorbed at 180°C for 4 min at a blowback flow rate of 15 ml/min. The trap baked at 180°C for 10 min. The analytes were focused in a trap at 180°C prior to injection into an HP6890/5973 GC-MS system. Separation was performed on an HP-VOC capillary column (60 m×0.2 mm, 1.12 µm film) (Hewlett-Packard, United States). The GC oven was temperature programmed as follows: held at 35°C for 3 min and then increased linearly from 35 to 80°C at a rate of 15°C/min. The temperature was then raised from 80 to 140°C at 5°C/min, and maintained for 1 min. The temperature was finally increased from 140°C to 230°C at a rate of 20°C/min. The MS was operated in selected ion monitoring mode. The MS scan range was at 45-260 amu with a scan time of 0.16 s/scan, an ion source temperature of 230°C, and an interface transmission temperature of 280°C.

The amounts of the selected VOCs were calculated by determining the ratio between the compound's main peak area and the internal standard peak area as seen in a typical ion mass chromatogram. Quantifications in all experiments were based on the average relative response factor (RF) for all compounds. It should be noted that due to the lack of

separation of p-xylene from o-xylene, these two chemicals were pooled and reported as one value. The detection limits for each VOC and SVOC are shown in Table 1.

## Quality Control

### General Principles

Quality control of the analyses was performed according to the Detailed Requirements for Quality Control of Investigations and Laboratory Analysis of Organic Pollutants in Important Drinking Water Sources in China as developed by China's Ministry of Water Resources.

### Control of Potential Contamination

In order to control for all potential contamination during sampling, transportation, and detection, the following blank controls were set up: reagent blanks, instrument blanks, field blanks, and travel blanks.

### Determination of Method Detection Limit (MDL)

The MDL for each compound was determined according to the United States EPA approach [9]. Measurements were taken on 10 samples of the prepared solution and the concentrations of compounds of interest and reference chemicals were 0.4 µg/L and 0.0833 µg/L for VOCs and SVOCs, respectively. All analytical procedures were the same as for the sample analysis. Results were tabulated and the standard deviation of the data set was determined. The MDLs were calculated and should be between 10% and 100% of the concentrations of the compounds [9]. The MDLs of individual compounds are listed in Table 1.

### Assessment of Accuracy and Precision

Ten model samples were prepared with super-pure water. The target compounds were added at a concentration of 5 µg/L; internal standard and reference compounds for recovery were also added and analyzed by the same protocols. The range of the recovery rates was 92.6-113.6% and the relative standard deviation for each target compound was 0.9-9.9%.

### Data Presentation

All quantitative data are expressed as the mean±SD of samples detected.

## Results

### Occurrences and Concentrations of VOCs and SVOCs in Lower Yangtze River in Jiangsu Segment

The occurrences and concentrations of VOCs and SVOCs in the Yangtze River samples are summarized in Table 2. Of the 25 VOCs tested, 1, 4-dichlorobenzene and

Table 1. The list, and limit of detection of VOCs and SVOCs tested.

