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# Changes of surface water pollution of Suzhou region: a case study in Taicang County, China

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**Abstract**—Environmental pollution is a by-product of industrialization when economy of a region is developing. China also suffers from such a problem, especially in the southern part like Suzhou region in Jiangsu Province. In this paper, data covering situations of surface water pollution and social and economic development showed that the surface water pollution in Taicang County, a typical economic zone of Suzhou region, is significantly correlated to the economic growth of this region.

**Keywords**: environmental pollution; economy development; surface water; Taicang County.

## 1 Introduction

It is well-known that environmental pollution is one of the products of industrialization. What is the relationship between economy development and environmental pollution? Will the environmental pollution control measures and environmental quality be improved when economy of a given region develops? These questions are strongly concerned by many Chinese environmental scientists in recent years.

Beginning in 1970s, the industrial economy of Suzhou region develops so fast as to make Suzhou as a very important base of light industry of southern part of Jiangsu Province. As a result of above thriving and prosperous economy, the severe environmental pollution results in most of surface water in Suzhou region not being suitable for drinking water supply for urban and rural areas, and poses them have to seek more possibility for exploiting groundwater resources.

In order to study the relationship between economy development and environmental pollution, Taicang County, a typical zone of Suzhou region, was selected as a research object for observing. We collected a series of surface water determined data in terms of water quality from 1983 to 1993, and the survey materials of industrial pollution sources in 1985 and 1991, respectively.

Taicang County, with an area of 815 square kilometers and including 24 rural administrative villages (Fig.1), is located at the southern side of Yangtze River, and near the City of Shanghai. There are many rivers, including rivers Liuhetang, Yantietang, Chenghe, Qixutang, Qianjing, and Yanglintang, crossing this county. Fig.2 shows the geographical distribution of surface water system in this county.

The industry of Taicang County develops from 1970s, and so far has included many sorts of departments such as manufacture, fibre, leather, plating, chemical, electronics, and metallurgy.

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In 1993, the gross industrial product of Taicang County was 16.2 billion RMB Yuan, 25 times of 1983's. Fig.3 shows the economy development of Taicang County during the period from 1983 to 1993 with three growth steps, low-speed growth from 1983 to 1987, no growth from 1988 to 1990, and high-speed growth from 1991 to 1993. As a result of economy development, environmental problems occur as following aspects:

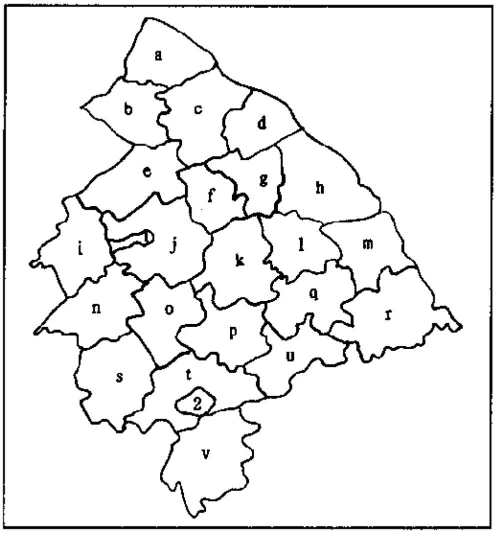


Fig.1 Map of administrative regionalization of Taicang County a: Luhe; b: Wangxiu; c: Pujing; d: Shisi; e: Guizhuang; f: Laozha; g: Jiuqu; h: Fuqiao; i: Zhitang; j: Shaxi; k: Yuewang; l: Pailou; m: Qianjing; n: Shuangfeng; o: Xinmao; p: Banqiao; q: Xintang; r: Liuhezhen; s: Xinhu; t: Loudong; u: Ludu; v: Nanjiaoju; 1: Shaxizhenju; 2: Chengxiangzhen

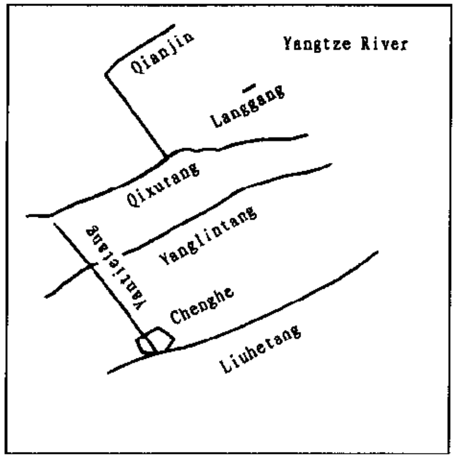


Fig.2 Map of surface water system of Taicang County

·The area of arable land decreased from 45322 $hm^2$ in 1983 to 37375 $hm^2$ in 1993. This process is negatively and significantly correlated to the growth of industrial economy development ($r = -0.9745$, $p = 0.01$).

