Comparison with Water uality of main Rivers in the world, based on OECD reports

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Abstract: We are faced with water pollutions on a population explosion. Considering the importance, we research European rivers based on OECD reports. Observations in the reports have defects that make evaluation of environmental situations be difficult. By using interpolations in the compensation quantitative structure-activity relation ships (CQSAR), we complement the defects in the water quality of rivers through big cities. Thus, we get complete data set for dissolved oxygen, biochemical oxygen demand, and total phosphorus. Using the data set, we examine re-naturalization of the Rhein and the Donau in Germany. We investigate the effect of dams between Slovakia and Hungary, by using reconstructions of neural networks in CQSAR. The reconstructions have functions to extract a principal relation. On the investigation, we examine assertions of conservation groups. As the result, we confirm the re-naturalization is effective, and find a negative effect of the dam construction on changes of dissolved oxygens in the Hungary Donau. We investigate the Seine and the Thames, too.

Keywords: water quality, Donau, Danube, Rhein, Rhine, re-naturalization, CQSAR

1. INTRODUCTION

We recognize the environmental problem to be important, today. We didn t attach the problem to reusable resources that were atmosphere, water, forest, and soil. However, that was inappropriate viewpoint. We see that the reusable resources are lapsing into an irreparable state [1]. OECD has published environmental data [2]. We believe there are important environmental information in them; and we wish to detect it by using neural network technologies.

Fresh water is indispensable to survival of man. 70% of the water is ice, and 29% is groundwater [3]. Although the river water is only 0.003%, it is a reusable important resource. Without effective use of the water, it is difficult to maintain today s society [4]. Most human beings live in cities, who take the water from rivers and drain sewage out rivers. So, it is important to watch water pollution of rivers that flow through cities. We find the water quality data in the OECD reports.

Our objective is to research the water pollution on scientific approaches. We use the compensation quantitative structure-activity relationships (CQSAR) that is our developed program product [5]. We have published the functions and the application in ICCAS 03/ 04 [6]. We believe OECD reports can be used for the object. We wish to investigate the reports and to predict the future of fresh water quality.

There are many defects in the OECD s, especially, in water quality data; therefore, the approaches are not so easy. We interpolate the defects on use of a function built in CQSAR. Although there are many rivers listed in OECD reports, we use data in European rivers. The rivers flow through big cities. Their characters have been changed by many public works. Thus, the water quality data includes much information.

2. WATER UALIT DATA and INTERPOLATION

2.1 Characters of water uality data

Water quality data in OECD reports include many observations. However, on each river, the observed number is 12-16 in 20 years [2]. The remains are defects. So, it is insufficient to evaluate status of rivers. The characters are;

1 the background is uniform or is changed slightly,

2 the sway has short period,

Extrapolation of the background is significance, but the sway is not.

Since we derive a significant from the insufficient data, an inter/extrapolation method is required. Non-linear method is high precision; however, the adoption is difficult because of the data characters.

2.2 Selection of interpolations

First, we tried multi-layer neural networks (a nonlinear method) which have robustness against noises. However, they emulated the sway of 2) , and didn t separate the background. After trials of low-pass filters, we adopted the least-squares method of a linear function. However, if it is used on assembly of partial-set of observed terms, the method is expaned as followings.

We write observations as $_i$ y_i, x_i , $0 \leq i$ N.

The expected linear function is expressed, y ax b,

so, the expectation E is, E $\Sigma_{i\ 0,N\ 1}$ $_i$ ax_i b ^{2}.

Using the differentials, $\partial E/\partial a$ 0, $\partial E/\partial b$ 0, we get,

$$a \quad N\Sigma xiyi \ \ \Sigma xi\,\Sigma yi \ / \ N\Sigma xi^2 \quad \Sigma xi \ ^2 \ ,$$

$$b \quad \Sigma xi^2\,\Sigma yi \ \ \Sigma xiyi\,\Sigma xi \ / \ N\Sigma xi^2 \quad \Sigma xi \ ^2 \ .$$

This is normal least-squares method. We can rewrite,

$$E_M \quad \Sigma_{i\ 0,M\ 1} \quad _i \ ax_i \ \ b \ ^2, M \quad N\ 1.$$

We get a_M, b_M, and y $_M$ ax b $_M$. So, we can represent non-linear function of $_i$ as assembly of y_M as,

$$\Sigma_{L\ 0,N\ 1\ M}\ y_L \ / \ N\ 1\ M \ .$$

The natural environment has been changed in 20 years. The period in 1980-1999 had a large change as an inevitable result of human beings economic development and globalization. Therefore, we don t believe that a function is valid for 20 years [7]. We complemented water quality data with the function in a period of 10 years. Thus; y_1 y_2,

E_1 $\Sigma_{i\ 1980,1990}$ p_i ax_i b ^{2}, E_2 $\Sigma_{i\ 1990,1999}$ p_i ax_i b ^{2},

where the suffix i means observed years, and the observation of 1990 must be overlapped.