| Selected compounds         | Limit of detection (mg/L)                   | Selected compounds       | Limit of detection (mg/L) |
|----------------------------|---|--------------------------|---------------------------|
| 1,1-Dichloroethene         | <0.18                                       | 2,4,6-Trichlorophenol    | <0.036                    |
| trans-1,2-dichloroethylene | <0.15                                       | p-Dinitrobenzene         | <0.020                    |
| cis-1,2-dichloroethylene   | <0.16                                       | m-Dinitrobenzene         | <0.026                    |
| 1,2-Dichloroethane         | <0.06                                       | o-Dinitrobenzene         | <0.032                    |
| Trichloromethane           | <0.18                                       | 2,4-Dinitrotoluene       | <0.040                    |
| 1,1,1-trichloroethane      | <0.10                                       | 2,4-Dinitrochlorobenzene | <0.021                    |
| Carbon tetrachloride       | <0.10                                       | 2,4,6-Trinitrotoluene    | <0.041                    |
| Benzene                    | <0.12                                       | PCP                      | <0.063                    |
| Trichlorethylene           | <0.06                                       | Trichlorphon             | <0.084                    |
| 1-Bromine dichloromethane  | <0.12                                       | AEs                      | <0.45                     |
| Toluene                    | <0.10                                       | Benzo(a)pyrene           | <0.025                    |
| 4-Chloroethylene           | <0.08                                       | Aniline                  | <0.016                    |
| Dibromo-1-Chloromethane    | <0.07                                       | Dichlorvos               | <0.037                    |
| Chlorobenzene              | <0.06                                       | Demeton                  | <0.033                    |
| m-xylene                   | Chromatographic peak                        | Rogor                    | <0.071                    |
| p-xylene                   | overlapped, and pooled as one value (<0.10) | Atrazine                 | <0.016                    |
| o-xylene                   | <0.06                                       | Lindane                  | <0.023                    |
| 3-Bromomethane             | <0.10                                       | Chlorothalonil           | <0.032                    |
| Cumene                     | <0.05                                       | Methyl parathion         | <0.063                    |
| 1,4-Dichlorobenzene        | <0.06                                       | Malathion                | <0.064                    |
| 1,2-Dichlorobenzene        | <0.04                                       | Parathion                | <0.057                    |
| 1,2,3-Trichlorobenzene     | <0.07                                       | Heptachlor epoxide       | <0.012                    |
| 1,2,4-Trichlorobenzene     | <0.03                                       | DDT                      | <0.065                    |
| Hexachlorobutadiene        | <0.04                                       | 1-Chlorine biphenyl      | <0.02                     |
| Styrene                    | <0.06                                       | Dichloro-diphenyl        | <0.02                     |
| Nitrobenzene               | <0.052                                      | Trichlorobiphenyl        | <0.02                     |
| 2,4-Dichlorophenol         | <0.046                                      | 4-Chlorobiphenyl         | <0.02                     |
| p-Nitrochlorobenzene       | <0.047                                      | Pentachlorodiphenyl      | <0.02                     |
| o-Nitrochlorobenzene       | <0.047                                      | Hexachloro-biphenyl      | <0.02                     |
| 1,2,3,5-Chlorobenzene      | <0.041                                      | Heptachlorobiphenyl      | <0.02                     |
| 1,2,3,4-Chlorobenzene      | <0.044                                      | Octachlorobiphenyl       | <0.02                     |
| 1,2,4,5-Chlorobenzene      | <0.029                                      |                          |                           |

1, 2-dichlorobenzene were detected in all eight sampling sites along the Yangtze River, i.e. the rate of occurrence for these VOCs was 100%. The ranges of their concentrations were 0.07-0.35  $\mu\text{g/L}$  and 0.04-1.43  $\mu\text{g/L}$ , respectively. Dichloromethane, another VOC, was detected in water samples from seven sampling sites, from the Zhenjiang to the Nantong parts of the Yangtze River. Benzene (0.27-0.62

$\mu\text{g/L}$ ) and toluene (0.10-1.48  $\mu\text{g/L}$ ) were only detected in water samples from the Nanjing sampling site of the Yangtze River. Out of the 38 SVOCs of interest, nitrobenzene (0.06-0.13  $\mu\text{g/L}$ ), phthalate (2-ethylhexyl) ester (PAEs) (0.16-1.67  $\mu\text{g/L}$ ), and O,O-dimethyl methylcarbamoylmethyl phosphorodithioate (Rogor) (0.07-1.82  $\mu\text{g/L}$ ) were detected in water samples from eight sampling

Table 2. Concentrations of VOCs and SVOCs at different sampling sites along the Yangtze River (Jiangsu Segment) ( $\mu\text{g/L}$ ).