·The waste water discharge increased. In 1993, the industrial waste water was discharged by 55 million tons in which there was only 42% of waste water treated and 50% of treated waste water acceptable for direct discharge. Consequently, a lot of pollutants in waste water were discharged into surface water to deteriorate water quality. Therefore, most of surface water of this county belonged to No.4 water category in accordance with the national standard guideline of water quality (GB 3838-88). The dominant pollution indices were dissolved oxygen (DO), chemical oxygen demand (COD), and ammonium-nitrogen ($NH_4$-N).

·There is a special characteristic of environmental pollution which is the growing pollution from rural industry. 85 percent of gross industrial product (GIP) came from this county's rural industry which developed widely within Taicang County anywhere, and was quiet difficult to manage waste water treatment and to effectively control waste water discharge to surface water system.

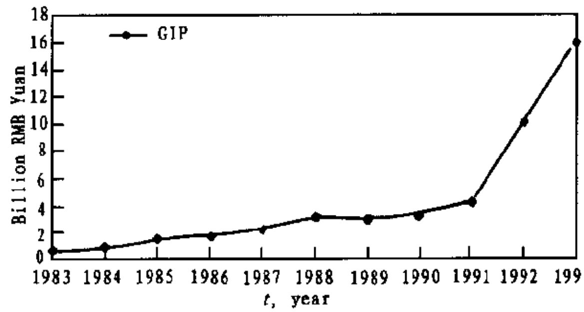


Fig. 3 The gross industrial products (GIP) of Taicang County during the period from 1983 to 1993

## 2 Materials and methods

The 11-year continuously observed and measured environmental data of surface water and statistical survey materials related to economy development from 1983 to 1993 were collected to be applied for integrated assessment and correlation analysis in order to study the relationship between economy development and environmental pollution with application of a computer software of STATGRAPHICS (version 3.0).

pH, electrical conductivity (EC), DO, COD, chromium with a valence of six ($Cr^{6+}$), Cu, $NH_4$-N, Volatile phenol (VP), and oils were selected as pollution indices for assessment of surface water quality in accordance with the national standard guideline of water quality for No. 3 water category (Table 1).

**Table 1 The national standard guideline of water quality for No. 3 water category (GB-3838-88)**

| Indices | Concentration, mg/L |
|---|---|
| Dissolved oxygen (DO) | 5 |
| Chemical oxygen demand (COD) | 6 |
| Chromium with a valence of six ($Cr^{6+}$) | 0.05 |
| Copper (Cu) | 0.01 |
| Ammonium-nitrogen ($NH_4$-N) | 0.5 |
| Volatile phenol (VP) | 0.005 |
| Cyanide (CYN) | 0.005 |
| Oils | 0.05 |

The mathematical equation was applied in this assessment as follows:

$$P(s) = \frac{1}{n}\sum_{i=1}^{n} P(i), \quad P(i) = Ci/Si,$$

where $P(s)$ is the value presenting integrated assessment of surface water quality; $P(i)$ is the individual assessment value by a given pollutant; $Ci$ is the observed concentration of a given pollutant; $Si$ is the standard concentration of a given pollutant for assessment; $n$ is the number of pollutants involved in assessment.

The result of water quality assessment of rivers in Taicang County is classified by the classification system presented in Table 2.

**Table 2 Classification of surface water quality assessment of Taicang County**

| $P(s)$ | Classification | Description |
|---|---|---|
| $<0.7$ | Clean | Indices are not detected or detected within the standard guideline for assessment |
| 0.7—2.5 | Slight pollution | Concentrations of several pollution indices excess the standard guideline for assessment |
| $>2.5$ | Severe pollution | Concentrations of most of pollution indices excess the standard guideline for assessment by many times |

# 3 Results and discussions

## 3.1 Change pattern of surface water's environmental quality

Fig.4 shows that seven rivers in Taicang County entered pollution stage from 1986 on, reached the first pollution peak in 1987, later kept stable, and finally in 1990s, had a trend to be polluted severely. There is a statistically significant correlation between $P(s)$ of surface water and gross industrial product ($r = 0.6942$, $p = 0.05$) (Table 3). Almost all of Taicang County's surface water can not be used for drinking water supply.

