Norwegian Institute for Water Research

REPORT

Main Office	Regional Office, Sørlandet	Regional Office, Østlandet	Regional Office, Vestlandet	Akvaplan-NIVA A/S
P.O. Box 173, Kjelsås	Televeien 1	Sandvikaveien 41	Nordnesboder 5	
N-0411 Oslo	N-4890 Grimstad	N-2312 Ottestad	N-5008 Bergen	N-9005 Tromsø
Norway	Norway	Norway	Norway	Norway
Phone (47) 22 18 51 00	Phone (47) 37 29 50 55	Phone (47) 62 57 64 00	Phone (47) 55 30 22 50	Phone (47) 77 68 52 80
Telefax (47) 22 18 52 00	Telefax (47) 37 04 45 13	Telefax (47) 62 57 66 53	Telefax (47) 55 30 22 51	Telefax (47) 77 68 05 09
Internet: www.niva.no				

Title	Serial No.	Date
Suzhou Creek Rehabilitation Project ECOLOGICAL STUDY 1998 Biological monitoring program	O-98041	26/11-1998
	Report No. Sub-No. 3958-98	Pages Price 42
Author(s)	**Topic group**	**Distribution**
Leif Lien Yin Haowen	Fresh water	Open
	Geographical area	**Printed**
	Shanghai, China	NIVA

Client(s)	Client ref.
Norwegian Directorate for Development Co-operation (NORAD) Shanghai Burea for Environmental Protection Interconsult international AS	

Abstract

Suzhou Creek, flowing through the central parts of Shanghai, is heavy polluted by sewage, metals and organic micro pollutants. Due to the pollution, lower parts of the creek have virtually no life of fish or macro-invertebrates, and the other biological communities are totally disturbed. Even at upstream sections the flora and fauna suffer from pollution. During the last decade the contamination has been slightly reduced in the creek. A biological monitoring program was designed for the creek based on an ongoing physical/chemical monitoring and on a biological study presented in this report. Microorganisms, macro-invertebrates and fish, in addition to assessment of attached organisms, were recommended parameters for biological monitoring of Suzhou Creek.

4 keywords, Norwegian	4 keywords, English
1. Biologisk vannovervåking	1. Biological monitoring
2. Fysisk/kjemisk vannovervåking	2. Physical/chemical monitoring
3. Suzhou Creek	3. Suzhou Creek
4. Shanghai, Kina	4. Shanghai, China

Leif Lien
Project manager

ISBN 82-577-3551-5

Dag Berge
Head of research department

Suzhou Creek Rehabilitation Project

ECOLOGICAL STUDY 1998

Biological monitoring program

Preface

The Suzhou Creek Rehabilitation Project is undertaken on commission of the Shanghai Bureau for Environmental Protection (SBEP) and The Norwegian Directorate for Development Co-operation (NORAD). The Project is a Chinese-Norwegian co-operation between Shanghai Academy for Environmental Sciences (SAES), and the Norwegian companies Interconsult International AS (ICI) and Norwegian Institute for Water Research. Syver Frøise (ICI) was the project leader.

In charge of the part project "Ecological Study" are Leif Lien (NIVA) and Yin Haowen (SAES). They are also authors of this report. In addition to Lin Weiqing (SBEP/SAES) and Dag Berge (NIVA), the following personnel from SAES have participated in the project, Zhao Huaqing, Chen Xiaoqian, Guo Rui, and Xu Weimin.

The identification of Macro-invertebrates has been performed by Professor Lai Wei, at the East China Normal University. Zhang Jin-ping, Shanghai Monitoring Center, identified the zoolplankton. They have both taken part in the discussion of this ecological project of Suzhou Creek.

Pål Brettum and Torleif Bækken, both NIVA, have contributed to the report on phytoplankton and macro-invertebrates respectively.

Norwegian Directorate for Development Co-operation (NORAD) has financed the project.

The co-operation among the participating institutions and personnel has been very positive. We will express our gratitude.

Oslo, 26. November 1998

Leif Lien

Contents

1. Summary

The aim of Suzhou Creek Rehabilitation is to reach an ecological restoration of the river. Evaluation of technical operations by means of bio monitoring is the most direct method of measuring the effect of these operations. This is one of the main reasons for preparing a biological monitoring program for Suzhou Creek.

Additional information rendered by the biological monitoring of Suzhou Creek is discussed: Correlation of physical/chemical analyses to biological monitoring results. Evaluation of possible variation of the physical/chemical concentrations in between the sampling periods. Evaluation of discharge episodes of toxic elements in between the sampling periods. Observation of small and slow changes of water quality over time are often more easily identified by inspecting the biological communities in addition to physical/chemical water parameters. Survival limits of biological components are sometimes more accurate than physical/chemical water parameters.

The construction of the biological monitoring program of Suzhou Creek is based on the present knowledge of a physical/chemical monitoring program run by Shanghai Environmental Monitoring Center, and the results of biological data collected and elaborated during this study.

A physical/chemical monitoring program of the water quality is performed in Suzhou Creek by Shanghai Environmental Monitoring Center. A network of six sampling stations exists along the whole Suzhou Creek from its entrance into Shanghai Municipality to the outlet to River Huang Pu. The sampling stations are Bai He, Huang Du, Hua Cao, Bei Xing Jing, Wu Ning Lu, and Zhe Jing Lu. The monitoring program includes sampling six times a year with two months intervals. The creek water have been analyzed since 1988 for the parameters: pH, dissolved oxygen (DO), chemical oxygen demand (COD), biological oxygen demand (BOD), oil, phenol, cyanide (CN), mercury (Hg), copper (Cu), cadmium (Cd), chloride (Cl), total phosphorus (Tot-P), total nitrogen (Tot-N), nitrite (NO_2-N), nitrate (NO_3-N), ammonia (NH_3-N), and ammonium (NH_4-N).

The water quality of Suzhou Creek changes considerably from its entrance into Shanghai municipal and downstream to the confluence with Huang Pu. The general tendency is that the pollution increases downstream the creek. Quite moderate deteriorations take place in the upper part. Downstream, the pollution is more pronounced, and extend considerably further down along the creek. Towards its outlet into Huang Pu the water quality improves due to tidal mixes with the less polluted water of Huang Pu. The main pollution consists of organic matter of various origins, but sewage is dominating. Also high concentrations of heavy metals, oil, and phenol are observed.

Another general tendency is that most of the pollutants of the creek have been reduced during the nineties. For some of the physical/chemical parameters the reductions are significant during the last seven years, e.g. for chemical oxygen demand measured by chromium oxidation, biological oxygen demand, and also for copper and phenol. However, for some parameters, e.g. dissolved oxygen, the tendency is deterioration during the decade.

Suzhou Creek is a very complex watercourse. Many tributaries and canals confluence with Suzhou Creek all the distance between the upper sampling site Bai He and the outlet into Huang Pu. Many of these tributaries and canals are of substantial size compared to Suzhou Creek. The water quality of these tributaries varies considerably, also compared to Suzhou Creek, and some of these are highly polluted, while some are quite clean. The water quality of the tributaries and canals therefore has an important impact on the water quality of Suzhou Creek. The biological community, dependent of the variations of the water quality in the creek, will also be highly influenced by the tributaries and the canals. It is also evident that the tributaries and the canals have its own biological communities that will influence Suzhou Creek by immigration of aquatic plants and animals. It implies that some species or groups of plants and animals, not occurring in the upper sections of the creek, might appear further down in the creek by entering from the tributaries and canals. The lower part of Suzhou Creek is influenced by the tide from Huang Pu, and the water in this section is actually flowing upstream during high tide. The water quality and also the biotic community are thereby highly influenced by the conditions in Huang Pu.

During this study several groups of organisms have been evaluated as biological monitoring elements in Suzhou Creek. These are microorganisms, phytoplankton, (attached organisms), zooplankton, macro-invertebrates, and

fish. The report gives the conclusion of these evaluations. Microorganisms, macro-invertebrates, and fish should be the parameters used for biological monitoring of Suzhou Creek. Attached algae should be further evaluated.

Taking into consideration the concentrations of the various chemical parameters and the occurrence and tolerance of the numerous biological groups in the different sampling sites, some of the physical/chemical parameters obviously have limiting effect regarding the survival of the biota. The concentration of dissolved oxygen should be one of the most critical factors in the middle and lower sections of the creek. The measured concentrations of ammonia, mercury, copper, oil, and phenol are also much too high for a healthy biological community.

There are only a limited number of hazardous components that have been studied in the water of Suzhou Creek. It should therefore not be excluded that other factors of critical effect on the biological community could be present in high concentrations. However, taking into account the measured physical/chemical parameters, the very low concentrations of dissolved oxygen are the main factor for explaining the very reduced biological community or almost total absence of certain organisms in the middle and lower sections of the creek.

Oxygen deficiency is not the only critcial factor. If the concentration of dissolved oxygen, in these parts of the creek is increased, most of the fauna will still suffer from the concentrations of ammonia. However, an increase of dissolved oxygen in the water will oxidize parts of the ammonia to non-toxic (nitrate) components, which is harmless for the fauna. Still, there will be a number of unfavorable components in the creek for the more sensitive groups of the flora (e.g. copper) and fauna (e.g. mercury or micro organic substances). The various biological groups/species are sensitive to different chemicals. Biological monitoring will therefore be of great help for identifying the most critical physical/chemical components left in the creek if or when the oxygen conditions are improved.

As described above, the physical/chemical data indicated a pronounced deterioration of water quality between Hua Cao and Bei Xing Jing. However, especially the results of the macro-invertebrates but also the microorganisms in the sediment showed considerable changes already between Bai He and Huang Du. This illustrates the high sensibility of biological monitoring parameters. Additional information for the main description of the creek is also achieved by using the biological parameters. Both the macro-invertebrates and the responding microorganisms between Bai He and Huang Du are living in the upper layers of the sediments. The differences between water quality data and biological data may also indicate that the pollution of the sediments is higher than what the present water quality shows. Remnants from a former higher water pollution still present in the sediments, could be an explanation to this phenomenon.

If the water quality will be improved in Suzhou Creek, there are certain expectancies for the biological communities for the different sections of the creek. In general, it is likely that communities from the upper part of the creek will colonize sections further downstream. Sections that are so polluted today that these organisms die if they are transported downstream. A certain upstream colonization from Huang Pu is also feasible. If improvement of water quality occur, some of the organisms will appear quite fast in former polluted sections, e.g. fish species could be seen within a few days. Other organisms will appear more slowly. E.g. some macro-invertebrates may take year(s) to be established.

The six operating physical/chemical sampling sites in Suzhou Creek are recommended to be continued also for the purpose of biological monitoring.

For an annual biological monitoring of Suzhou Creek a following sampling frequency is recommend at seasons indicated:

Microorganisms	4 times a year (winter, spring, summer, autumn)
(Possibly attached algae)	4 times a year (winter, spring, summer, autumn)
Macro-invertebrates	2 times a year (spring, autumn)
Fish	1 time a year (autumn)

The total personnel requirements for annual biological monitoring are estimated to approximately eight man months, one for technical personnel and seven for scientific personnel.
The field- and laboratory equipment is present at SAES.

2. Introduction

2.1 Objectives for biological monitoring of Suzhou Creek

The aim of Suzhou Creek Rehabilitation is to reach an ecological restoration of this creek. Evaluation of any technical operations by means of bio monitoring is the most direct method of measuring the effect of these operations. This is one of the main reasons for preparing a biological monitoring in Suzhou Creek.

Various objectives for biological monitoring of Suzhou Creek have been identified:
* Assessment of ecological restoration processes.
*Correlation of physical/chemical analyses to biological monitoring results.
*Evaluation of possible variation of the physical/chemical concentrations in between the sampling periods
*Evaluation of discharge episodes of toxic elements in between the sampling periods
*Observation of small and slow changes of water quality over time are often more easily identified by judging the biological communities compared to physical/chemical water parameters.
*Detection limits of biological parameters are sometimes more accurate than physical/chemical water parameters.

The construction of the biological monitoring program of Suzhou Creek is based on the present knowledge of a physical/chemical monitoring program run by Shanghai Environmental Monitoring Center, and the results of biological data collected and elaborated during this study.

The water quality varies very much from the upper part of Suzhou Creek to the lower section. The biological communities are also expected to change considerably along the creek. Correlation of physical/chemical data with observations of biological groups at different localities in Suzhou Creek will be of interest. The presence or non-presence of different plant- or animal group(s) is the main method for these biological assessments.

Any fluctuations or discharge episodes of toxic, physical/chemical elements will hardly be detected by the six times annual sampling of the present non-biological monitoring program. By including biological parametres, such episodes could be observed.

Small and slow, continuos changes of water quality taking place over a longer time period is not always easy to observe by physical/chemical monitoring based on only six annual samples. If changes occur, the appearance or disappearance of biological groups is a strong confirmation of real changes of water quality.

Detection limits of biological parameters are sometimes more sensitive than physical/chemical water parameters. It means that sometimes the biological parameters will reflect small changes of water quality earlier than the physical/chemical water parameters. Any changes of biological parameters from time to time might therefore act as an early warning indicator. However, changes in biological parameters do usually not point out exactly which of the physical/chemical parameters that has changed. Knowledge of specific sensitivity of the different biological groups usually give indication of effects on changes within physical/chemical parameters.

Up to now, all biological data available for monitoring purposes in Suzhou Creek deal mainly with microorganisms. The present study will in addition to microorganisms also assesses the possibilities of using zooplankton, macro-invertebrates, and fish.

2.2 The present physical/chemical monitoring program for Suzhou Creek.

At present, a physical/chemical monitoring program of the water quality is performed by Shanghai Environmental Monitoring Center. Among a large number of monitoring locations in Shanghai, the program also includes Suzhou Creek. A total of six sampling stations exist along the whole Suzhou Creek from its entrance into Shanghai Municipality to the outlet to River Huang Pu. The sampling station at the entrance to Shanghai Municipal, Bai He, will act as a reference locality for the whole downstream Suzhou Creek. The other downstream stations are: Huang Du, Hua Cao, Bei Xing Jing, Wu Ning Lu, and finally Zhe Jiang Lu located close to the entrance to River Huang Pu (see Figure 1)

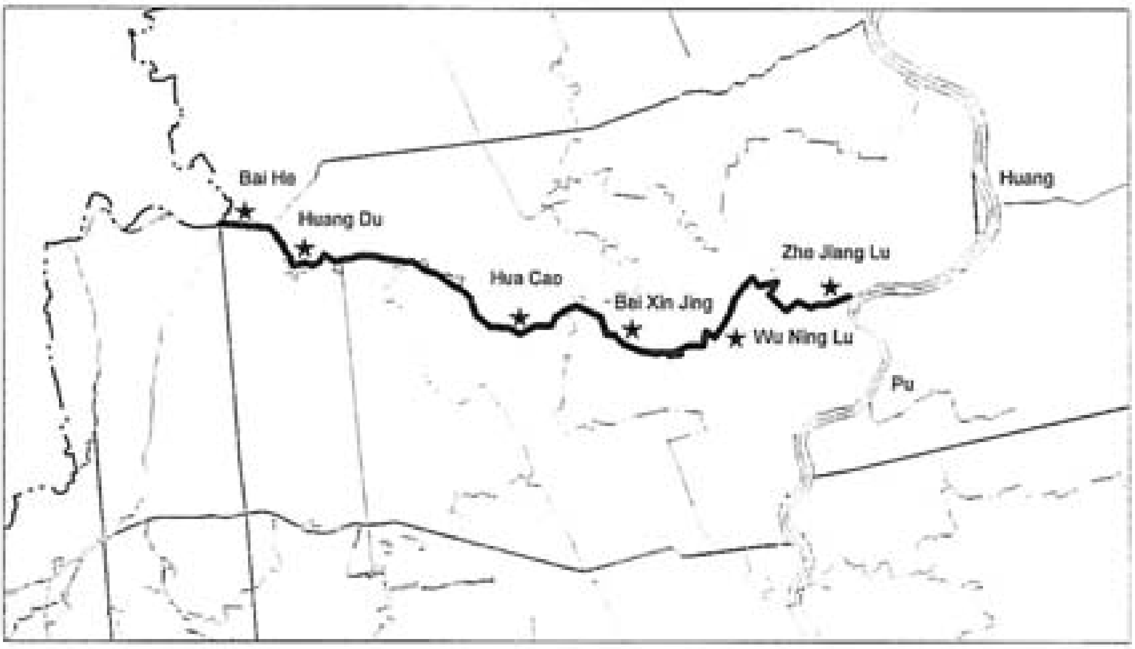


Figure 1 Schematic map of Suzhou Creek with location of the six sampling sites Bai He, Huang Du, Hua Cao, Bei Xing Jing, Wu Ning Lu, and Zhe Jiang Lu.

The monitoring program includes sampling six times a year. The sampling usually takes place every second month, but not always at the same months each year. The creek water are analyzed for the parameters: pH, dissolved oxygen (DO), chemical oxygen demand (COD), biological oxygen demand (BOD), oil, phenol, cyanide (CN), mercury (Hg), copper (Cu), cadmium (Cd), chloride (Cl), total phosphorus (Tot-P), total nitrogen (Tot-N), nitrite (NO_2-N), nitrate (NO_3-N), ammonia (NH_3-N), and ammonium (NH_4-N).