| Target compounds       | Nanjing1  | Nanjing2  | Zhenjiang | Changzhou | Taizhou   | Jiangyin  | Zhangjiagang | Nantong   |
|------------------------|-----------|-----------|-----------|-----------|-----------|-----------|--------------|-----------|
| Trichloromethane       | -         | -         | 0.20±0.02 | 0.42±0.05 | 0.65±0.05 | 0.49±0.04 | 0.77±0.05    | 1.09±0.06 |
| Carbon tetrachloride   | -         | -         | 0.12±0.03 | -         | -         | -         | -            | -         |
| Benzene                | 0.37±0.05 | 0.49±0.13 | -         | -         | -         | 0.33±0.05 | -            | -         |
| Trichlorethylene       | -         | -         | -         | -         | -         | -         | 0.17±0.07    | -         |
| Toluene                | 0.37±0.06 | 0.10±0.01 | 1.13±0.07 | -         | 1.10±0.39 | -         | -            | 0.21±0.02 |
| 4-chloroethylene       | -         | -         | -         | -         | -         | -         | 0.11±0.02    | -         |
| Chlorobenzene          | -         | -         | -         | -         | -         | 0.71±0.04 | -            | -         |
| m, p-xylene            | 0.71±0.06 | -         | 0.70±0.12 | -         | -         | -         | -            | 1.02-4.46 |
| o-xylene               | 0.11±0.03 | -         | 0.12±0.02 | -         | -         | -         | -            | 1.36±0.14 |
| 1,4-Dichlorobenzene    | 0.09±0.02 | 0.09±0.03 | 0.13±0.02 | 0.18±0.04 | 0.29±0.05 | 0.19±0.07 | 0.15±0.02    | 0.11±0.02 |
| 1,2-Dichlorobenzene    | 0.05±0.01 | 0.06±0.02 | 0.10±0.02 | 0.15±0.02 | 1.34±0.13 | 0.13-0.30 | 0.19±0.03    | 0.13±0.02 |
| 1,2,4-Trichlorobenzene | -         | -         | -         | -         | -         | -         | 0.04±0.01    | -         |
| Hexachlorobutadiene    | -         | -         | 0.05±0.01 | -         | -         | -         | -            | -         |
| Nitrobenzene           | 0.07±0.02 | 0.10±0.02 | 0.07±0.01 | 0.10±0.02 | 0.11±0.01 | 0.11±0.02 | 0.11±0.01    | 0.13±0.01 |
| 2,4-Dichlorophenol     | -         | -         | 0.11±0.02 | -         | -         | 0.17±0.03 | -            | 0.1±0.02  |
| p-Nitrochlorobenzene   | -         | -         | -         | -         | 0.06±0.02 | 0.06±0.02 | -            | -         |
| 2,4,6-Trichlorophenol  | -         | -         | -         | -         | -         | 0.05±0.01 | -            | -         |
| 2,4,6-Trinitrotoluene  | -         | -         | -         | -         | -         | -         | -            | 0.07±0.02 |
| PCP                    | 0.09±0.02 | 0.18±0.04 | 0.12±0.02 | -         | 0.09±0.01 | 0.08±0.01 | 0.16±0.04    | 0.15±0.05 |
| PAEs                   | 0.23±0.05 | 0.35±0.07 | 0.26±0.06 | 0.33±0.03 | 0.18±0.02 | 0.25±0.04 | 0.31±0.03    | 1.65±0.12 |
| Aniline                | -         | -         | -         | -         | -         | 0.10±0.02 | -            | 0.04±0.02 |
| Demeton                | -         | -         | -         | -         | -         | 0.05±0.02 | -            | 0.04±0.01 |
| Rogor                  | 0.62±0.03 | 1.14±0.12 | 0.40-0.46 | 0.74±0.02 | 0.64±0.03 | 1.07±0.06 | 1.24±0.23    | 1.67±0.12 |
| Atrazine               | -         | -         | -         | -         | -         | -         | 0.14±0.04    | -         |

Values are expressed as mean± SD of 6 samples in each station, ‘-’ – non-detectable

sites, and pentachlorophenol (PCP) (0.07-0.22  $\mu\text{g/L}$ ) was detected in water samples from seven sampling sites along the Yangtze River. Demeton (0.03-0.05  $\mu\text{g/L}$ ) was detected only in water samples from the Jiangyin sampling site along the Yangtze River.