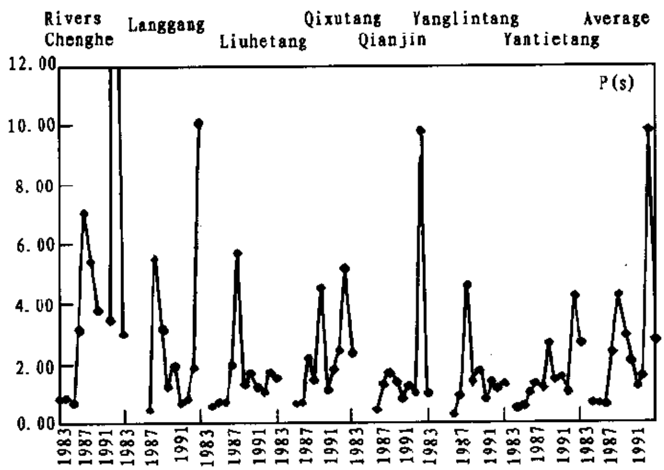


Fig.4 Changes of $P(s)$ of Taicang County's surface water in different years

**Table 3 Correlation between pollution indices and gross industrial product of Taicang County**

| Observed indices | Linear regression | | | Power regression | | | Exponential regression | | |
|---|---|---|---|---|---|---|---|---|---|
| | $a$ | $b$ | $r$ | $\log a$ | $b$ | $r$ | $a$ | $b$ | $r$ |
| pH | 7.72 | −1.87E-7 | −0.6164* | 2.21 | −0.014 | −0.7283** | 2.04 | −2.46E-8 | −0.6165* |
| EC | 452.38 | 2.91E-4 | 0.8601** | 3.64 | 0.21 | 0.7712** | 6.14 | 4.44E-7 | 0.7892** |
| DO | 5.08 | −1.47E-6 | −0.7672** | 3.87 | 0.19 | −0.8378** | 1.63 | −3.74E-7 | −0.8099** |
| COD | 5.64 | 2.78E-6 | 0.8384** | −0.46 | 0.19 | 0.8201** | 1.74 | 3.74E-7 | 0.8051** |
| $Cr^{6+}$ | 0.022 | −6.92E-9 | −0.0338 | −0.59 | −0.273 | −0.5730* | −3.91 | −2.50E-7 | −0.2586 |
| Cu | 6.51E-3 | 2.20E-9 | 0.0858 | −6.34 | 0.13 | 0.1839 | −4.63 | 5.35E-9 | 0.0037 |
| $NH_4$-N | 1.33 | 1.08E-6 | 0.4333 | −4.32 | 0.38 | 0.6533* | 0.15 | 6.60E-7 | 0.5612 |
| VP | 0.024 | 3.85E-8 | 0.5181 | −14.64 | 0.78 | 0.5656* | −5.63 | 1.89E-6 | 0.6757* |
| CYN | 5.13 | −1.34E-9 | 0.2161 | −4.65 | −0.07 | −0.1284 | −5.46 | −1.73E-7 | −0.1548 |
| Oils | 0.31 | 2.91E-7 | 0.3059 | −1.55 | 0.06 | 0.0707 | −0.76 | 5.56E-8 | 0.0414 |
| $P(s)$ | 1.29 | 2.58E-6 | 0.4827 | −6.52 | 0.57 | 0.6942* | 0.10 | 9.69E-7 | 0.5354 |

* statistically significant ($p = 0.05$); ** statistically significant ($p = 0.01$)

## 3.2 Change patterns of different pollution indices in rivers

### 3.2.1 Integrated indices

Fig.5 shows that pH of rivers decreased with time, especially in Rivers Chenghe and

Yantietang. Fig.6 shows that the electrical conductivity of water increased dramatically, and some of them exceeded 1000 $\mu$V/cm in 1993. From Fig.7, the average concentration of DO in these seven rivers also decreased below 2.00 mg/L in 1993.