The monitoring program of Suzhou Creek is run by Shanghai Environmental Monitoring Center. This institute is doing the sampling, the analyses of the physical/chemical parameters, and is reporting the results to Shanghai Bureau of Environmental Protection. The data are reported annually, and the data are also reported every five years. These five years' reports sum up the results on a five years basis. This monitoring program has been operating continuously with comparable data since 1986. This report will summarize the main physical/chemical data available from the last years, 1991 – 1997.

Two other institutions do also regularly collect water quality data from Suzhou Creek: Shanghai Hydrometric Stations and Shanghai Environmental Sanitary Bureau. Data from these two institutions are not reported to Shanghai Bureau of Environmental Protection, but to other departments within Shanghai, and none of these data are further coordinated up to now.

Most of the data from all of the institutes is treated confidentially. It means that the data is not immediately accessible to others that might be interested. However, data can be available to most institutes and departments on special requests. Only physical/chemical data from Shanghai Environmental Monitoring Center are used in this report.

2.3 Description of water quality of Suzhou Creek.

The water quality of Suzhou Creek changes considerably from its entrance into Shanghai municipal and downstream to the confluence with Huang Pu. The general tendency is that the pollution increases downstream the creek. Quite moderate deterioration takes place in the upper part. Downstream, the pollution increases are more pronounced, and extend considerably further down along the creek. Towards its outlet into Huang Pu the water quality improves due to tidal mixes with the less polluted water of Huang Pu. The main pollution consists of organic matter of various origins, but sewage is dominating. Also high concentrations of heavy metals, oil, and phenol are observed. All main physical/chemical data are presented as annual means in the appendix. A general impression of the variation of pollution at the six monitoring stations along Suzhou Creek can be illustrated by the concentration of total nitrogen for the various years. (Figure 2.)

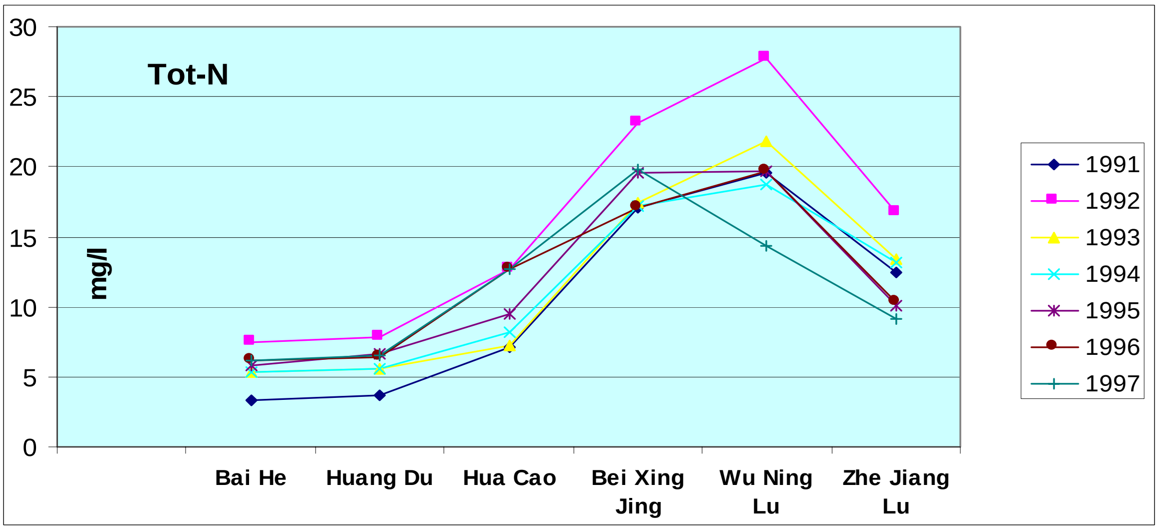


Figure 2. Annual mean concentration of total nitrogen from the six sampling sites in Suzhou Creek for the years 1991 to 1997.

As mentioned above, the concentrations of the different parameters increased from the upper to the lower sampling sites. The greatest differences are usually seen between Bai He and Wu Ning Lu. In order to give a description of the general water quality of the whole creek, the annual mean range between these two stations are given in table 1.

Another general tendency is that most of the pollutants of the creek have been reduced during the nineties. For some of the physical/chemical parameters the reductions are significant during the last seven years, e.g. for chemical oxygen demand measured by chromium oxidation, biological oxygen demand, and also for copper and phenol. However, for some parameters, e.g. dissolved oxygen, the tendency is deterioration during the decade.

The present monitoring program of Suzhou Creek does not include any biological monitoring. However, a few biological parameters, protozoa and benthic animals were measured by Shanghai Monitoring Center in Suzhou Creek, but not as a routine or a systematic monitoring program. In addition, some biological parameters are included, e.g. for River Huang Pu (phytoplankton and attached vegetation, Yin & Zhao 1994).

Table 1. Range of annual mean values of physical/chemical parameters measured at Bai He and Wu Ning Lu in Suzhou Creek, 1991 – 1997. Copper, cadmium, mercury, and phenol in µg/l, the other values in mg/l.

Physical/chemical parameters	Bai He	Wu Ning Lu
Chemical oxygen demand (CODMn)	5.5 – 8.2	12.6 – 28.6
Chemical oxygen demand (CODCr)	24.3 – 28.0	53.8 – 158.4
Biological oxygen demand (BOD5)	2.8 – 7.0	11.9 – 66.9
Dissolved oxygen (DO)	4.0 – 5.6	0.7 – 2.1
Total nitrogen (Tot-N)	3.2 – 7.5	14.3 – 27.7
Ammonia (NH4-N)	1.7 – 4.2	12.1 – 19.9
Total Phosphorus (Tot-P)	0.16 – 0.3	0.51 – 1.4
Copper	6 – 18	29 - 71
Cadmium	0.3 – 1.1	0.3 – 12.1
Mercury	0.05 – 0.13	0.5 – 5.43
Oil	0.07 – 0.33	1.0 – 3.3
Phenol	1 – 9	46 – 186
Cyanide	3	12 - 15

3. Biological monitoring in Suzhou Creek in 1998.

3.1 Microorganisms

In addition to phytoplankton, zooplankton, macro-invertebrates, and fish, microorganisms were suggested as biological monitoring parameter. The microorganisms are easy to collect, and the method is sensitive. The microbes play an important role in the recycling of organic substances, and it can be classified by trophic level, such as autotrophy or heterotrophy. Microorganisms also reflect habitat conditions, e.g. aerobic or anaerobic. The microbes, as a functional group, can also indicate ongoing processes like self-purification or mineralization in addition to identify distinct organic pollution.

Microorganisms were sampled from both surface water and sediment. 100 ml of water was taken with a water sampler just below the water surface. Part of the sample was emptied into a WHIRL-PAK^{R} bag. Sediment samples were taken with a core sampler. The upper 2-3 cm of the sediment layer was sliced off, and stored in an antiseptic plastic bag. Both water- and sediment samples were transported in icebox, and incubated maximum 24 hours after collection.

Table 2. Number of microorganisms (colonies per ml water) in the surface water of Suzhou Creek 3 June 1998.

Sampling station	Anaerobic microorganisms	Heterotrophic microorganisms	Autotrophic microorganisms
Bai He	3.0×10^3	3.6×10^4	6.0×10^3
Huang Du	2.5×10^4	2.4×10^4	6.0×10^3
Hua Cao	3.1×10^4	2.5×10^4	6.0×10^3
Bei Xing Jing	2.1×10^5	1.3×10^6	1.4×10^4
Wu Ning Lu	1.5×10^5	1.2×10^6	1.1×10^4
Zhe Jiang Lu	1.9×10^5	1.3×10^6	1.6×10^4

Table 3. Number of microorganisms (colonies per g wet weight) of sediment in Suzhou Creek 3 June 1998.

Sampling station	Anaerobic microorganisms	Heterotrophic microorganisms	Autotrophic microorganisms
Bai He	1.2×10^4	5.6×10^4	6.0×10^3
Huang Du	2.9×10^4	1.2×10^4	1.2×10^4
Hua Cao	6.2×10^4	1.0×10^5	2.7×10^4
Bei Xing Jing	4.6×10^4	2.8×10^5	1.5×10^4
Wu Ning Lu	5.8×10^4	2.5×10^5	1.2×10^4
Zhe Jiang Lu	3.5×10^4	5.3×10^5	2.6×10^4

The natural bacterial communities of freshwaters plays a major role in the self-purification processes, which biodegrade organic matters. They are particularly important with respect to the decomposition of sewage effluents. Bacterial communities can be characterized as "functional groups" of. Three groups, autotrophic, heterotrophic, and anaerobic bacteria were measured in water column and sediment. The results are listed in tables 2 and 3 and illustrated in figures 3 and 4. This is the first microbiological study reported from Suzhou Creek

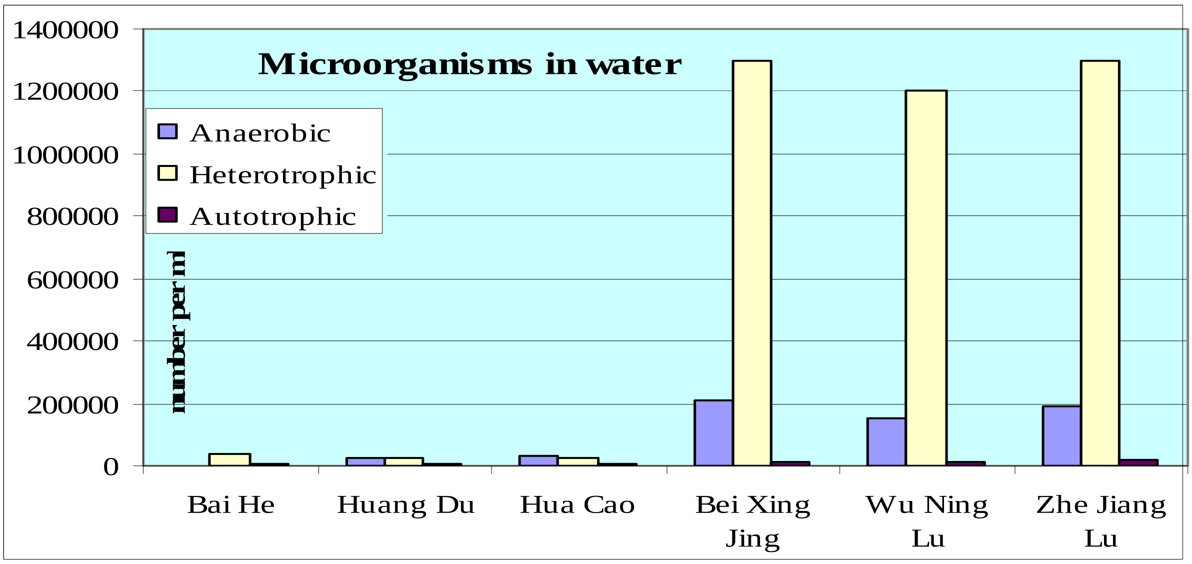


Figure 3. Number of microorganisms recorded from water in Suzhou Creek 3 June 1998.

Most of the microbiological groups showed great differences in abundance between the sampling site, both in the water column and in the sediment. In the water column the number of anaerobic bacteria were lowest at Bai He and at the downstream stations Huang Du and Hua Cao (Figure 3). At the next three stations the numbers rose by ten times, and a maximum value was found at Bei Xing Jing.

The heterotrophic bacteria showed an even greater increase from the upper three stations to the lower three sampling sites, and rose by 100 times. The greatest increase occurred between Hua Cao and Bei Xing Jing. Clearly, there were a lot of organic effluents entering the creek between these two stations. This high amount of discharge was not seen between other stations. Both the numbers of anaerobic and heterotrophic bacteria showed close relationship to chemical and biological oxygen demand (COD and BOD) and also inverse relationship to dissolved oxygen (DO). See appendix for the values.

The autotrophic bacteria also increased in number between Bai He and Huang Du, but only a doubling of number was observed. The mineralization process was mainly an anaerobic degradation at Bei Xing Jing and Wu Ning Lu. Ammonia is a product of anaerobic degradation, and the high ammonia concentrations at these sites reflect the chemical measures in the water (see appendix).

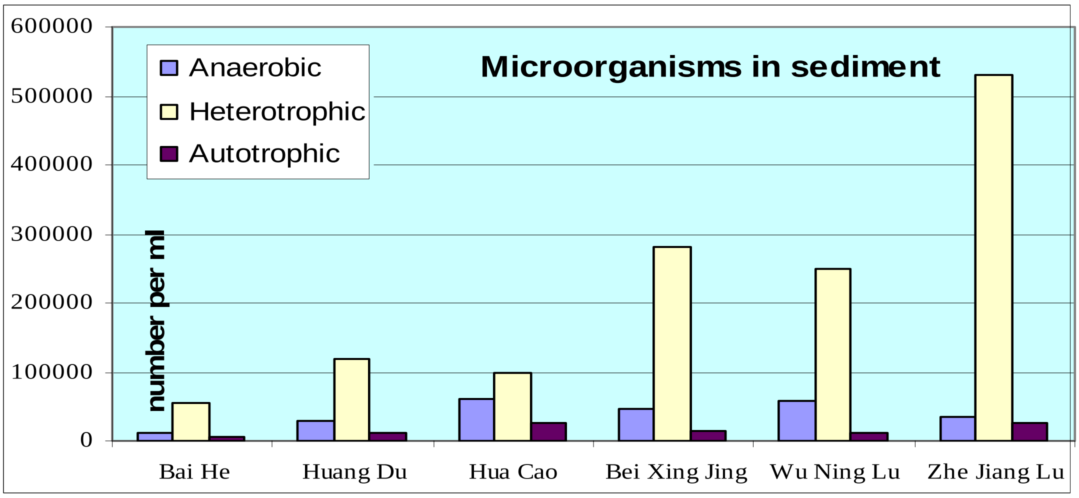


Figure 4. Number of microorganisms recorded from sediments in Suzhou Creek 3 June 1998.

Comparing bacteria in the sediments to bacteria in the water columns, the chemical and physical conditions of the sediments are more stabile. The microbes in the sediment reflect the accumulation of pollution over a longer time period.

The number of autotrophic bacteria had a maximum value at Hua Cao and was somewhat lower at the next stations, Bei Xing Jing and Wu Ning Lu. The number of microbes increased towards the outlet at Zhe Jing Lu. These results indicate that decomposing processes had little effect on the mineralization of this sediment.

In Suzhou Creek the large increase in bacterial growth was associated with reduction of dissolved oxygen. The load of organic discharges from Hua Cao to Wu Ning Lu was so large that the available oxygen was used and could not be replaced as fast as the oxygen are consumed. Under these conditions anaerobic fermentation occurred, especially in deposits of suspended solids, which accumulate in surface sediment. These processes are complex and not fully understood. Anaerobic bacterial activity plays an important role in the early stages of bio-degradation. From Hua Cao to the river mouth, the heterotrophic bacteria dominate the creek. The anaerobic bacteria were the second-rate dominant group. The bacteria distribution gives a good characterization of the decomposing processes in Suzhou Creek.

Monitoring methods including microorganisms are simple to perform, small economical cost, and limited amount of special equipment are required. Fast responses to changes in water quality are measured by this method. A disadvantage with these organisms is that they are easily moved by water currents, and therefore may reflect a water quality e.g. further upstream the sampling locality. However, by sediment this problem is avoided.

Based on discussion above, the conclusion should be that microorganisms are very well suited for bio monitoring of Suzhou Creek. It should be possible to prepare a system of recovery index based on microorganisms for the rehabilitation study of Suzhou Creek

3.2 Phytoplankton

One litre of water was taken with a water sampler 50 cm below the water surface outside the littoral zone at the six monitoring stations of Suzhou Creek. The sample was preserved with 30 ml lugol immediately after sampling and stored without exposure to sun until further elaboration. Another sample was taken from the same water and similarly conserved. These samples were identified at SAES and NIVA respectively. A third sample of water was taken in the same way from the same localities and analyzed at SAES for Chlorophyll-a according to international method.

The main phytoplankton data are listed in table 4 and illustrated in figure 5. A detailed species list is presented in the appendix (Table B1). NIVA was responsible for the species identification and biomass estimate (volume), while SAES produced the other results.

Table 4. Number of phytoplankton species, biomass of phytoplankton measured as volume, number of cells, chlorophyll-a, and number of unique species found at the various sampling sites in Suzhou Creek June 1998.

Sampling station	Bai He	Huang Du	Hua Cao	Bei Xing Jing	Wu Ning Lu	Zhe Jiang Lu
Number of species	32	29	38	26	19	17
Biomass (mm^3/m^3)	13808	3682	16089	4471	5691	380
Cells (no.x10^6/l)	2,49	1,9	4,87	3,83	5,95	0,36
Chlorophyll-a (mg/m^3)	55,7	148,5	16,5	19,3	23,3	11,9
No. of unique species	5	3	8	4	5	2

The number of species increased slightly from Bai He to Hua Cao, and then decreased continuously downstream to the river mouth. The highest number of species, 38 at Hua Cao was (more than) the double compared to Wu Ning Lu and Zhe Jiang Lu.