#### Occurrences and Concentrations of VOCs and SVOCs in Surface Water in Jiangsu Province

VOC and SVOC levels in lake, reservoir, and river samples from Jiangsu province are summarized in Table 3. Of the VOCs, benzene was detected only in water samples from Wuxi Meiliang Bay, at a range of 0.22-0.34  $\mu\text{g/L}$ , while 1, 2-dichloroethane (18.92-27.79  $\mu\text{g/L}$ ) was detected in water samples from the Yixing Hengshan Reservoir. Trichlorethylene (0.06-0.28  $\mu\text{g/L}$ ) and Chloroethylene (0.08-0.11  $\mu\text{g/L}$ ) were detected only in water samples from Eastern Taihu Lake at Suzhou. Regarding SVOCs, PAEs

(0.17-0.45  $\mu\text{g/L}$ ) were detected in all water samples and atrazine (0.02-0.42  $\mu\text{g/L}$ ) was detected in six sampling sites from seven reservoirs and rivers in Jiangsu. Rogor (0.08-1.00  $\mu\text{g/L}$ ) was detected only in surface water samples from Wuxi Taihu Meiliang Bay and Yancheng Xinyang Port. PCP was detected only in water samples from the Yangzhou Liaojiagou River.

#### Distributions of VOCs and SVOCs in Reservoirs in Zhejiang Province

A significantly larger number of VOCs were detected in the Hangzhou Shanhusha Reservoir than in others reservoirs in Zhejiang. Of the VOCs tested, 1, 1-dichloroethylene, chloroform, carbon tetrachloride, trichloroethene, toluene, dibromo-1-chloromethane, 1, 2-dichlorobenzene, 1,2,3-trichlorobenzene, and 1,2,4-trichlorobenzene were detected in the Hangzhou Shanhusha Reservoir. Other

VOCs, trichloromethane, and styrene were detected in water samples from the Taizhou Changtan Reservoir. The distribution of the concentrations of PAEs in the main reservoirs and the detailed differential distributions of the levels of detected VOCs and SVOCs in all water samples from reservoirs in Zhejiang are shown in Table 3.

#### Distributions of VOCs and SVOCs in Reservoirs in Shandong Yuqing Lake

Carbon tetrachloride, benzene, toluene, m, p-xylene, styrene, PAEs (0.32-0.41 $\mu\text{g/L}$ ) and atrazine (0.03-0.05 $\mu\text{g/L}$ ) were detected in water samples from Shandong Yuqing Lake. The detailed differential distribution of the levels of detected VOCs and SVOCs in all water samples from Yuqing Lake in Shandong is shown in Table 3.

### Discussion

Our study detected low-level 19 VOCs and 10 SVOCs in surface drinking water sources, indicating that the Yangtze River and other surface water sources have been polluted as a consequence of the rapid development of the economy [10, 11]. However, differential distribution of VOCs was shown along the Yangtze River and surface water sources of Jiangsu, Zhejiang, and Shandong provinces. Specifically, higher levels of 1, 2-dichloroethane were detected in the Yixing Hengshan Reservoir, which shows there are point-pollution sources, but more BTEX (benzene, toluene, ethylbenzene, xylene) was detected in the Yangtze River Nanjing segment, Wuxi Taihu Meiliang Bay, and Shandong Yuqing Lake.

One kind of SVOC, PAEs, was detected in all samples collected from the Yangtze River and in the surface water sources of Jiangsu, Zhejiang and Shandong. Because PAEs are released from synthetic plastics, this can perhaps be sourced to the production and application of plastics products over the last three decades in China [12]. The detected nitrobenzene, 1, 4-dichlorobenzene and 1, 2-dichlorobenzene in the Yangtze River may also result from pollution by the chemical industry in the Yangtze River Delta Region. Even though PCP was banned a few decades ago, the organochlorine pesticide was still detected in all samples from the Yangtze River and the vicinity of the Liaojiagou River, but could not be detected in surface waters of Jiangsu, Zhejiang, and Shandong. PCP was used to kill *Oncomelania hupensis*, a small freshwater snail and an important vector of human schistosomiasis, along both sides of the Yangtze River from the 1960s to the late 1990s [13, 14]. The application of PCP has polluted marshland soils and river sediments. This result is consistent with other research reports [15, 16]. Due to the persistence of PCP and its continued release from soil to water [17], and particularly because this chemical is not eliminated by routine drinking water treatment in China, this chemical has caused widespread pollution and has threatened drinking water safety and human health [18].