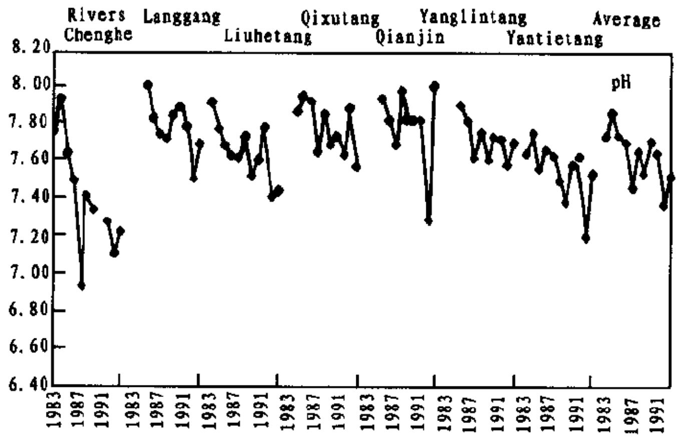


Fig.5 Change of pH of Taicang County's surface water in different years

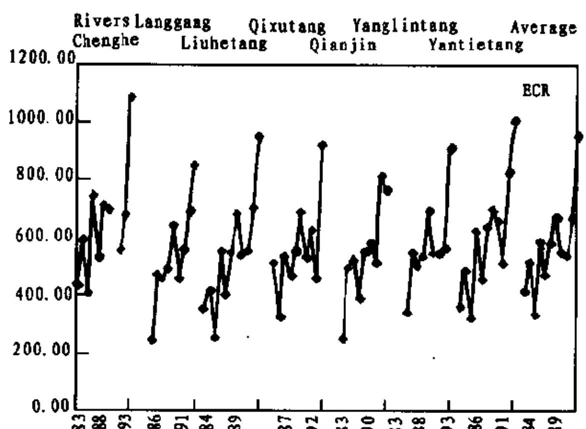


Fig.6 Changes of EC of Taicang County's surface water in different years, $\mu$V/cm

Fig.8 shows that concentrations of COD increased. In 1993, they reached approximately 13.00 mg/L and beyond the standard guideline of No.5 water category.

Generally, the surface water quality of Taicang County based on assessment by above four integrated indices deteriorated. The positive correlation exists between economy development and environmental pollution from the regression analysis of pH, electrical conductivity, DO and COD of seven rivers with gross industrial product of this county in different years (Table 3).

### 3.2.2 Individual indices

Fig.9 shows that $Cr^{6+}$ pollution of seven rivers in Taicang County was mitigated and its concentrations in these rivers were near 0.02 mg/L. Overall, $Cr^{6+}$ concentration of surface water was stable within the standard guideline of No.3 water category. Therefore, the $Cr^{6+}$ pollution to surface water was effectively controlled during these years in Taicang County.