Comparing Bei Xing Jing and Wu Ning Lu with the upper site, Bai He, the number of cells increased, while the biomass and chlorophyll-a decreased. At Hua Cao the biomass reached a peak value, and the cell density was almost four times that of Huang Du, but the chlorophyll-a value was largely lowered compared to Huang Du. Passing Huang Du and Hua Cao, the algal community showed clear signs of ecological stres. Further downstream many of the algae species did not survive.

An analysis of dominant phytoplankton species showed that there were six species in the creek with volumes higher than 10^3 mm^3/m^3 (Table 5). These were *Cyclotella meneghiniana, Stephanodiscus hantzelli v. pusillus, Cryptomonas erosa, Cryptomonas erosa v. reflexa, Peridinium sp.*, and *Euglena exyuris v. minor*. These species can be divided into two groups according to their distribution. *Cyclotella meneghiniana and Stephanodiscus hantzelli v. pusillus*, both Bacillariophyseae, were numerous at all sites, while the other species were dominant only in certain sampling localities.

At Bai He there was a somewhat complex and dubious dominance according to the description of the phytoplankton saprobic system. At Hua Cao three of the dominant species (*Cyclotella meneghiniana*

Stephanodiscus hantzelli v. pusillus, and Cryptomonas erosa) are known for preferences to α-mesosaprobic waters. *Peridinium sp.*, occurring in the upper and lowest part of the creek is a saprobic saprophobus genus, while *Cryptomonas erosa* and related species, occurring at the same sites are saprobiotic forms. In some Chinese literature (Hu et al. 1980, Lin & Xei 1988) these are expected to be saprophilous species, which generally occur in nitrogen polluted waters.

Generally, it is somewhat difficult to use phytoplankton for accurate assessment of water quality of Chinese rivers. However, a rough judgment of successions of pollution can be achieved, particularly in slowly flowing rivers located on flatlands.

Another problem with the planktonic algae is that they represent the water quality somewhat upstream the locality where they are sampled.

Suzhou Creek is largely influenced by a number of tributaries and canals of considerable size compared to the creek itself. These tributaries and canals have sometimes a totally different water quality and also phytoplankton community compared to the water quality and phytoplankton at the confluence area of the creek. This phenomenon will highly influence unexpected phytoplankton compositions at the different sampling sites.

The nutrient content of Suzhou Creek is very high and should support an alga biomass in the order of 20 000 – 50 000 mm^3/m^3 at the three lowermost stations. The low alga biomass observed shows clearly that the water is toxic to the algae at these localities.

Another algae group, the attached algae, is considered to be more sensitive to river pollution than the planktonic forms (Fjerdingstad 1964, Lindstrøm 1991, Yin & Zhao 1994). The attached algae were taken into consideration when planning the biological monitoring of Suzhou Creek, and during the first sampling trips, samples for attached algae were collected. However, the substrata for the attached algae were so different at the different sampling localities that the communities of attached algae were expected not to be comparable. An elaboration of the collected material combined with further sampling and evaluation of attached algae along Suzhou Creek are recommended.

The following methods are recommended for sampling and preservation of attached algae and additional attached organisms, include filamentous algae, bacteria, mosses and other attached organisms. The sampling should be adjusted to the topography of the creek. In the lower part of the creek the former littoral zone is completely replaced by vertical stone walls. Also in the upper part of the creek also some stone walls were found. At all monitoring stations, mainly (vertical) stone walls should be sampled for attached organisms. Just above or below the present water level, the samples should be collected with a small spade, and transported in plastic bags to SAES. Thereafter they will be preserved with lugol and stored in glass bottles for later elaboration.

It seems that the phytoplankton can be used for biological monitoring of Suzhou Creek, but it should be concluded that it is not an ideal group for this purpose in this creek. A use of attached algae as a monitoring group should be further evaluated for the creek.

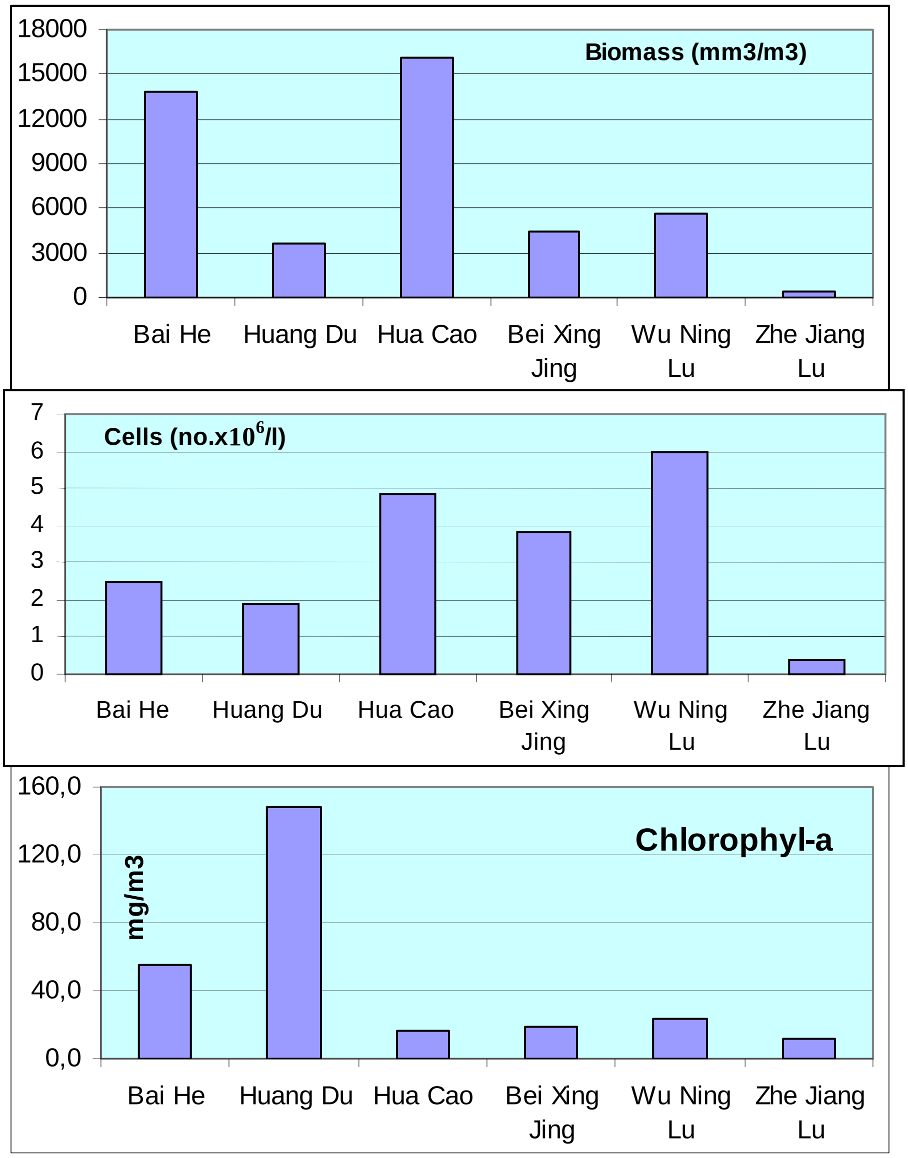


Figure 5. Biomass of phytoplankton measured as volume (upper), number of cells (middle), and chlorophyll-a (lower) from the different stations in Suzhou Creek, June 1998.

Table 5. Dominant phytoplankton species according to sampling locality: 1 = Bai He, 2 = Huang Du, 3 = Hua Cao, 4 = Bei Xing Jing, 5 = Wu Ning Lu, 6 = Zhe Jiang Lu. Maximum number (in order of magnitude) is given for each species. Sampling localities were the species occurs in maximum numbers is presented in bold. The main ecological indication of the species in the saprophobius system is given with references.

Dominant species	Sampling locality	Maximum number	Main ecological indication Saprophobius system
Cyclotella meneghiniana	1 2 **3** 4 5 6	<100000	α-meso. (Zelinka & Marvan 1961)
Stephanodiscus hantzchii v. pusillus	1 2 **3** 4 **5** 6	<10000	α-meso. β-meso. (Fott 1971)
Cryptomonas erosa	**1** 2 3 6	<10000	α-meso. (Hu et al 1980, Lin & Xei 1988)
Cryptomonas erosa v. reflexta	1 2	<10000	α-meso. (Hu et al 1980, Lin & Xei 1988)
Peridinium sp.	**1** 2 3 6	<10000	β-meso.(oligo.) (Environmental Committee 1975)
Euglena oxyuris v. minor	1 2 **3** 6	<1000	β-meso.(Lin & Xei 1988)

3.3 Zooplankton

Zooplankton was collected with a zooplankton net, diameter 18 cm and mesh size 64 µm. The net was lowered and lifted slowly three times from close to the bottom of the creek to the surface. After each lifting, the plankton net was emptied into a 50 - 100 ml bottle. After the final lift, the net was washed two times into the same bottle, and the whole sample was preserved in lugol.

Zoolpankton was identified by Zhang Jin-ping, Shanghai Monitoring Center. The list of species recorded from the different stations in Suzhou Creek is listed in appendix, Table B2.

A small sub-sample of zooplankton from Bai He was also taken to NIVA for identification. There was an acceptable agreement of species identified by NIVA and Shanghai Monitoring Center.

Table 6. Zooplankton recorded from six stations in Suzhou Creek, arranged according to occurrence in the creek, collected 5 June 1998.

Species - Genus/ Sampling station	Bai He	Huang Du	Hua Cao	Bei Xing Jing	Wu Ning Lu	Zhe Jiang Lu
Schizocerca diversicornis	x					
Schmackeria forbesi		x				
Bosminopsis richard		x				
Diaphan. leuchtenbergianum		x				
Brachionus capsuliflorus			x			
Asplanchna priodorta	x	x	x			
Diaphanosoma brachyurum	x	x	x			
Brachionus angularis		x		x		
Filinia longiseta		x	x	x		
Polyarthra trigulu	x	x	x	x		
Eucyclops serrulatus	x	x	x	x		
Monia micrura		x	x	x		
Thermocyclops sp.			x	x		
Arcella vulgaris				x		
Vorticella sp.				x		
Mesocyclops sp.				x		
Arcella sp.		x	x	x	x	
Mesocyclops leuckarti		x	x		x	x
Brachionus urceus		x	x	x		x
Diaphanosoma sarsi	x	x	x	x	x	
Filinia maior	x				x	x
Thermocyclops hyalinus	x	x		x	x	x
Bosmina fatalis	x	x	x		x	x
Brachionus calyciflorus	x	x	x	x	x	x
Brachionus caudatus	x	x	x	x	x	x
Moinodaphnia macleayii						x
Daphnia magna						x
Microcyclops sp.						x

A total of 28 groups of zooplankton were identified in Suzhou Creek. Some species or genus occurred in all or most parts of the creek (*Diaphanosoma sarsi, Filinia maior, Thermocyclops hyalinus, Bosmina fatalis, Brachionus calyciflorus, and Brachionus caudatus.* Other species were also found in most of the creek: *Arcella sp, Mesocyclops leuckarti, and Brachionus urceus.* These species are of no particulate interest concerning the monitoring of the creek.

Another group of zooplakton species, *Moinodaphnia macleayii, Daphnia magna, and Microcyclops sp,* was found only at the lowest station, Zhe Jiang Lu. These species, were probably flushed in by the tide from the River Huang Pu. Thereby, they do not reflect the water quality of Suzhou Creek.

The group of species or genus of particular interest for monitoring should be those occurring in the upper part of the creek, and gradually disappear as the water quality deteriorates downstream (Table 6). These are *Schizocerca diversicornis,* only found at Bai He, and *Schmackeria forbesi, Bosminopsis richard,* and *Diaphanosoma leuchtenbergianum* only found at Huang Du. Also some of those species or groups found downstream to Hua Cao (*Asplanchna priodorta* and *Diaphanosoma brachyurum),* and even to Bei Xing Jing (*Brachionus angularis, Filinia longiseta, Polyarthra trigulu, Eucyclops serrulatus,* and *Monia micrura)* are of certain interest for biological monitoring.

As mentioned for phytoplankton, the influence of the large tributaries and canals along the whole Suzhou Creek are also of great importance to the zooplankton community. Different water qualities with different zooplankton species are entering the Suzhou Creek all along its course. This zooplankton are flushed downstream to the nearby sampling sites and included in the evaluation of the sample.

Zoolpankton have been useful for biological monitoring in many water bodies, but mainly in lakes. The number of four to ten groups of zooplankton with a certain interest for biological monitoring in Suzhou Creek is small compared to the total of almost 30 zooplankton groups identified. The zooplankton is also a group of animals that is drifting almost passively downstream with the water flow. Therefore, the zooplankton community found in one section of the creek might represent the water quality somewhere further up steam in the creek. Zooplankton is not an ideal biological group for monitoring of Suzhou Creek.

3.4 Macro-invertebrates

Macro-invertebrates were collected with a sediment core sampler. The corer had an inner diameter of 6 cm. The total surface of a sample was thereby 0.002826 m2. The upper 5 cm of the sediment was sliced off the core, and filtered through a 250 µm net. The samples were thereafter conserved by 96 % alcohol for later identification.

A total of thirteen species or groups of macro-invertebrates were recorded in Suzhou Creek. They are listed in the appendix in table B3, and the number of taxa at each station are illustrated in figure 6. Professor Lai Wei, East China Normal University, identified the macro-invertebrates.
The diversity of macro-invertebrates in Suzhou Creek is generally low, even at the least polluted site, Bai He. Here, the number of taxa was twelve. At the two next downstream sampling sites, Huang Du and Hua Cao, the number of species/groups was reduced to four and three respectively. This indicates a substantial degree of contamination of the creek. Further down, at Bei Xing Jing and Wu Ning Lu the water quality and the sediments of the creek are quite unsuitable for macro-invertebrates. The two species/groups observed here were both parasitic Diptera mainly relying on fungi. At the lowermost site, Zhe Jiang Lu, the number of species were also two. These were Oligochaeta species. The presence of these was due to the improvement of water quality caused by influx of tidal water of better quality from Huang Pu.

The distribution of the main groups: Oligochaeta, leeches (Hirudinea), snails (Gastropoda), mussels (Bivalvia), and Diptera are shown in figure 7. At Bai He the diversity is highest, and all five groups are present.

At the next downstream station, Huang Du, the most sensitive groups, the snails and the mussels, have been wiped out. The more pollution tolerant groups, the leeches, the Oligochaeta, and the Diptera were present. Also, the total number of individuals was lower at Huang Du compared to Bai He. That was expected due to the increased pollution of the water.

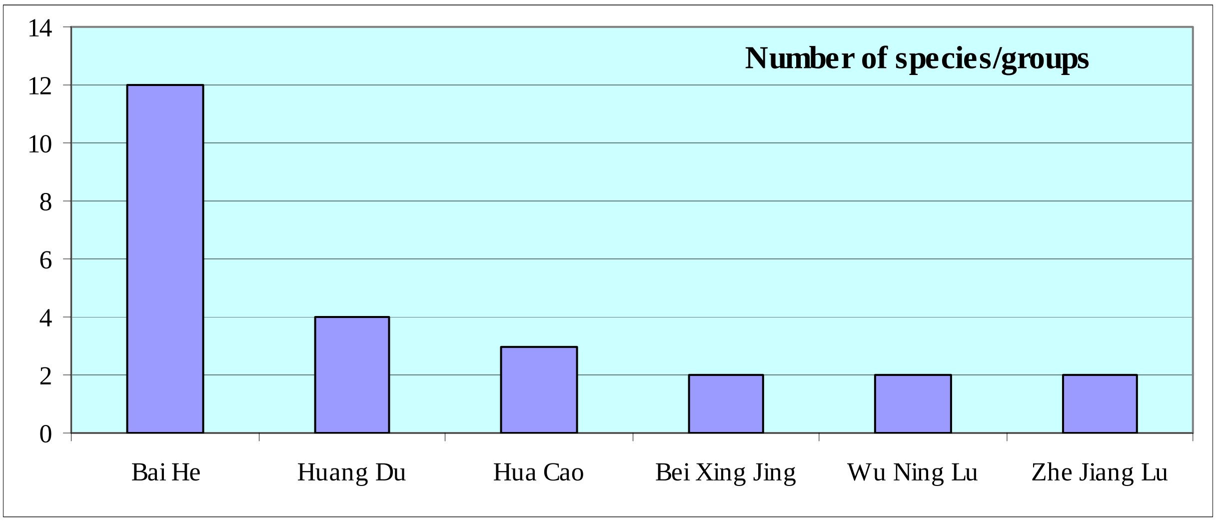


Figure 6. Number of species (or groups) of macro-invertebrates identified at each sampling sites in Suzhou Creek 5 June 1998.

At Hua Cao only Oligochaeta were found, and one species, *Limnodrilus hoffmeisteri*, was dominating in huge numbers (see also figure 8 and appendix table B3). Oligochaeta is usually one of the most pollution resistant macro-invertebrates. When the other macro-invertebrate groups have been wiped out, the competition from these groups is absent. At the same time also most of the predators of the macro-invertebrates, e.g. the fish, are reduced both in numbers and species. Most of the pollution in Suzhou Creek is organic matter, which is food for the Oligochaeta. Therefore, the conditions for resistant organisms like some Oligochaeta are optimal at Hua Cao, and they appear in huge numbers.