Rogor was the only kind of SVOC detected in all samples from the Yangtze River. However, because it is undetectable in surface water in Jiangsu, it seems that pollution from pesticide residue can only be attributed to the upstream Yangtze River. Another herbicide, atrazine, was generally detected in surface water samples from Jiangsu and Shandong, but could not be detected in surface waters of Zhejiang, which may be caused by heavy reliance on this agricultural herbicide in Jiangsu and Shandong Provinces. In maps of Zhejiang Province, it can be seen that the Hangzhou Shanhusha Reservoir is interconnected with the Qiantang River. Thus, pollutant levels in the Hangzhou Shanhusha Reservoir could be representative of levels of the corresponding pollutants in the Qiantang River.

Taken together with studies in other regions [19-22], it can be concluded that VOCs and SVOCs have become ubiquitous water pollutants, and should be considered a global problem. Therefore, detected VOCs and SVOCs in drinking water sources and concentrations in the treated drinking water should be determined to assess the potential adverse effects of these pollutants on human health [23, 24]. In addition, the point and non-point source VOC pollution in the surface waters of Jiangsu, Zhejiang, and Shandong should be traced and controlled [25-27].

In summary, 19 out of 25 target VOCs and 10 out of 38 target SVOCs were detected in the 21 important surface water source sites for urban areas along the Yangtze River and surface waters in Jiangsu, Zhejiang, and Shandong provinces. PAEs and other SVOCs have become ubiquitous in the surface waters and Rogor was only detectable in the Yangtze River, while atrazine was only detectable in the surface water of Jiangsu and Shandong Provinces. Especially, though PCP has been banned for use since 1990s, it is still visible in the present surface water sources, which means that the sins of the past are still found in the present water quality. Thus, all potential sources should be traced and mediated in addition, because these persistent pollutants may be a health risk if transferred to drinking water; drinking water quality must be controlled specifically for certain VOCs, and design and installation of a monitoring program/quality control for drinking water resources is needed. From the point of ecology, this screening study should be extended to sediments and soils to clarify the transfer and potential bioaccumulation of these chemicals.

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Table 3. The concentration levels of VOCs and SVOCs in different sampling sites from surface water sources in Jiangsu and Zhejiang ( $\mu\text{g/L}$ ).