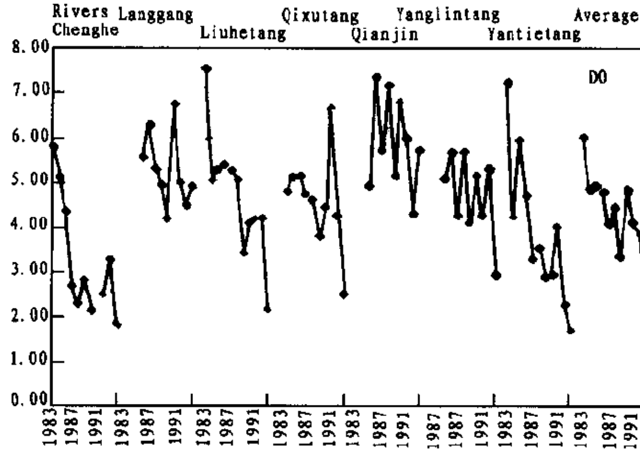


Fig. 7 Changes of DO of Taicang County's surface water in different years, mg/L

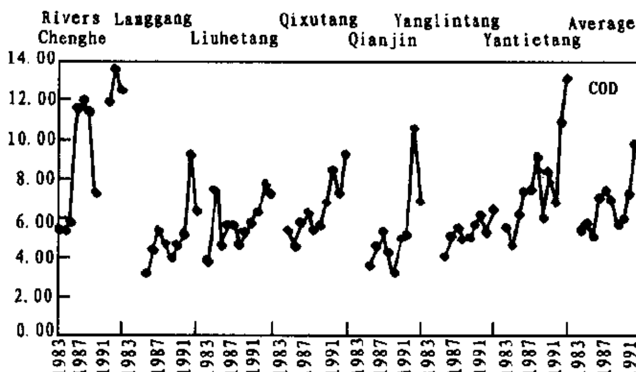


Fig. 8 Changes of COD of Taicang County's surface water in different years, mg/L

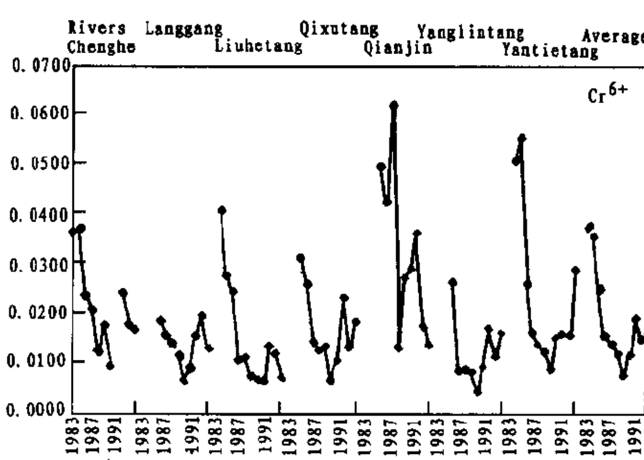


Fig. 9 Changes of $Cr^{6+}$ in Taicang County's surface water in different years, mg/L

The change pattern of copper pollution in seven rivers was similar to $Cr^{6+}$ pollution as

Fig.10 shows.

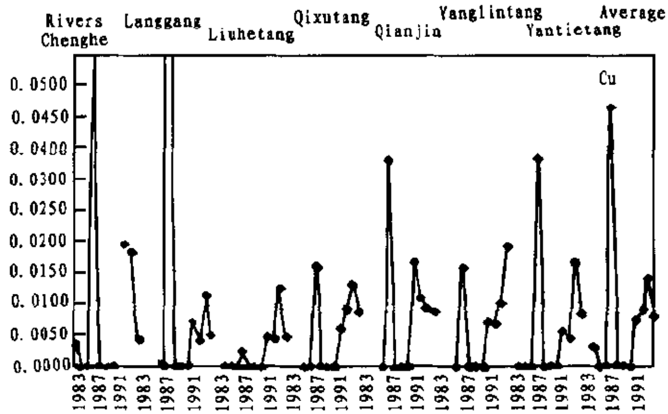


Fig.10 Changes of Cu in Taicang County's surface water in different years, mg/L

Ammonium-nitrogen pollution was a severe problem in Taicang County's surface water system. Fig.11 shows that concentrations of $NH_4$-N in rivers have been beyond the standard guideline of No.3 water category by 2 to 10 times, especially in rivers Chenghe and Qixutang. Every river had a concentration peak in 1988. There is a positively significant correlationship between $NH_4$-N concentration in rivers and gross industrial product by power regression analysis ($r = 0.6533$, $p = 0.05$) in Table 3.

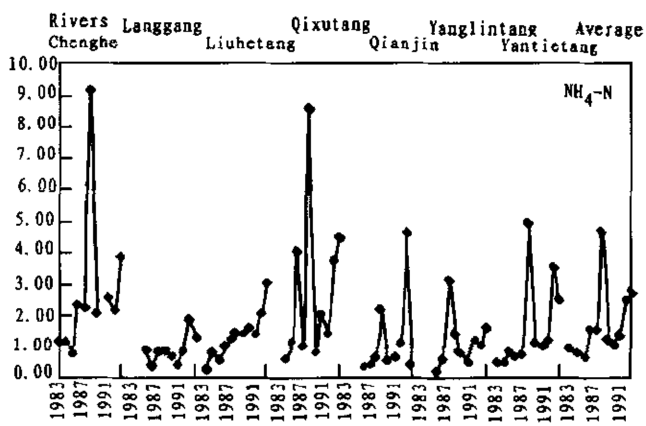


Fig.11 Changes of $NH_4$-N in Taicang County's surface water in different years, mg/L

Volatile phenol comes from waste water discharge of industries of paper making and chemicals. Fig.12 shows that there were much higher concentrations of volatile phenol in rivers Chenghe, Liuhetang and Yantietang. On the one hand, in 1993, volatile phenol concentration in River Langgang increased fast, and reached average concentration of 0.266 mg/L which was 51 times more than the standard guideline of No.3 water category. On the other hand, rivers Yanglintang, Qixutang, and Qianjing always kept in good condition. Rivers Qixutang and Yantietang were the two rivers with severe cyanide pollution in which concentrations of cyanide were beyond the standard guideline of No. 3 water category in most of years observed as

Fig.13 shows.