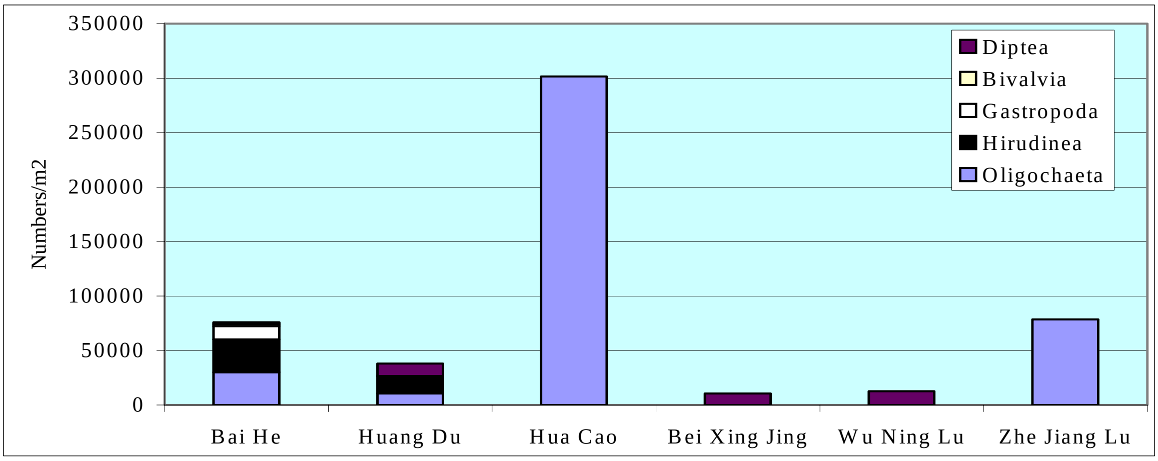


Figure 7. Number per square meter of the different main groups of macro-invertebrates in Suzhou Creek, 5 June 1998.

Further downstream, at Bei Xing Jing and Wu Ning Lu, the conditions for Oligochaeta have become to rough for survival. Several physical/chemical factors may exceed their tolerance, e.g. the low oxygen concentration of the water. This will be discussed in detail for all biological monitoring groups later. At Bei Xing Jing a few Diptera was recorded in one of the samples. Some species of this group can survive without oxygen for some periods.

At the lowest site, Zhe Jiang Lu, the physical/chemical conditions have improved to acceptable for some Oligochaeta. However, the number of individuals is lower than at Hua Cao.

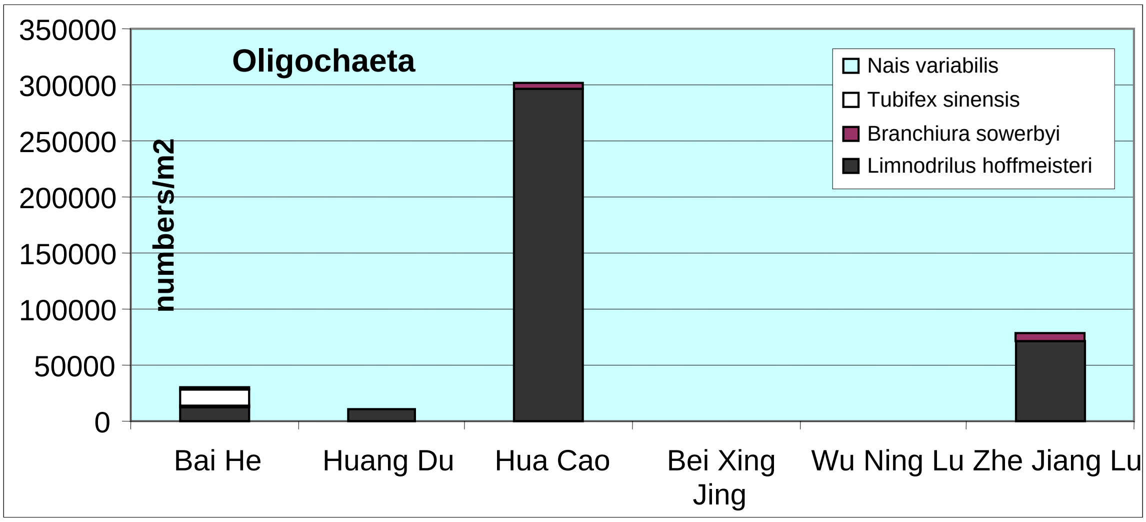


Figure 8. Number per square meter of the different species of Oligochaeta at various sites in Suzhou Creek, 5 June 1998.

As seen from appendix table B3, there is a great variation in number and taxonomic groups between the various samples collected at the same locality. It is therefore important to have a representative number of samples from each sampling site. At least five parallel samples should be collected at each locality.

The macro-invertebrates differentiate very well between the various sampling sites even at the level of the main taxonomic groups (Oligochaeta, Hirudinea, Gastropoda, Bivalvia, and Diptera). At the species level within the main groups the differentiation is indeed more pronounced (see appendix table B3.), especially the Oligochaeta species (Figure 8.). At Bai He four species occur with *Limnodrilus hoffmeisteri* and *Tubifex sinensis* as the dominant ones. Further downstream *Limnodrilus hoffmeister* is the overall dominant species where Oligochaeta is present. At Hua Cao and Zhe Jiang Lu another species, *Branchiura sowerbyi*, appeared in low numbers.

Limnodrilus hoffmeisteri is obviously the most tolerant Oligochaeta in Suzhou Creek. From a monitoring point of view, it will be of great interest to observe if or when this species will be able to establish e.g. at Bei Xing Jing or Wu Ning Lu if the water quality improves in future. Any deterioration of water quality is also expected to influence the Oligochaeta community as well as the whole macro-invertebrate fauna.

One of the great advantages by using benthic living macro-invertebrates for biological monitoring is the limited ability of this group to move for longer distance along the creek. Most species or groups can stay in the same area for years if not disturbed e.g. by pollution. On the other hand, reproduction stages like eggs or imagoes of insects are able to spread quite fast in order to occupy new areas if accessible.

Macro-invertebrates are easy to sample by means of core sampler. It is also easy to collect several parallel samples at the same locality. One obstacle could be access to an invertebrate expert for species identification. However, the present composition of the macro-invertebrates in Suzhou Creek require actually no species identification in order to differentiate between the various sampling sites for biological monitoring purpose.

<u>Based on discussions above we can conclude that benthic living macro-invertebrates are very well suited for biological monitoring of Suzhou Creek.</u>

3.5 Fish

Information's of fish and their tolerance to the water quality of Suzhou Creek was collected by two methods: (1) By bringing water from Suzhou Creek to SAES laboratory and expose the test species Zebra fish, *Brachydanio rerio*, to the water from the various stations. (2) Interview of inhabitants at the different sampling localities. (A third method by submerging cages holding Zebra fish at each locality was rejected due to high risk of loosing the cages.)

By the first method, the fish was exposed to water brought from the different monitoring station in Suzhou Creek to aquarium in SAES laboratory. Prior to exposure the water was aerated for 30 minutes. The water quality of the lower part of the creek showed almost no content of oxygen, and high content of ammonia, both lethal to fish. By aeration of water from the lower parts of the creek in the laboratory, the oxygen concentration was increased and the concentration of ammonia stripped off to acceptable concentration to fish. When reaching concentrations lower than 10 µg/l of ammonia after 30 minutes of aeration, the fish were introduced to the aquarium. Whatever will be seen of fish mortality in the laboratory aquariums after this treatment should therefore reflect effects of other elements than oxygen and ammonia.

Suzhou Creek water from Bai He, Bei Xing Jing, Wu Ning Lu, and Zhe Jiang Lu were brought to SAES 27 July 1998. After aeration, 20 Zebra fish of 2 – 3 cm of length were exposed to aquariums containing 10 liters of water for four days without any more aeration. No mortality was observed in the water from Bai He, Wu Ning Lu, or Zhe Jiang Lu. Two fish (10 %) died the third day in the water from Bei Xing Jing. The reason for the mortality was not examined.

The second method of gaining information of fish was by undertaking interviews of local inhabitants, preferably fishermen and boatmen. Preliminary interviews were accomplished during the sampling trips 3 and 5 June 1998. Based on experience from that, a third interview took place 11 August and included the following questionnaires:

1. Have you seen fish in this section of Suzhou Creek the last year?
2. If yes, what species?
3. Have you ever before seen fish in this section of Suzhou Creek?
4. If yes, how many year ago?
5. If yes, what species?

Fish information's based on initially interviews, 3 and 5 June 1998, and the third interview 11 August 1998:

Bai He: Small shoals of fish was observed along the shores and two species were caught, locally named "ping pong fish" (*Rhodeus sp*.) and "cuan tiao" (*Hemiculter sp*.). Local inhabitants (boatmen) told us that many species of fish are caught in this section of the creek. Many species of fish, shrimps, and snails occur at the site.

Huang Du: Local inhabitants (fishermen) told us that several species were caught this year in this area, including "ping pong fish" (*Rhodeus sp*.) and "cuan tiao" (*Hemiculter sp*.). Many species of fish, shrimps, and snails still occur at the site. Ten years ago, many more fish species and more individuals were present in this section of the creek.

Hua Cao: Local inhabitants (boatmen) told us that small fish are sometimes seen in the creek surface in the evenings when the boat traffic is low. Other informers said that one (or a few) fish species were always present in this section of the creek.

Bei Xing Jing: Local inhabitants (boatmen) told us that one fish species was seen in this area. 20 years ago fish was present in this section of the creek

Wu Ning Lu: One water snake was observed during sampling. Local inhabitants (boatmen) told us that no fish was seen in this area. In the ninety sixties fish appeared at the site.

Zhe Jiang Lu: Local inhabitants (boatmen) told us that at present, no fish has been seen in this area since the beginning of the 1960’s. Before the 1960’s both fish and shrimps were present. However, fish appear also today at the site during and after typhoons.

The aquarium studies of Zebra fish exposed to water from Suzhou Creek reflect quality of the water passing the sampling station only during the very short time period of collecting the water. It is the same situation when taking a water sample for analyzing once every second month. Only the quality of the water passing the sampling station the few seconds it takes to collect the sample is examined. This is in strong contrast to some of the biological monitoring where the biological subjects are located in the creek and thereby exposed to the water all the time between each sampling. The aquarium test of the Zebra fish does not represent a long time study of the creek water. A long time water study could imply Zebra fish located in cages at each site in the creek. However, this study was rejected due to high risk of loosing the cages.

Although the fish aquarium studies could provide information of hazardous elements not regularly analyzed in the water, this type of fish studies are not recommended for this biological monitoring program.

Fish is used as (early) warning organisms for detection of sudden discharges of hazardous wastes in many rivers, e.g. River Rhine in Europe, River Seine in Paris, River Themes in London, and River Akerselva in Oslo. The advantage by using the fish is mainly that any appearance of dead or dying specimens are easily seen, and not only experts but most people are aware of what is going on and will report any events to proper authorities.

The general water quality, color, and transparency does not imply that the people along the lower part of Suzhou Creek are able to report any fish kill at the moment. However, if or when the water quality of the creek improves, the reporting of fish kills to e.g. Shanghai Environmental Monitoring Center, are recommended. The Environmental Center should then as soon as possible collect (water) samples of the creek in order to identify the discharge and the responsible for the event.

Interviews on fish are simple to obtain in connection to other field sampling of Suzhou Creek. If any definite improvement of water quality occur especially in the lower part of Suzhou Creek, a rather fast immigration of fish is likely. The fish interview study should therefore take place once a year as a part of the biological monitoring study, and preferably with some future arrangement on reporting of fish kills.

4. General discussion

Suzhou Creek is a very complex watercourse (see Figure 1). Many tributaries and canals confluence with Suzhou Creek all the distance between the upper sampling site Bai He and the outlet into Huang Pu. Many of these tributaries and canals are of considerable size compared to Suzhou Creek. The water quality of these tributaries varies considerably, also compared to Suzhou Creek (ICI/SAES/NIVA 1995), and some of these are highly polluted, while some are quite clean. The water quality of the tributaries and canals therefore has an important impact on the water quality Suzhou Creek. The tributaries and the canals will also largely influence the biological community of Suzhou Creek by immigration of aquatic plants and animals. It implies that some species or groups of plants and animals, not occurring in the upper sections of the creek, might appear further down in the creek by entering from tributaries and canals. The lower part of Suzhou Creek is influenced by the tide from Huang Pu, and the water in this section is flowing upstream during high tide. The water quality and also the biotic community are thereby highly influenced by the conditions in Huang Pu.

The water quality and the biological flora and fauna of Suzhou Creek are presented above. Taking into consideration the concentrations of the various physical/chemical parameters and the occurrence and tolerance of the numerous biological groups in the different sampling sites, some of the parameters obviously have an important negative effect on the survival of the biota. The concentration of dissolved oxygen should be one of the most critical factors in the middle and lower sections of the creek. The measured concentrations of ammonia, mercury, copper, oil, and phenol are also much too high for a healthy biological community.

There are only a limited number of hazardous components that have been studied in the water of Suzhou Creek. It should therefore not be excluded that other factors of critical effect on the biological community could be present in high concentrations. However, taking into account the measured physical/chemical parameters, the very low concentrations of dissolved oxygen are adequate for explaining the reduced biological community or almost total absence of certain organisms in the middle and lower sections of the creek.

Oxygen deficiency is not the only crucial factor. If the concentration of dissolved oxygen, in these parts of the creek is increased, most of the fauna will still suffer from high concentrations of ammonia. However, an increase of dissolved oxygen in the water will oxidize parts of the ammonia to non-toxic (nitrate) components, which is harmless for the fauna. Still, there will be a number of insidious components in the creek for the more sensitive groups of the flora (e.g. copper) and fauna (e.g. mercury or organic micro substances). The various biological groups/species are sensitive to different chemicals. Biological monitoring will therefore be of great help for identifying the most critical physical/chemical components left in the creek if or when the oxygen conditions are improved.

As described above, the physical/chemical data indicated a pronounced deterioration of the water quality between Hua Cao and Bei Xing Jing. However, especially the results of the macro-invertebrates but also the microorganisms in the sediment showed considerable changes already between Bai He and Huang Du. This illustrates the higher sensitivity of using biological monitoring parameters. Additional information for the main description of the creek is also achieved by using the biological parameters. Both the macro-invertebrates and the responding microorganisms between Bai He and Huang Du are living in the upper layers of the sediments. The differences between water quality data and biological data may also indicate that the pollution of the sediments is higher than what the present water quality shows. Former higher degree of water pollution still present in the sediments, could be an explanation to this phenomenon.

If the water quality will be improved in Suzhou Creek, there are certain expectancies for the biological communities for the different sections of the creek. In general, it is likely that communities from the upper part of the creek will colonize sections further downstream. Sections that are so polluted today that these organisms die if they are transported downstream. A certain upstream colonization from Huang Pu is also feasible. If improvement of water quality occur, some of the organisms will appear quite fast in former polluted sections, e.g. fish species could be seen within a few days. Other organisms will appear more slowly. E.g. some macro-invertebrates may take year(s) to be established.

5. Proposal for a permanent biological monitoring program for Suzhou Creek.

5.1 Sampling stations

The physical/chemical monitoring program has been run for many years with six sampling sites in Suzhou Creek. Ecological monitoring includes both physical/chemical data and biological data. Proposal for further biological sampling stations in addition to the six stations operating in the creek will therefore also imply physical/chemical measures at these additional stations. These possible new stations will not have any former data indicating any changes over time. Based on the results of this biological monitoring, no need for additional sampling stations was identified. Neither during our field sampling in Suzhou Creek, any new sampling site was considered necessary. At present, the six operating physical/chemical sampling sites are recommended to be continued also for the purpose of biological monitoring.

5.2 Sampling frequency.

For a permanent future biological monitoring of Suzhou Creek, a following sampling frequency is recommend at the seasons indicated:

Microorganisms	4 times a year (winter, spring, summer, autumn)
Phytoplankton (incl. Chl-a)	4 times a year (winter, spring, summer, autumn)
(possibly attached algae)	4 times a year (winter, spring, summer, autumn) (Yin & Zhao 1994b)
Macro-invertebrates	2 times a year (spring, autumn)
Fish	1 time a year (autumn)

Preferably the biological sampling should take place within the same time period as sampling for water quality data are collected.

5.3 Sampling manual for the biological monitoring program.

5.3.1 Microorganisms.

Water sampling: 100 ml of water is taken with a water sampler just below the water surface. The sampler must be washed three times with local site water before taking samples. The sample is emptied into WHIRL-PAKR bags.
Sediment sampling: The sample will be taken with a sediment core sampler. The upper 2-3 cm of the upper sediment layer will be sliced off, and transported in an antiseptic plastic bag.
Both water- and sediment samples should be stored and transported in an icebox. All samples should be incubated as soon as possible, maximum 24 hours after collection.