| Selected compounds      | Jiangsu   |            |           |           |           |            | Zhejiang    |           |           |           |           |           | Shandong  |  |
|-------------------------|-----------|------------|-----------|-----------|-----------|------------|-------------|-----------|-----------|-----------|-----------|-----------|-----------|--|
|                         | Wuxi      | Yixing     | Suzhou    | Huaian    | Yiancheng | Liaojiagou | Lianyungang | Hangzhou  | Ningbo    | Wenzhou   | Jinhua    | Taizhou   | Jinnan    |  |
| 1,2-Dichloroethane      | -         | 25.79±2.42 | -         | -         | -         | -          | -           | 0.07±0.02 | -         | -         | -         | -         | -         |  |
| 1,1-Dichloroethane      | -         | -          | -         | -         | -         | -          | -           | 3.09±0.95 | -         | -         | -         | -         | -         |  |
| Trichloromethane        | 0.49±0.07 | 0.21±0.03  | -         | -         | 0.49±0.04 | -          | 0.52±0.05   | 0.68±0.09 | 0.11±0.02 | 0.21±0.07 | 1.53±0.42 | -         | -         |  |
| Trichloroethylene       | -         | -          | 0.22±0.06 | -         | -         | -          | -           | 1.72±0.25 | -         | -         | -         | -         | -         |  |
| 4-Chloroethylene        | -         | -          | 0.10±0.02 | -         | -         | -          | -           | -         | -         | -         | -         | -         | -         |  |
| Hexachlorobutadiene     | -         | -          | -         | -         | -         | -          | -           | 0.05±0.01 | -         | -         | -         | -         | -         |  |
| Dibromo-1 Chloromethane | -         | -          | -         | -         | -         | -          | -           | 0.23±0.05 | -         | -         | -         | -         | -         |  |
| Carbon tetrachloride    | -         | -          | -         | -         | -         | -          | -           | 0.13±0.03 | 0.21±0.04 | -         | -         | 0.11±0.02 | -         |  |
| Benzene                 | 0.32±0.04 | -          | -         | -         | -         | -          | -           | -         | -         | -         | -         | 0.18±0.03 | -         |  |
| Toluene                 | -         | -          | -         | -         | -         | -          | -           | 0.21±0.03 | 0.22±0.02 | -         | 0.28±0.04 | 1.94±0.15 | -         |  |
| m, p-xylene             | -         | -          | -         | -         | -         | -          | -           | -         | -         | -         | 0.11±0.02 | 0.27±0.04 | -         |  |
| Chlorobenzene           | 0.81±0.04 | -          | -         | -         | -         | -          | 0.70±0.01   | -         | -         | -         | -         | -         | -         |  |
| 1,4-Dichlorobenzene     | 0.23±0.05 | -          | 0.08±0.02 | -         | -         | -          | -           | -         | -         | -         | -         | -         | -         |  |
| 1,2-Dichlorobenzene     | 0.23±0.06 | 0.05±0.02  | 0.08±0.03 | 0.06±0.02 | -         | -          | 0.05±0.01   | 0.08±0.02 | -         | -         | -         | -         | -         |  |
| Nitrobenzene            | 0.09±0.03 | -          | -         | 0.06±0.01 | 0.07±0.02 | 0.07±0.01  | -           | 0.10±0.02 | -         | -         | -         | -         | -         |  |
| p-Nitrochlorobenzene    | -         | -          | -         | -         | -         | 0.07±0.02  | -           | 0.38±0.04 | -         | -         | -         | -         | -         |  |
| 1,2,3-Trichlorobenzene  | -         | -          | -         | -         | -         | -          | -           | 0.16±0.03 | -         | -         | -         | -         | -         |  |
| 1,2,4-Trichlorobenzene  | -         | -          | -         | -         | -         | -          | -           | 0.67±0.12 | -         | -         | 0.04±0.02 | -         | -         |  |
| 2,4,6-Trinitrotoluene   | -         | -          | -         | -         | -         | -          | -           | -         | 0.05±0.02 | 0.07±0.04 | -         | -         | -         |  |
| Aniline                 | 0.12±0.04 | -          | -         | -         | -         | -          | -           | -         | -         | -         | -         | -         | -         |  |
| Styrene                 | -         | -          | -         | -         | -         | -          | -           | 0.10±0.02 | 0.10±0.03 | -         | 0.29±0.07 | 1.46±0.36 | 0.63±0.07 |  |
| 2,4-Dichlorophenol      | 0.11±0.02 | -          | -         | -         | -         | -          | -           | -         | -         | -         | -         | -         | -         |  |
| PCP                     | -         | -          | -         | -         | -         | 1.09±0.05  | -           | -         | -         | -         | -         | -         | -         |  |
| PAEs                    | 0.28±0.04 | 0.23±0.02  | 0.28±0.04 | 0.41±0.05 | 0.21±0.03 | 0.30±0.04  | 0.28±0.04   | 0.32±0.06 | 0.52±0.04 | 0.62±0.05 | 0.33±0.05 | 0.37±0.04 | -         |  |
| Rogor                   | 0.88±0.12 | -          | -         | -         | 0.15±0.04 | -          | -           | -         | -         | -         | -         | -         | -         |  |
| Atrazine                | 0.10±0.02 | -          | 0.39±0.03 | 0.06±0.01 | 0.20±0.02 | 0.03±0.01  | 0.06±0.02   | -         | -         | -         | -         | -         | 0.04±0.01 |  |

Values are expressed as mean± SD of 6 samples in each station, '-', - non-detectable

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