The short complement was considered also. Although it is close to non-linear fitting, in many cases the defects were continual for 4-5 years, we judged the measurement data would be needed in the period of about 10 years.

By using the least-squares method, we extrapolate observations linearly. Where there is no increase of information; however, it is necessary when we examine relations between environmental status and economical indexes that are not represented numerically. If the environmental problem is considered without economical considerations, we cannot take effective measures.

2.3 Marking of European rivers

Considering meanings of water quality indexes, we mark rivers that have low dissolved oxygen (DO), and high biological oxygen demands (BOD), and high total-phosphorus (T-P).

About DO the Guadalquivir Spain , the Gediz Turkey , and the Seine rance .

About BOD the Severn Britain , the Guadalquivir, and the Morava Czech Republic .

About T P the Thames UK , the Mersey UK , the Seine.

We should also mark rivers that flow big cities; these are;

the Seine Paris , the Thames London , the Rhein Koln , the Donau Vienna, BudaPest .

We find many reports about these rivers, where the current status of nature are shown. However, we read few article that shows the time series of pollutions and the causes. We have CQSAR that interpolates defects and finds the causality. We have examined it in water quality problems of Tamagawa in Tokyo [6]. Thus, we reconstruct the time series of rivers pollutions and forecaste the causality on the information technique.

2.4 Re-naturali ation of rivers in Europe

In some European rivers, banks have broken down and vast flood fields are revived. To revive natural flow in rivers, and to increase in self-purification functions, it is a new thought of river improvement. It is called re-naturalization.

In the 1980s, environmental directives about the pollution of surface waters were concluded in EC (EU in after years). The directives regulated that each country drains contamination into rivers. At the end of 80s, directives of rivers maintenance were merged [8]. There is a possibility that the reflections are found in the water quality data of OECD.

3. DO VALUES OF T E DONAU

3.1 Comparison of Germany-, Austria-, ungary-Donau

Oxygen in water is expressed by the DO index [mg/L]. The index is related to self-purification of rivers, survival of aquatic life. It is known fishes survive in the water over 5 [mg/L]. Amounts of DO are decreasing when rivers are contaminated. We show DO-changes of the Donau in Fig.1.

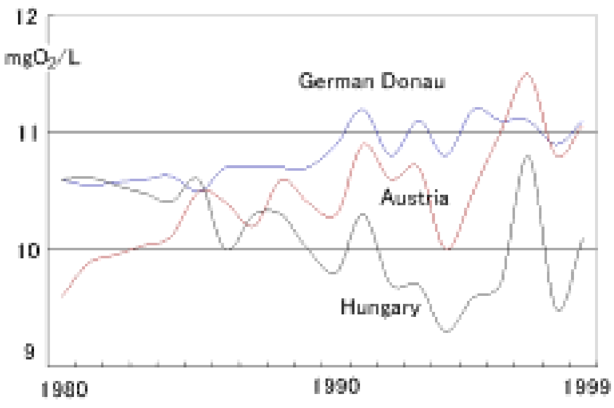

Fig.1. Changes of DO-index of the Donau.

The figure is plotted by observations and interpolated data of 4-6. Each curves are drawn by E CEL, and the smoothing function is used. The observations are in OECD reports, and the interpolation method is in section 2.2. Data in the downstream, ugoslavia and Romania, are not published.

The Donau is an international river that flows Germany, Austria, Hungary, and so on. The DO values in Fig. 1 are high, which are more than 7.5 [mg/L]. It is the water of type A in Japanese standard. Fig. 1 shows that Germany and Austria domains are becoming pure in these 20 years. The sanctification in Austria is large especially. On the other hand, in Hungary, the sanctification is not found, and it is regressing. It is a remarkable fact.

3.2 Dam and DO values in ungary

CzechoSlovakia and Hungary have agree with a plan to make dams, Gabcikovo and Nagymaros, in 1977 [9]. The construction started in 1987, and it had completed 90% on 1989/7. However, Hungary interrupted the construction, under rising of campaigns against the dams. It is well known an international dispute. Since we find a document in Web [10], we believe the dams are completed. DO value of the Hangary Donau is deteriorated from 1980 to 1992 of agreement cancellation. After that, the DO level is kept near the cancellation point.

Branches in the Donau are in table 1. To find the cause of deterioration, we investigated relation among the branch s water and main stream.