5.3.2 Attached organisms.

The sampling of attached organisms in Suzhou Creek must be adjusted to the topography of the creek. In the lower part of the creek the former littoral zone is completely replaced by vertical stone walls. Also in the upper part of the creek stone walls are found. In order to find comparable localities at all monitoring stations, (vertical) stone walls should be sampled for attached organisms. During the sampling trips, attached organisms were seen on many various objects including on more or less permanent located boats. Sampling from boat sides should be avoided due to movements of boats from one section of the creek to another.

Ideally, the sampling of attached organisms should first include an assessment of the percentage of the different groups of vegetation: Filamentous algae, bacteria, mosses and other attached organisms. Thereafter, a representative sample of each group should be collected for later identification. Experience from the sampling trips indicated difficulties to follow this complete sampling procedure. However, just collecting representative samples of attached organisms at each station could be satisfactory for this biological monitoring program.

The samples will be collected with a small spade (shovel) preferably with a long handle. The samples will be collected just above or below the present water level depending on the tide, and transported in plastic bags or small glass bottles. The samples will be stored in glass bottles and preserved with water and lugol.

5.3.3 Macro-invertebrates.

Macro-invertebrates will be sampled by sediment cores. The upper 5 cm of the sediment, at least, will be sampled by a core sampler, and filtered through a 250 µm net. The samples will thereafter be conserved by 96 % alcohol for later identification.

5.3.4 Fish.

Fish will be monitored by interviewing local inhabitants, fishermen or boatmen at the different sampling stations. The interviews should include questionnaires to be filled in during sampling for other biological parameters. The questionnaires should include questions about fish present by this time, but also if any changes have taken place during the last years.

The questionnaires should be set up very simple, and include six questions:

1. Have you seen fish in this section of Suzhou Creek the last year?
2. If YES, what species?
3. Have you ever before seen fish in this section of Suzhou Creek?
4. If YES, how many year ago?
5. If YES, what species?
6. Name(s) of the informer(s).

All biological samples of phytoplankton, attached organisms, zooplankton, and macro-invertebrates will be stored for any possible future examinations. The microorganisms will be stored as photos.

5.4 Annual resource requirements.

Biological sampling will take place four times a year. Each sampling will be completed during one day. This will require two scientific trained persons in addition to two technical assistants and a driver. The sampling of biological monitoring will thereby require a total of approximately one man-month of work each year. In addition, a car must be available four days a year.

For preparation and identification of the various biological groups the estimated time requirements are totally six man months: Three man months for microorganisms, one and a half-month for phytoplankton, and the same for identification of macro-invertebrates. One man month is necessary for annual reporting. The total personnel requirements for annual biological monitoring are then approximately eight man months, one for technical personnel and seven scientific man months.

The field- and laboratory equipments are all present at SAES, and the only extra need is bottles and chemicals for preservation and storing of the biological material. The costs of these are limited. The expences of a car for four days should be added.

6. References

ICI/SAES/NIVA. Interconsult International, Shanghai Academy of Environmental Sciences & Norwegian Institute for Water Research. 1995. Rehabilitation of Suzhou Creek. Pre-feasibility study. Report. Shanghai 1995.

Environmental Committee. 1975. Environment and Bio- indicator. Kyoritsu Comp Ltd.. p. 78. (in Japanese)

Fjerdingstad, E. 1964. Pollution of streams estimated by benthal phytomicroorganisms. Int. Rev. ges. Hydrobiol. 49: 63 – 131.

Fott, B. 1971. Algenkunde. VEB Gustav Fischer Verlag. p. 424 – 428.

Jarlman, A., Lindstrøm, E.-A., Eloranta, P. & Bengtson, R. 1996. In Whitton, B.A., Rott, E. (Eds.) Use of algae for monitoring rivers II: 17-28. Inst. fur Botanik, Univ. Innsbruck.

Hu, H. ,Li, X., We. Y., Zhu, H., Chen, J. & Shi, Z. 1980. Algae of Freshwater in China. Sciences and Technological Press p. 91 – 92. (in Chinese).

Lin, B. & Xei, S. 1988. Aquatic Algae and Pollution Monitoring in Waters. Liao Ning University Press. p. 234 – 236. (in Chinese).

Lindstrøm E.-A. 1996. River algal studies in Norway. In Whitton, B.A., Rott, E. (Eds.) Use of algae for monitoring rivers II: 143-148. Inst. fur Botanik, Univ. Innsbruck.

Yin, H. & Zhao. H. 1994a. Use of attached algae community to assess water quality in the upper reaches of the Huang Pu river. Acta Ecol. Sinica 14: 14 - 21. (in Chinese).

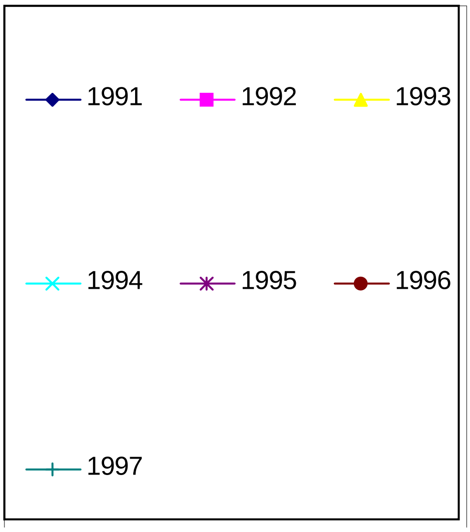
Yin, H. & Zhao. H. 1994b. Sampling Design for Monitoring Attached Algae in Tidal River. Shanghai Environ. Sci. 13 (7): 12 – 15. (in Chinese).

Zelinka, M. & Marvan, P. 1961. Zur Praziesierung der biologischen klassification der Reinhait fliesserde Gewasser.Arch. Hydrobiol. 57: 389 – 408.

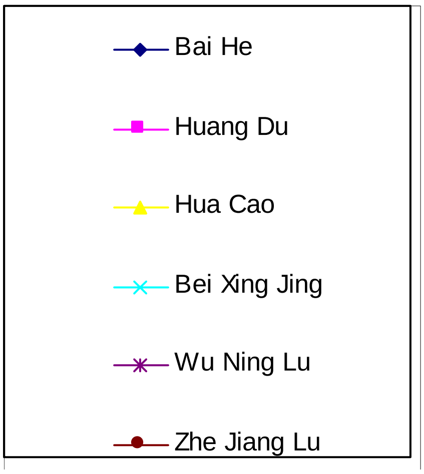
Appendix A

Physical/chemical monitoring data.

Tables and figures A1 to A11 present the water quality data from 1991 to 1997 in Suzhou Creek. The values are given as annual means for the different monitoring sites: Bai He, Huang Du, Hua Cao, Bei Xing Jing, Wu Ning Lu, and Zhe Jiang Lu.



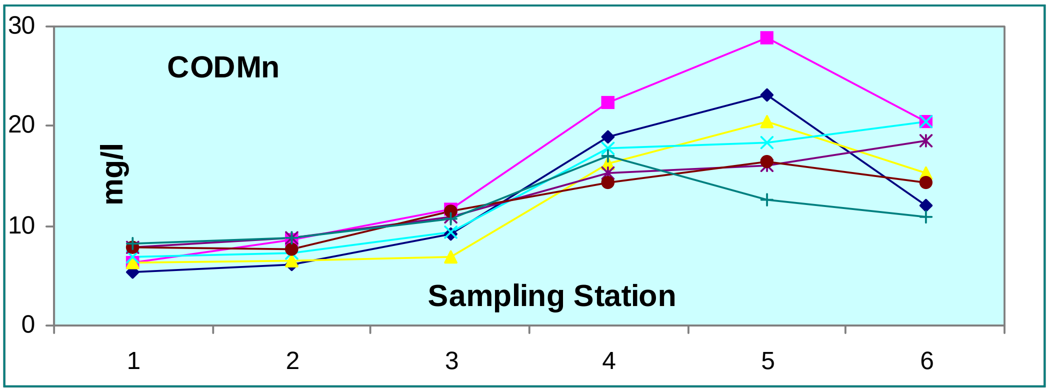
The figure above gives the legend for the values of the different years presented in Table/Figures A1 – A11 on the next pages.

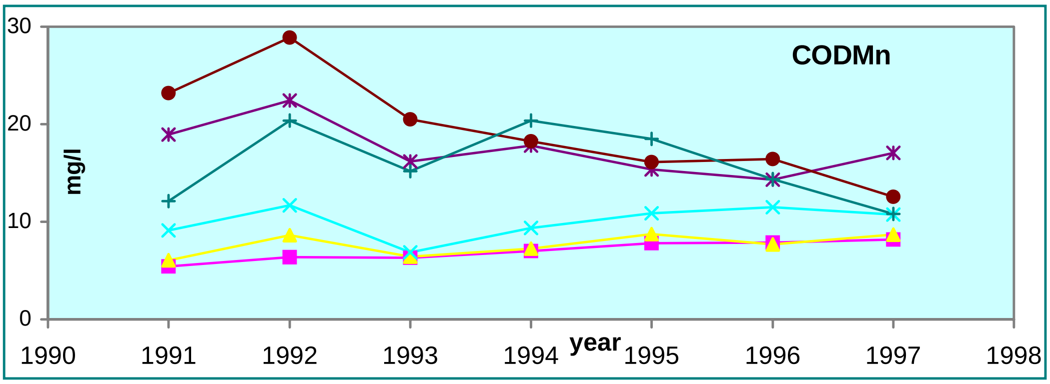


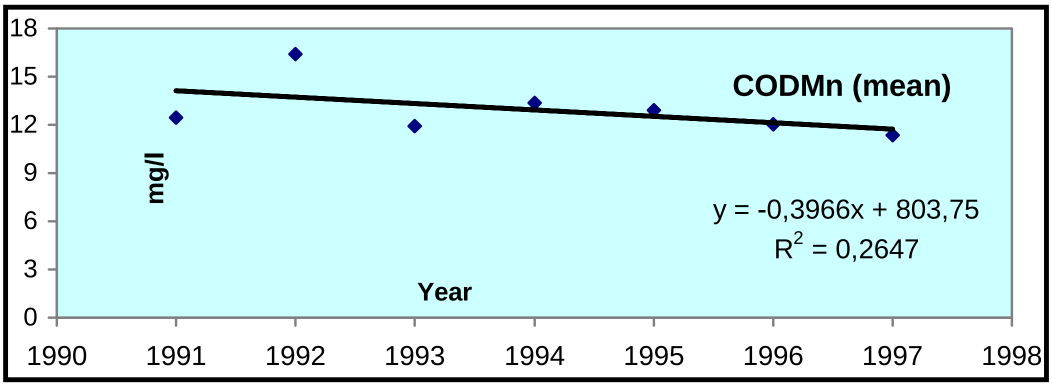
The figure above gives the legend for the different sampling stations presented in Table/Figures A1 – A11 on the next pages

Table/Figures A1. Physical/chemical water quality data from Suzhou Creek, annual means. Chemical oxygen demand (in mgO2/l) from six stations in 1991 – 1997. Upper figure according to sampling station. Middle figure according to sampling year. Lower figure according to mean values for all seven years.

Station	1991	1992	1993	1994	1995	1996	1997
Bai He	5,44	6,35	6,33	6,97	7,82	7,89	8,18
Huang Du	6,06	8,64	6,44	7,28	8,75	7,68	8,71
Hua Cao	9,1	11,68	6,89	9,39	10,86	11,5	10,77
Bei Xing Jing	18,95	22,42	16,21	17,81	15,38	14,34	17,04
Wu Ning Lu	23,17	28,85	20,51	18,27	16,13	16,41	12,59
Zhe Jiang Lu	12,12	20,38	15,21	20,37	18,53	14,37	10,80
Mean	12,47	16,39	11,93	13,35	12,91	12,03	11,35

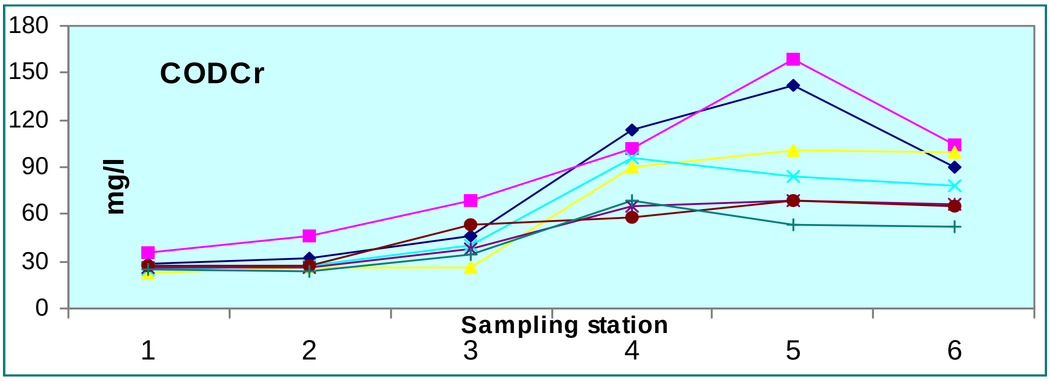


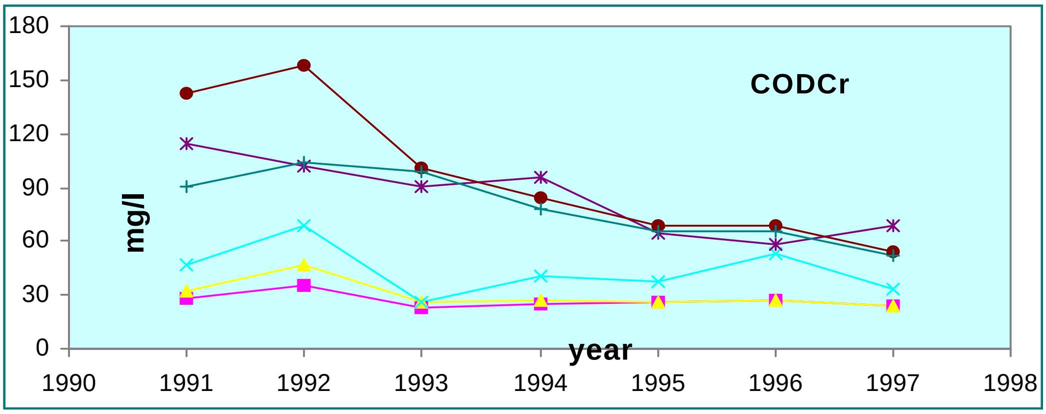


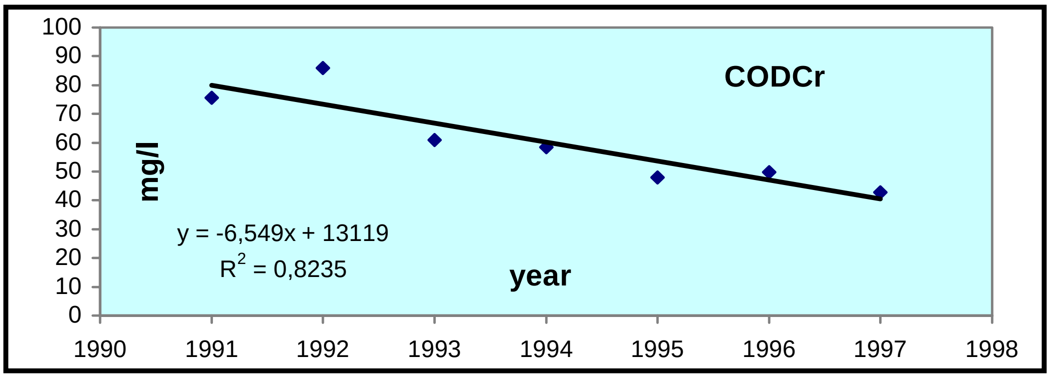


Table/Figures A2. Physical/chemical water quality data from Suzhou Creek, annual means. Chemical oxygen demand (in mgO2/l) from six stations in 1991 – 1997.Upper figure according to sampling station. Middle figure according to sampling year. Lower figure according to mean values for all seven years.