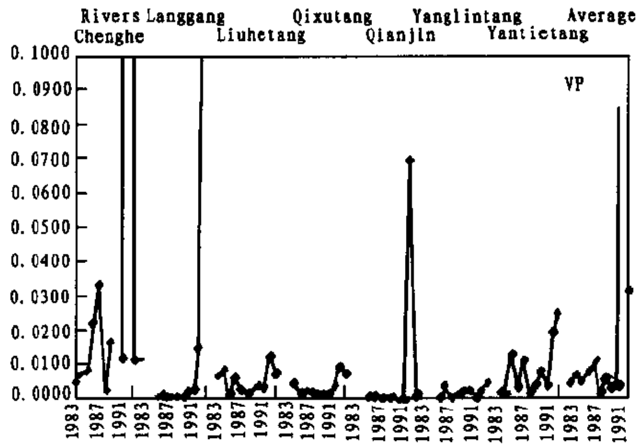


Fig.12 Changes of VP in Taicang County's surface water in different years, mg/L

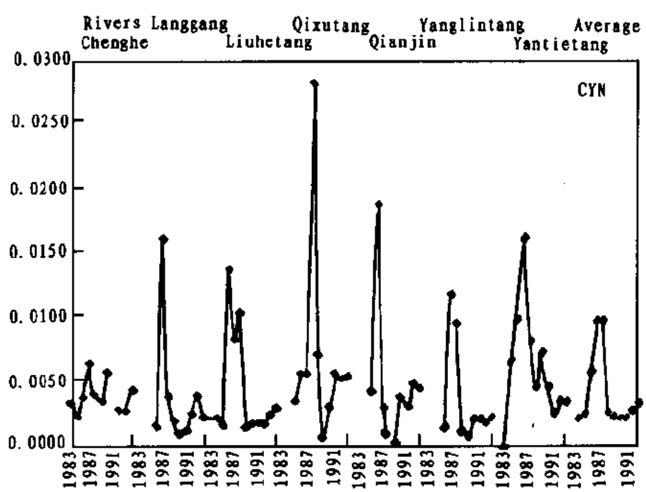


Fig.13 Changes of CYN in Taicang County's surface water in different years, mg/L

Like $NH_4$-N pollution, oils pollution was also serious in Taicang County's surface water (Fig.14). The observed data in seven rivers mostly beyond the standard guideline of No.3 water category of 0.05 mg/L. After reaching their first peak in 1987, concentrations of oils in rivers Chenghe, Liuhetang, and Yanglintang decreased, but rivers Langgang, Qianjing, and Yantietang increased gradually.

## 4. Conclusion

In Taicang County, there is a statistically significant correlation between economy development and environmental pollution which highly contributes to the deterioration of surface water quality.

In recent years, oils pollution from chemical industries to surface water is the dominant

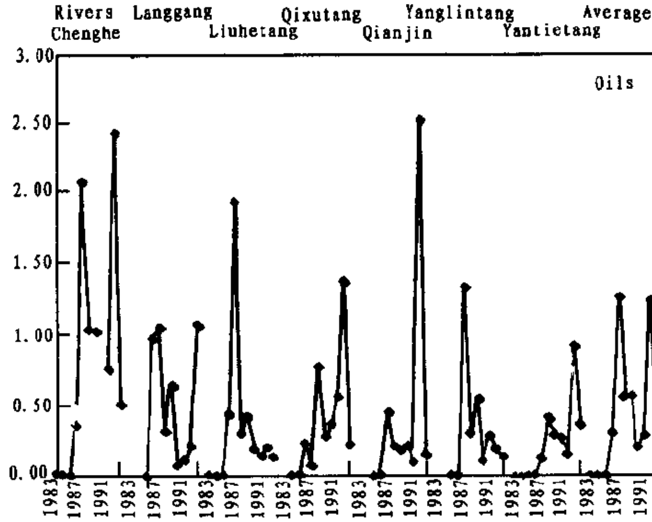


Fig. 14 Changes of oils in Taicang County's surface water in different years, mg/L

pollution in Taicang County.

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