Station	1991	1992	1993	1994	1995	1996	1997
Bai He	28,03	35,6	23,04	25,1	25,65	26,7	24,34
Huang Du	32,23	46,66	25,93	26,7	25,55	26,8	23,86
Hua Cao	46,45	69,04	26,53	40,84	37,63	53,2	33,78
Bei Xing Jing	114	101,5	90,21	95,37	64,61	58,08	68,97
Wu Ning Lu	142,35	158,36	100,9	84,65	68,7	68,57	53,79
Zhe Jiang Lu	90,59	104,04	98,89	78,48	65,77	65,58	52,21
Mean S.C.	75,61	85,87	60,92	58,52	47,99	49,82	42,83



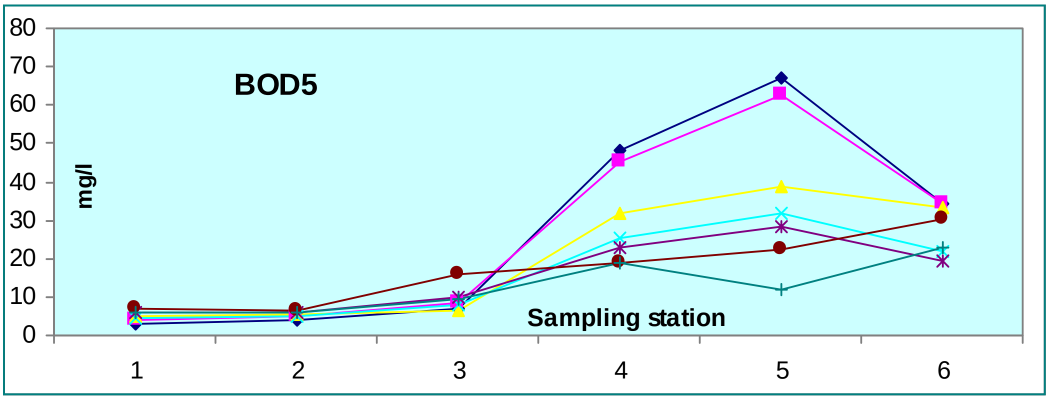


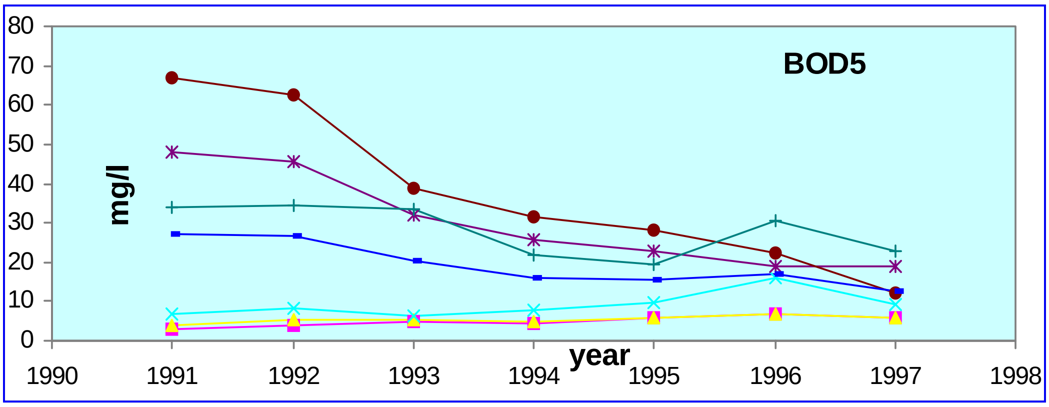


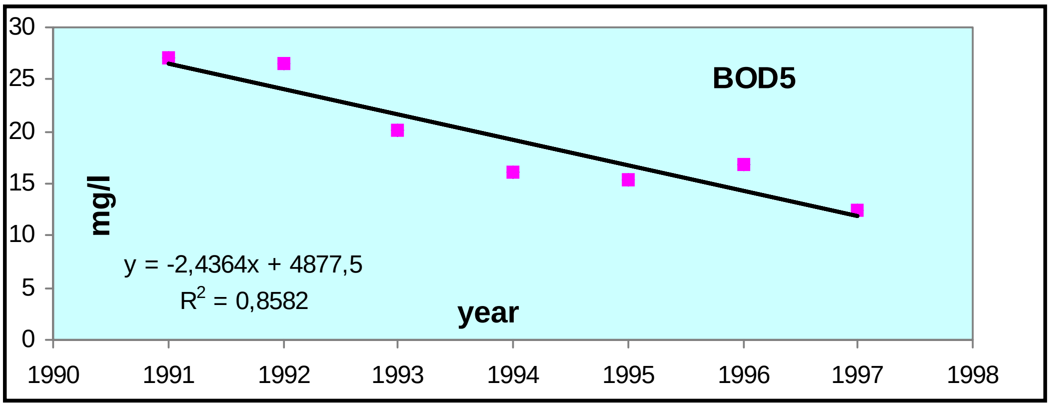
7.

Table/Figures A3. Physical/chemical water quality data from Suzhou Creek, annual means. Biological oxygen demand (in mgO2/l) from six stations in 1991 – 1997. Upper figure according to sampling station. Middle figure according to sampling year. Lower figure according to mean values for all seven years.

Station	1991	1992	1993	1994	1995	1996	1997
Bai He	2,83	3,79	4,73	4,51	5,79	6,94	6
Huang Du	4	5,15	5,47	4,98	5,81	6,62	5,77
Hua Cao	6,73	8,41	6,4	7,99	9,91	15,95	9,23
Bei Xing Jing	48,19	45,35	31,9	25,52	22,68	18,8	19,1
Wu Ning Lu	66,85	62,43	38,98	31,65	28,21	22,3	11,9
Zhe Jiang Lu	34,14	34,2	33,27	21,79	19,35	30,5	22,7
Mean	27,123	26,56	20,13	16,07	15,29	16,85	12,5

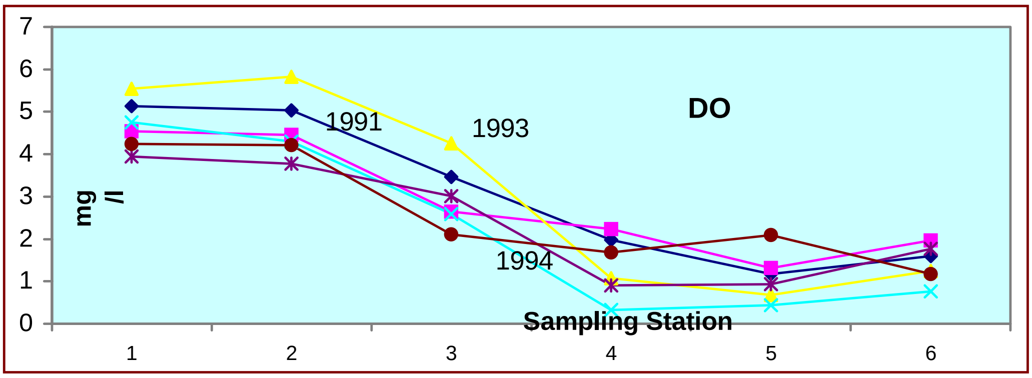


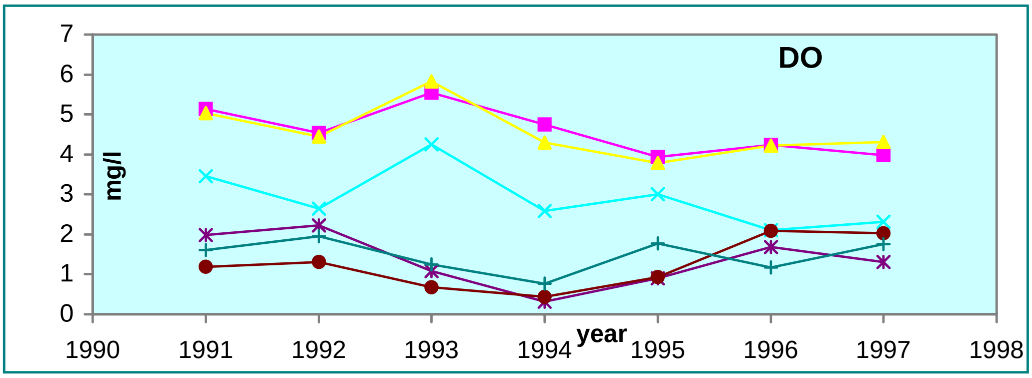


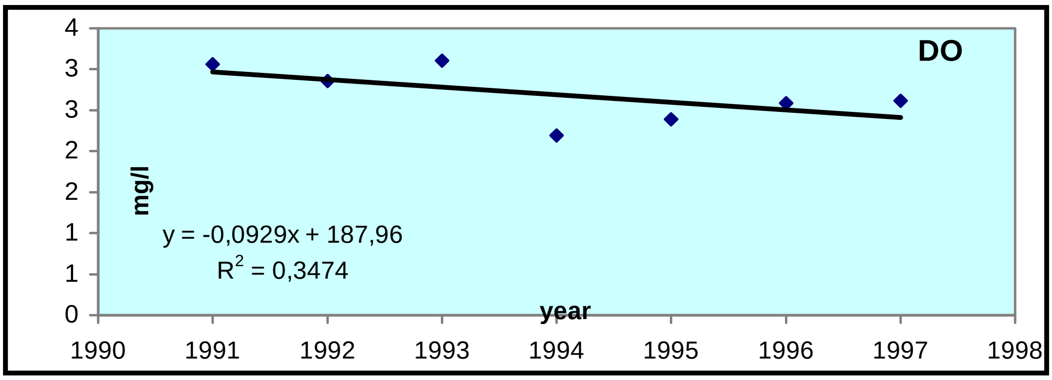


Table/Figures A4. Physical/chemical water quality data from Suzhou Creek, annual means. Dissolved oxygen (in mgO2/l) from six stations in 1991 – 1997. Upper figure according to sampling station. Middle figure according to sampling year. Lower figure according to mean values for all seven years.

Station	1991	1992	1993	1994	1995	1996	1997
Bai He	5,14	4,54	5,55	4,75	3,94	4,24	3,98
Huang Du	5,03	4,45	5,83	4,3	3,78	4,22	4,31
Hua Cao	3,46	2,65	4,25	2,59	3,01	2,11	2,32
Bei Xing Jing	1,98	2,23	1,08	0,32	0,9	1,68	1,31
Wu Ning Lu	1,18	1,31	0,68	0,44	0,93	2,09	2,03
Zhe Jiang Lu	1,6	1,96	1,25	0,76	1,77	1,17	1,76
Mean S.C.	3,07	2,86	3,11	2,19	2,39	2,59	2,62

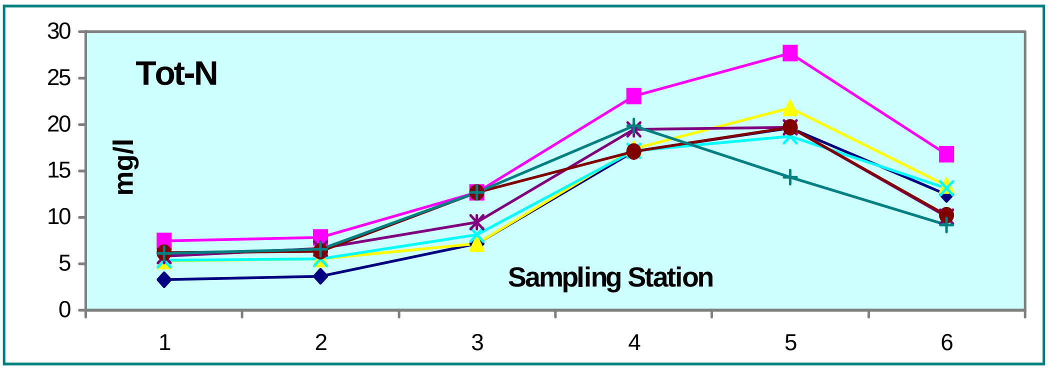


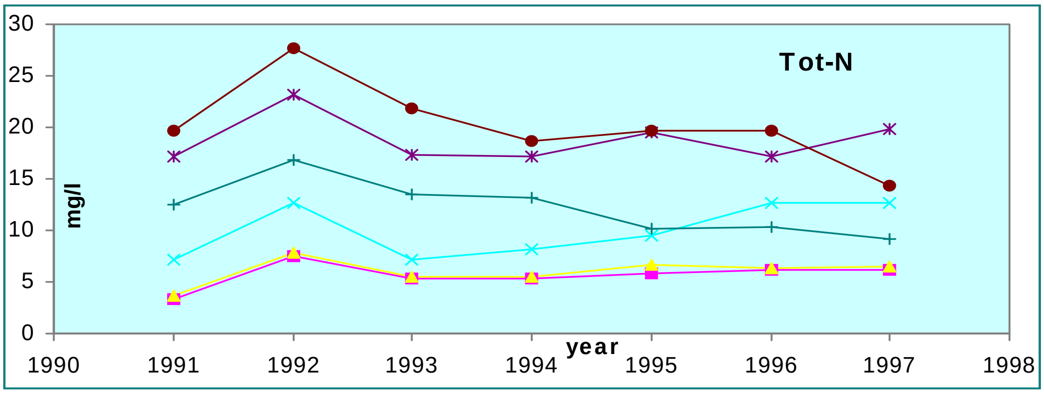


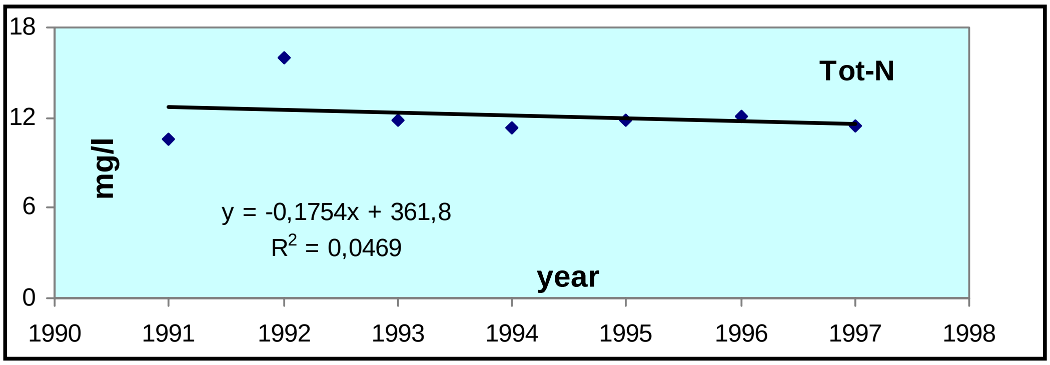


Table/Figures A5. Physical/chemical water quality data from Suzhou Creek, annual means. Total nitrogen (in mg/l) from six stations in 1991 – 1997. Upper figure according to sampling station. Middle figure according to sampling year. Lower figure according to mean values for all seven years.

Station	1991	1992	1993	1994	1995	1996	1997
Bai He	3,28	7,49	5,33	5,39	5,83	6,18	6,14
Huang Du	3,62	7,87	5,53	5,53	6,62	6,35	6,56
Hua Cao	7,13	12,7	7,18	8,14	9,45	12,65	12,69
Bei Xing Jing	17,09	23,09	17,4	17,16	19,51	17,1	19,86
Wu Ning Lu	19,6	27,71	21,79	18,71	19,72	19,69	14,3
Zhe Jiang Lu	12,43	16,76	13,43	13,11	10,11	10,26	9,18
Mean	10,53	15,94	11,78	11,34	11,87	12,04	11,46

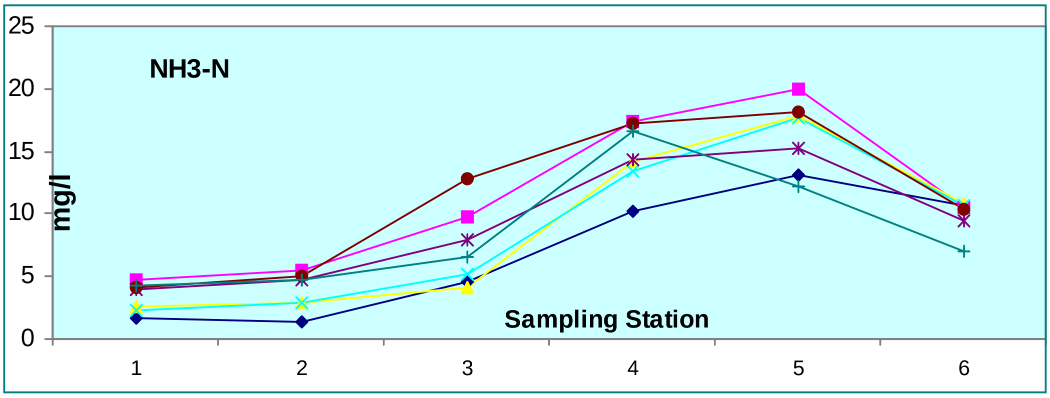


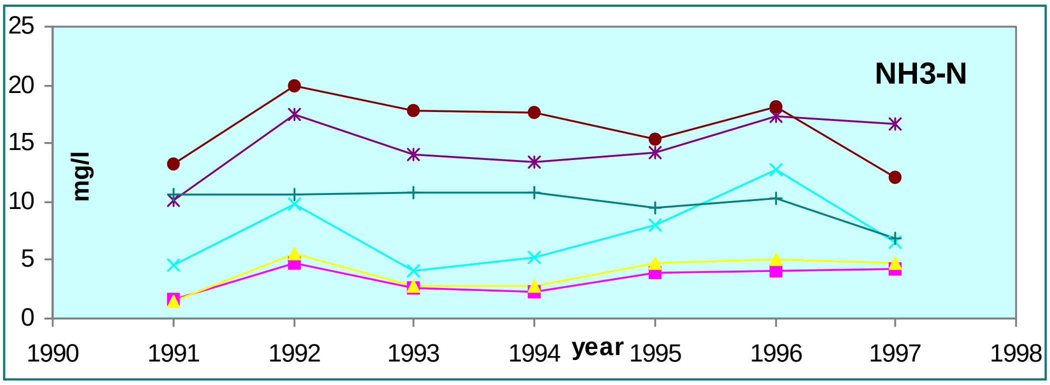


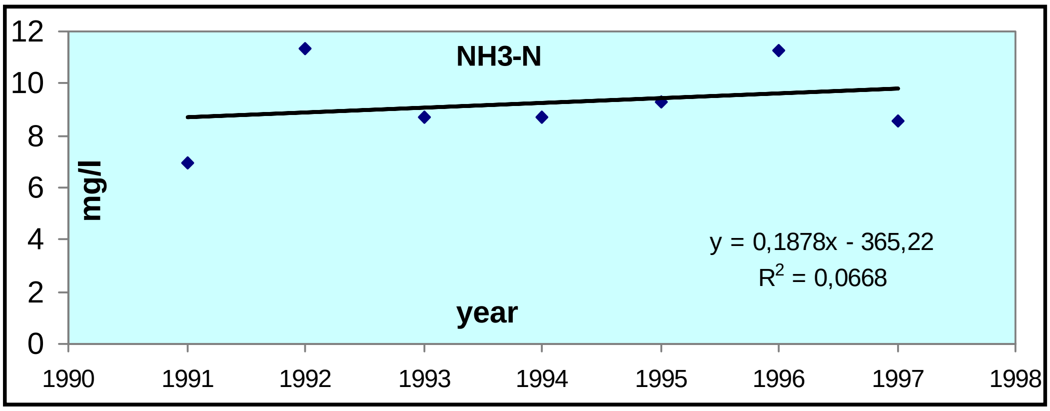


Table/Figures A6. Physical/chemical water quality data from Suzhou Creek, annual means. NH3-N (in mg/l) from six stations in 1991 – 1997. Upper figure according to sampling station. Middle figure according to sampling year. Lower figure according to mean values for all seven years.

Station	1991	1992	1993	1994	1995	1996	1997
Bai He	1,65	4,72	2,65	2,35	4	4,11	4,24
Huang Du	1,41	5,49	2,85	2,85	4,74	4,99	4,74
Hua Cao	4,5	9,77	4,12	5,16	7,93	12,75	6,5
Bei Xing Jing	10,21	17,44	14,13	13,34	14,28	17,3	16,7
Wu Ning Lu	13,18	19,93	17,8	17,66	15,32	18,11	12,1
Zhe Jiang Lu	10,67	10,56	10,8	10,72	9,45	10,31	6,94
Mean	6,93	11,32	8,73	8,68	9,29	11,26	8,54

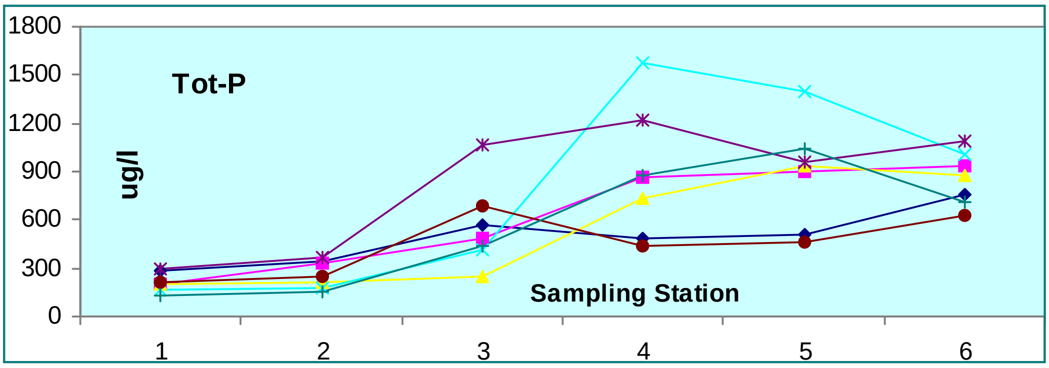


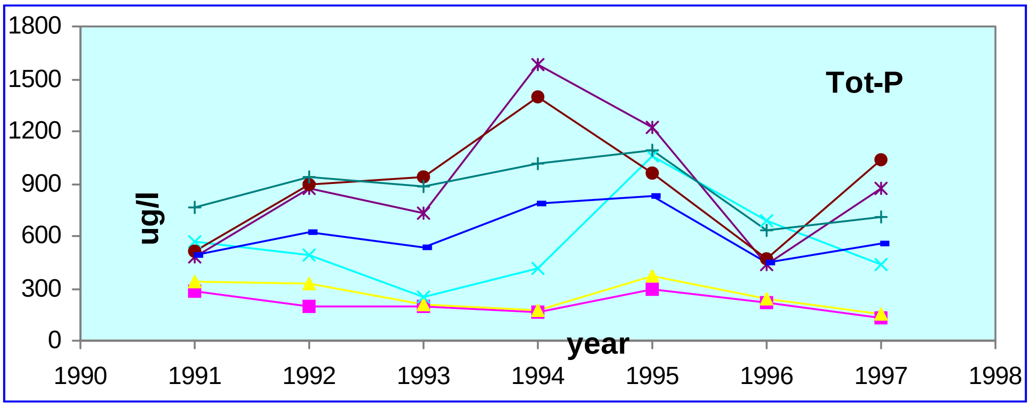


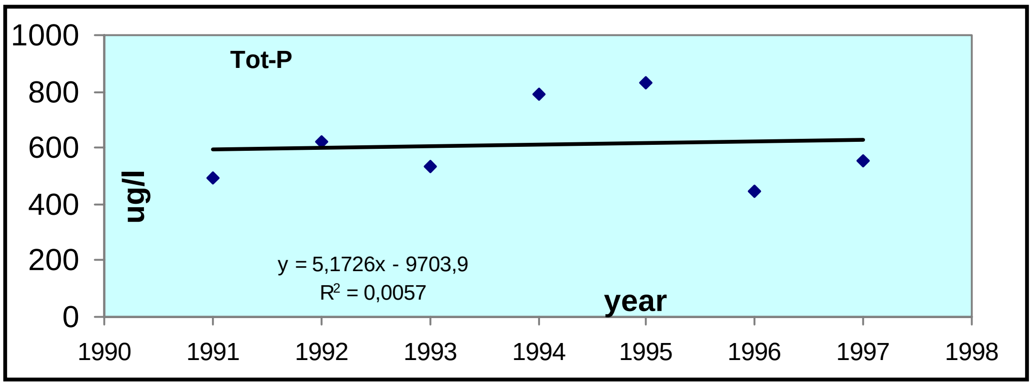


Table/Figures A7. Physical/chemical water quality data from Suzhou Creek, annual means. Total phosphorus (in ug/l) from six stations in 1991 – 1997. Upper figure according to sampling station. Middle figure according to sampling year. Lower figure according to mean values for all seven years.

Station	1991	1992	1993	1994	1995	1996	1997
Bai He	280	200	200	160	300	219	131
Huang Du	340	330	210	180	370	243	149
Hua Cao	570	490	250	410	1060	685	434
Bei Xing Jing	480	870	730	1580	1220	437	871
Wu Ning Lu	510	900	940	1400	960	464	1038
Zhe Jiang Lu	760	940	880	1010	1090	632	710
Mean	490	621	535	790	833	446	556

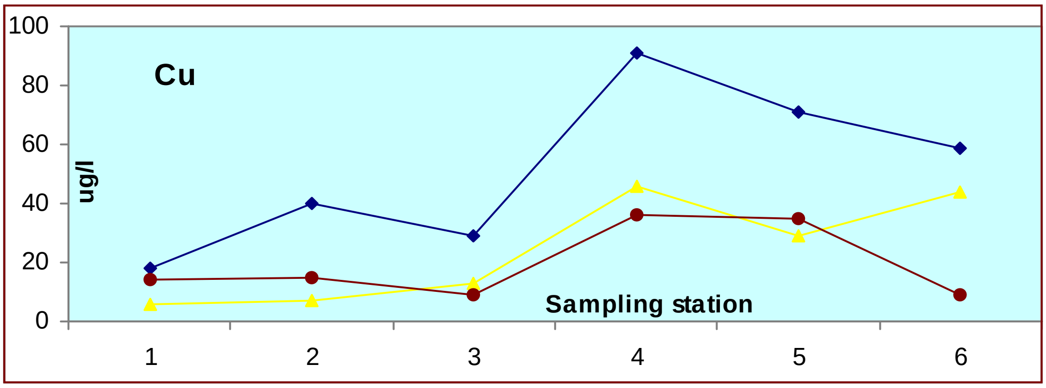


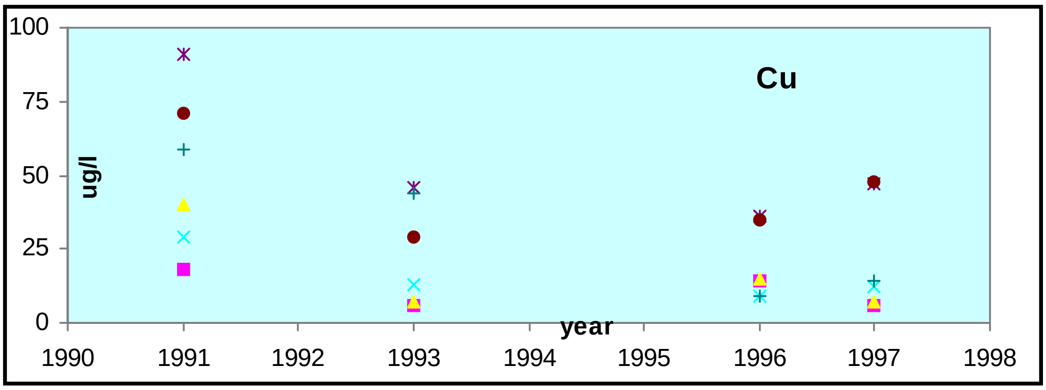


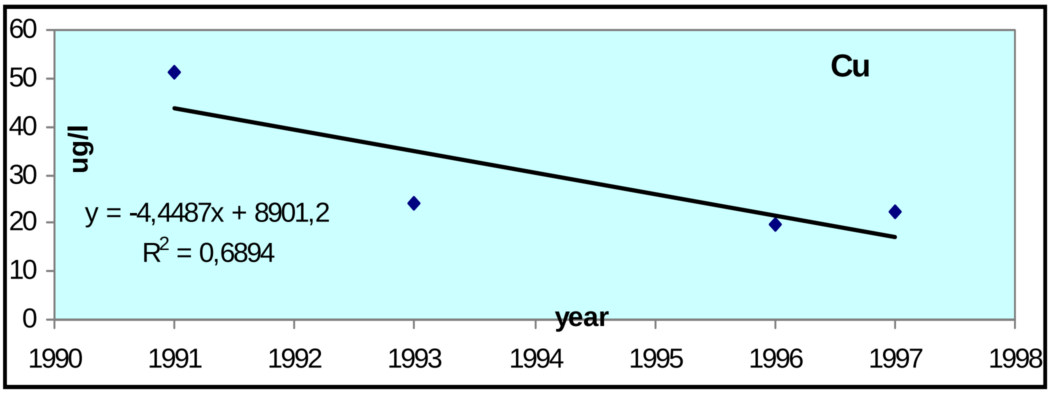


Table/Figures A8. Physical/chemical water quality data from Suzhou Creek, annual means. Copper (in ug/l) from six stations in 1991 – 1997. Upper figure according to sampling station. Middle figure according to sampling year. Lower figure according to mean values for all seven years.

Station	1991	1992	1993	1994	1995	1996	1997
Bai He	18		6			14	6
Huang Du	40		7			15	7
Hua Cao	29		13			9	12
Bei Xing Jing	91		46			36	47
Wu Ning Lu	71		29			35	48
Zhe Jiang Lu	59		44			9	14
Mean	51		24			20	22

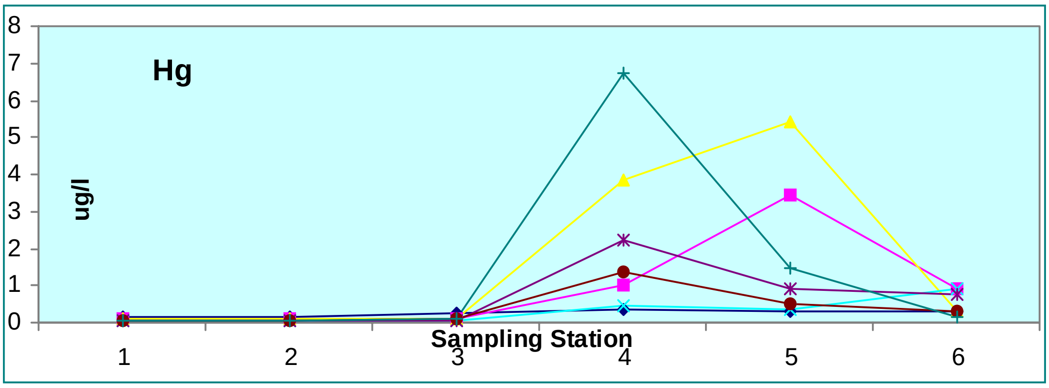


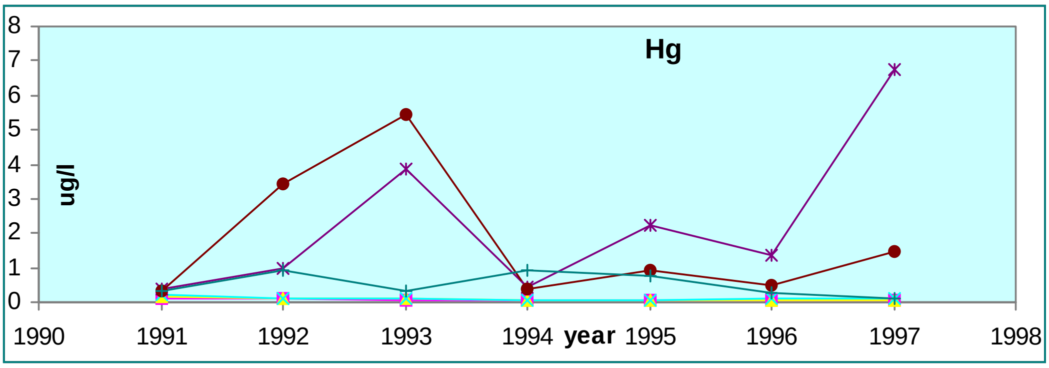


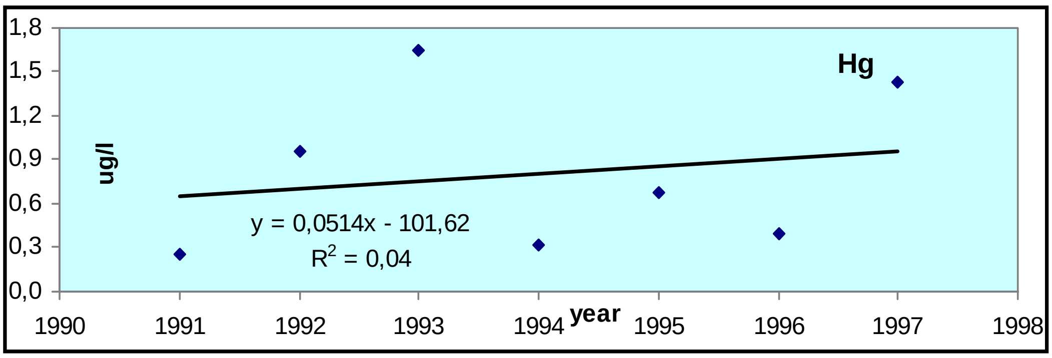


Table/Figures A9. Physical/chemical water quality data from Suzhou Creek, annual means. Mercury (in ug/l) from six stations in 1991 – 1997. Upper figure according to sampling station. Middle figure according to sampling year. Lower figure according to mean values for all seven years.

Station	1991	1992	1993	1994	1995	1996	1997
Bai He	0,13	0,09	0,08	0,05	0,05	0,06	0,06
Huang Du	0,16	0,12	0,1	0,05	0,06	0,05	0,06
Hua Cao	0,24	0,12	0,09	0,06	0,05	0,12	0,12
Bei Xing Jing	0,37	1	3,87	0,44	2,25	1,35	6,75
Wu Ning Lu	0,32	3,45	5,43	0,36	0,9	0,5	1,45
Zhe Jiang Lu	0,3	0,93	0,3	0,93	0,74	0,28	0,13
Mean	0,25	0,95	1,65	0,32	0,68	0,39	1,43

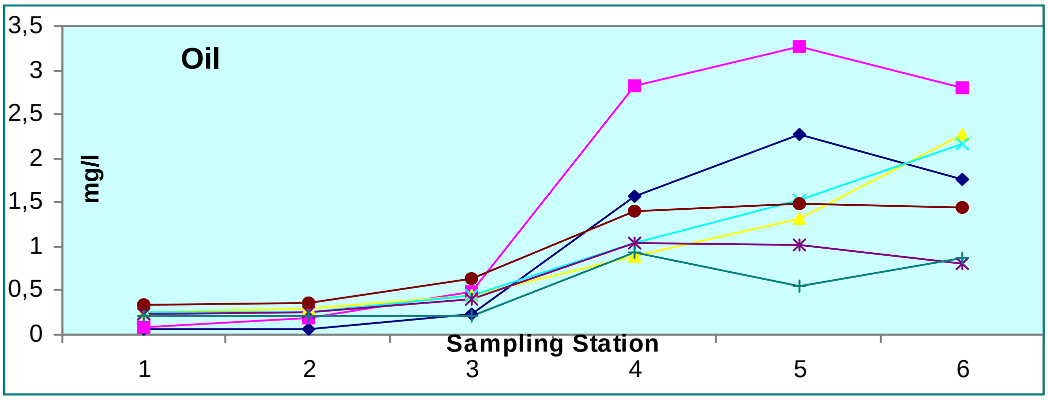


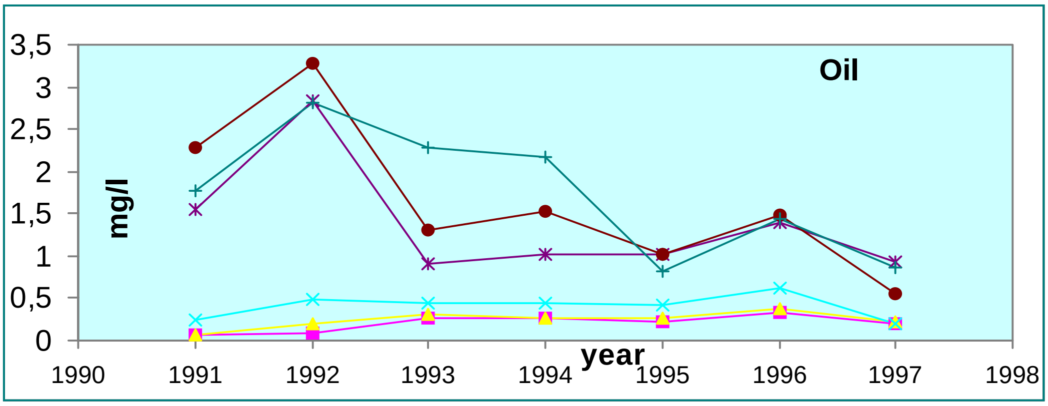


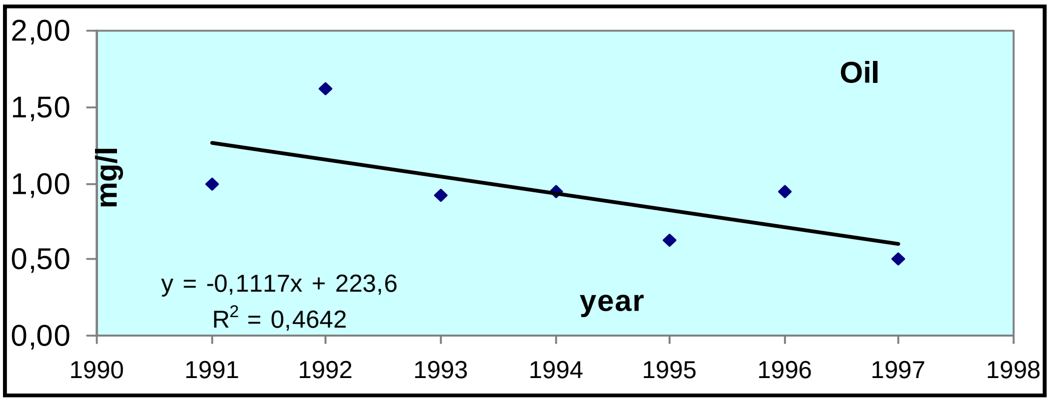


Table/Figures A10. Physical/chemical water quality data from Suzhou Creek, annual means. Oil (in mg/l) from six stations in 1991 – 1997. Upper figure according to sampling station. Middle figure according to sampling year. Lower figure according to mean values for all seven years.

Station	1991	1992	1993	1994	1995	1996	1997
Bai He	0,07	0,09	0,26	0,26	0,23	0,33	0,21
Huang Du	0,06	0,2	0,3	0,26	0,26	0,37	0,22
Hua Cao	0,24	0,49	0,44	0,45	0,41	0,63	0,21
Bei Xing Jing	1,56	2,83	0,9	1,03	1,03	1,39	0,94
Wu Ning Lu	2,28	3,27	1,31	1,53	1,01	1,49	0,55
Zhe Jiang Lu	1,77	2,81	2,28	2,16	0,81	1,44	0,87
Mean	1,00	1,62	0,92	0,95	0,63	0,94	0,50

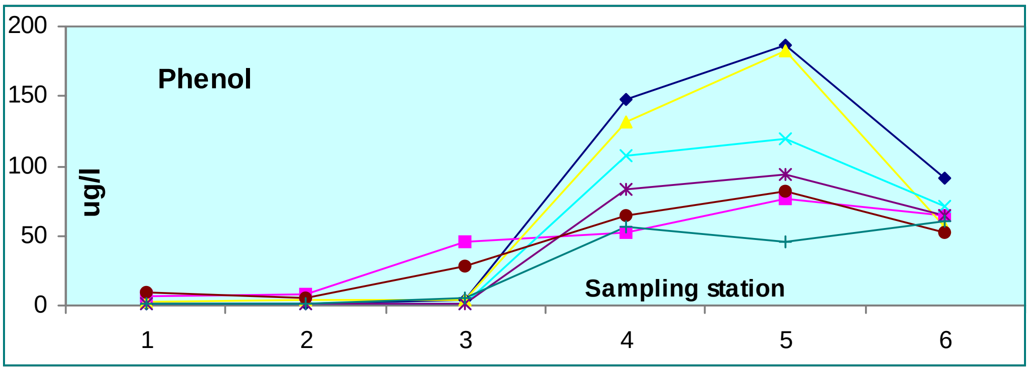


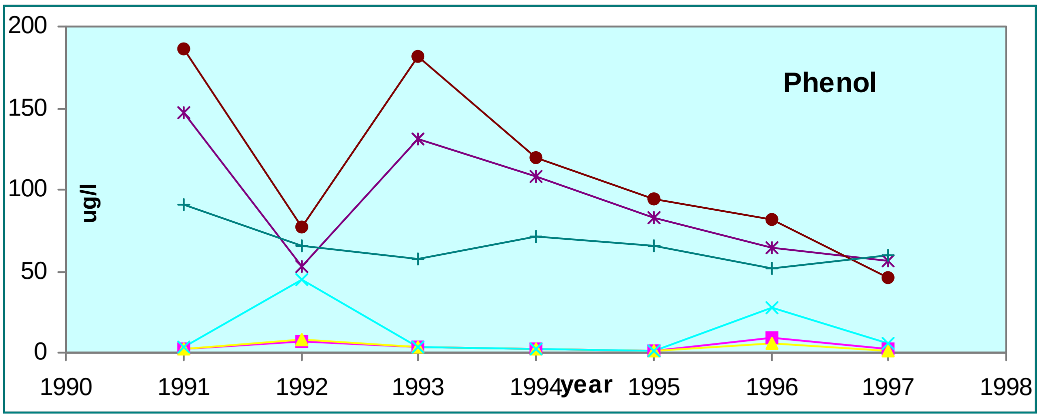


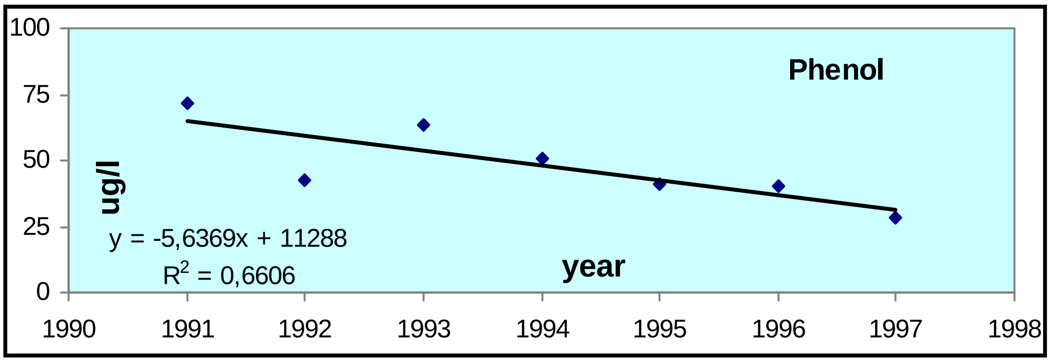


Table/Figures A11. Physical/chemical water quality data from Suzhou Creek, annual means. Phenol (in ug/l) from six stations in 1991 – 1997. Upper figure according to sampling station. Middle figure according to sampling year. Lower figure according to mean values for all seven years.

Station	1991	1992	1993	1994	1995	1996	1997
Bai He	2	7	3	2	1	9	2
Huang Du	2	8	4	2	1	6	1
Hua Cao	4	45	4	2	1	28	6
Bei Xing Jing	147	53	131	108	83	64	56
Wu Ning Lu	186	77	182	120	94	82	46
Zhe Jiang Lu	91	65	57	71	65	52	60
Mean	72	42	64	51	41	40	29







Appendix B

Biological monitoring data

Table B1. Phytoplankton groups and species arranged according to sampling localities in Suzhou Creek. Samples taken 3 June 1998

	Bai He	Huang Du	Hua Cao	Bei Xing Jing	Wu Ning Lu	Zhe Jiang Lu
Chlorophyceae						
Ankistrodesmus falcatus	*					
A . hantzschii			**			
Closterium sp.			*	**		*
7.1.1 C. asteroideum		*		**		
C. microprum			**			
C. limneticum					**	
Chlamydomonas sp.	**		*			
Crucigenia tetrapedia	*	*	*	*	*	
C. fenestrata			**			
Crucigeniella pulchra	*	*		*		
Dictyosphaerium subsolitarium			*			
Kirchneriella obesa	*	*			*	*
Koliella. longiseta						**
Monoraphidium contortum	*		*			
M. minutum	*	*				
Occystus sp.					*	
Pandorina cf. charkowiensis	*		*			
P. morum			*			
Pediastrum privum		*				
Pediastrum duplex			*	**		
Scenedesmus acutus				**		
S. armatus	*	*	*	**		
S. bicaudatus	*			*		
Scenedesmus sp.		*	*			
S. denticulatus			**	**	**	
S. dimorphus			**			
S. opoliensis			**	**	*	**
S. quadricauda			**	*		
S. ecornis					*	
S. spinosus					**	
Selenastrum capricornutum			*		**	
Tetrastrum staurogeniforme		*	*	**	*	*
Tetmedron minimum				*		
Chlorella sp.		*			*	
Xanthophyceae						
Centritractus belenophorus			*			

Table B1. continue

	Bai He	Huang Du	Hua Cao	Bei Xing Jing	Wu Ning Lu	Zhe Jiang Lu
Chrysophyceae						
Mallomonas spp.	*					
Ochromonas sp.						*
small Chrysomonades (<7)	**	*	***	***	***	**
bigger Chrysomonades (>7)	**	*	***	**	***	**
Synura sp.	*					
Bacillariophyceae						
Aulacoseira gramilata v. angustissima	*		**	*		*
A. granulata					***	
Cyclotella meneghiniana	****	****	*****	****	****	***
Cyelotella sp.		**				
Fragilaria ulna "acus"	*	*	*	*		
F. ulna "ulna"	*	*				
Stephanodiscus hantzehii v. pusillus	***	***	****	***	****	*
Nitzschia sp.		*	**	*	*	*
Cryptophyceae						
unident. *Cryptomoate*		**				
Cryptomcnas cf. erosa	****	***	***			*
C. curvata	*					
C. erosa v. reflexa	***	***				
C marssonni.	*	**				
C. spp.	*	*				*
Rhodomonas lacustris	***	**	***	*		
Katablepharis ovalis			*			
Dinophyceae						
Ceratium furcoides	*	*	**			
Peridinium penardiforme	**					
Peridinium sp.	****	***	***			*
Euglenophyceae						
Euglena acus	*	*	**	**	**	
E. oxyuris v. minor	*	**	***			
Euglena sp.	*		**			*
Pharus curvicauda				**		
Ph. pleuronectes			**			
Ph. tortus			**	**		
Ph. longicauda				**		
Strombomonas verrucosa			*			
My algae						
My algae	*	***	***	***	***	**

Table B2. Zooplankton recorded from six stations in Suzhou Creek, taxonomically arranged, and collected 5 June 1998.

Species - Genus / Sampling station	Bai He	Huang Du	Hua Cao	Bei Xing Jing	Wu Ning Lu	Zhe Jiang Lu
Arcella sp.		x	x	x	x	
Arcella vulgaris				x		
Brachionus calyciflorus	x	x	x	x	x	x
Brachionus caudatus	x	x	x	x	x	x
Brachionus capsuliflorus			x			
Brachionus angularis		x		x		
Brachionus urceus		x	x	x		x
Schizocerca diversicornis	x					
Vorticella sp.				x		
Asplanchna priodorta	x	x	x			
Filinia longiseta		x	x	x		
Filinia maior	x				x	x
Polyarthra trigulu	x	x	x	x		
Diaphanosoma brachyurum	x	x	x			
Diaphan. leuchtenbergum		x				
Diaphanosoma sarsi	x	x	x	x	x	
Bosmina fatalis	x	x	x		x	x
Bosminopsis richard		x				
Monia micrura		x	x	x		
Schmackeria forbesi		x				
Moinodaphnia macleayii						x
Daphnia magna						x
Microcyclops sp.						x
Eucyclops serrulatus	x	x	x	x		
Mesocyclops leuckarti		x	x		x	x
Mesocyclops sp.				x		
Thermocyclops hyalinus	x	x		x	x	x
Thermocyclops sp.			x	x		

Table B3. Macro-invertebrates identified from six stations in Suzhou Creek, sampled 5 June, 1998

	Bai He							**Huang Du**				
Species-Group/Sample no.	**1**	**3**	**4**	**5**	**6**	**Sum**	**Ind./m2**	**1**	**2**	**3**	**Sum**	**Ind./m2**
Limnodrilus hoffmeisteri	1	1	4		1	7	12385	2		8	10	10616
Branchiura sowerbyi			1			1	1769					
Tubifex sinensis	2	1			5	8	14154					
Nais variabilis		1				1	1769					
Sum Oligochaeta	**3**	**3**	**5**		**6**	**17**	**30078**	**2**		**8**	**10**	**10616**
Barbronia weberi	4	1		1		6	10616		1		1	1062
Batracobdella nuda	4			2	5	11	19462					
Hirudinea unidentified							0	5	3	6	14	14862
Sum Hirudinea	**8**	**1**		**3**	**5**	**17**	**30078**	**5**	**4**	**6**	**15**	**15924**
Bellamya aeruginosa	1					1	1769					
Bellamya limnophila		1		1	1	3	5308					
Stenothyra grabra		1			1	2	3539					
Semisulcospira mandarina		1				1	1769					
Sum Gastropoda	**1**	**3**		**1**	**2**	**7**	**12385**					
Corbicula langilliarti	1					1	1769					
Sum Bivalvia	**1**					**1**	**1769**					
Insecta, Diptera		**1**				**1**	**1769**	**1**	**10**		**11**	**11677**
Sum Macro-invertebrates	**13**	**8**	**5**	**4**	**13**	**43**	**76079**	**8**	**14**	**14**	**36**	**38217**

Table B3. continue

	Hua Cao						**Bei Xing Jing**							
Species-Group/Sample no.	**1**	**2**	**3**	**5**	**Sum**	**Ind./m2**	**1**	**2**	**3**	**4**	**5**	**6**	**Sum**	**Ind./m2**
Limnodrilus hoffmeisteri	71		41	98	210	297240								
Branchiura sowerbyi	1		1	1	3	4246								
Tubifex sinensis														
Nais variabilis														
Sum Oligochaeta	**72**		**42**	**99**	**213**	**301486**								
Barbronia weberi														
Batracobdella nuda														
Hirudinea unidentified														
Sum Hirudinea														
Bellamya aeruginosa														
Bellamya limnophila														
Stenothyra grabra														
Semisulcospira mandarina														
Sum Gastropoda														
Corbicula langilliarti														
Sum Bivalvia														
Insecta, Diptera												**5**	**5**	**10616**
Sum Macro-invertebrates	**72**	**0**	**42**	**99**	**213**	**301486**	**0**	**0**	**0**	**0**	**0**	**5**	**5**	**10616**

Table B3. continue

	Wu Ning Lu								Zhe Jiang Lu							
Species-Group/Sample no.	**1**	**2**	**3**	**4**	**5**	**6**	**Sum**	**Ind./m2**	**1**	**2**	**3**	**4**	**5**	**6**	**Sum**	**Ind./m2**
Limnodrilus hoffmeisteri									6	4	1	9	2	12	34	72187
Branchiura sowerbyi									1			1		1	3	6369
Tubifex sinensis																
Nais variabilis																
Sum Oligochaeta									**7**	**4**	**1**	**10**	**2**	**13**	**37**	**78556**
Barbronia weberi																
Batracobdella nuda																
Hirudinea unidentified																
Sum Hirudinea																
Bellamya aeruginosa																
Bellamya limnophila																
Stenothyra grabra																
Semisulcospira mandarina																
Sum Gastropoda																
Corbicula langilliarti																
Sum Bivalvia																
Insecta, Diptera																
Sum Macro-invertebrates	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**7**	**4**	**1**	**10**	**2**	**13**	**37**	**78556**