Table1. Branches of the Donau

country	confluence city	tributary1	tributary2
Germany	Deggendorf	Isar	
Austria	Passau	Inn	
	Linz, Wien		
Slovakia	Bratislava	Morava（from Czech）	
	Komarno	Vah	
Hungary	(no confluence)	Tisza	
	BudaPest		
Yugoslavia	Beograd	Tisza	Sava(from Croatia, Bosnia-Hercegovina)
	Smederevo	Morava(Yugo's)	
Romania			
Black Sea			

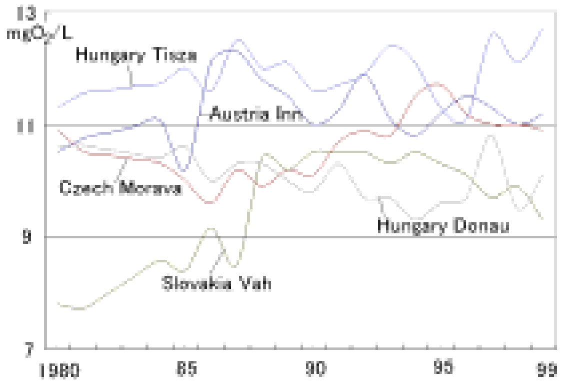

Fig.2 DO changes of Donau branches (the Inn, the Morava, the Vah, the Tisza) before BudaPest.

We think that the measurement point of Hangary Donau is BudaPest from science chronology [3].

The DO value of the Hungary Donau is well alike to the water quality of the Morava and the Inn in 1980-1987. The Vah has small contribution. The Donau is polluted by the Vah till 1987. After it, the river is purifying the Donau. The water quality of the Inn headed for improvement since 1985. The quality of the Morava was improved after delay of 2 or 3 years. However, the water quality of the Hungary Donau after 1988 was not improved. It shows that the water is not contaminated by branches.

Re-naturalization of the Inn is reported, which has carried out from around 1988 [11]. It seems that the effect has appeared in the Austria Donau; however, the water quality of the Hungary Donau is deteriorating. The factor of dam construction cannot be disregarded. It is shown that DO value of another big river Tisza (that flows to ugoslavia and joins the Donau) of Hungary domain is high for 20 years. Therefore, we believe the contamination is little in Hungary.

Fig. 3 shows resemblance of DO values between Hangary Donau and these branches, which are calculated by Euclid distances.

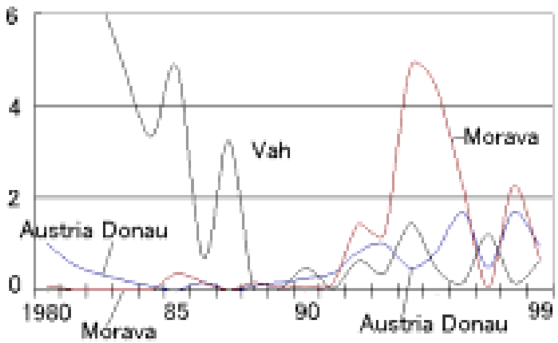

Fig. 3 Euclid distances of DOs among the Hungary-, the Austria-Donau, the Vah, the Morava.

Fig.3 showed that the DO value of the Hungary Donau was similar to the Morava till 1991, but it has been different since 1992. The water quality of Hungary Donau also differs from the Austria Donau of a main since 1992. These facts show that some accidents happened to the Donau around 1988-9 before 1992.

3.3 Effect of dam construction

We evaluated the effect of Gabcikovo-Nagymaros dams construction [12], as for the DO of the Hungary Donau. We used CQSAR [3,4], where a multi-layer neural network was learned by the back-propagation with the reconstructions. Information of dam construction and the lakes were represented by (0,1) vectors, which were called as dummy data .

Table2. Dummy data of dam construction and the lakes.

year	dam construction	dam lake completion
1980	0	0
1981	0	0
1982	0	0
1983	0	0
1984	0	0
1985	0	0
1986	0	0
1987	1	0
1988	1	0
1989	1	0
1990	1	0
1991	1	0
1992	1	0
1993	0	1
1994	0	1
1995	0	1
1996	0	1
1997	0	1
1998	0	1
1999	0	1

Using the dummy data and the DOs of the Austria Donau and the Morava, as descriptors of CQSAR, we calculated their effect. On the calculation, we should pay attention to the scaling of descriptors. In the scaling routine, interval [0, 1] is adopted automatically. If it was carried out, observations were multiplied by scaling coefficients. The coefficients were got for different kinds of measurements. Thus, the neural network learns correlation as a pattern of DO value change. It is not suitable. So, we converted scaling-codes to make the DO values be scaled by a common coefficient. After recoding, the neural network recognized the change as patterns with measured values.

The number of hidden-layer neurons was set to 4 at first, and the neurons were selected by back propagation learning with reconstructions. Finally, the neurons were reduced to 1. The learning error are shown in Fig. 4.

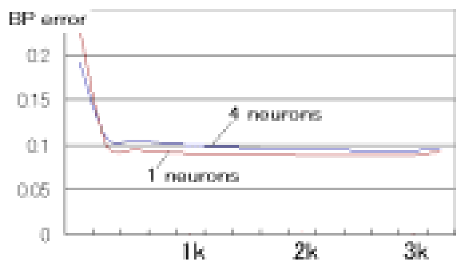

Fig. 4 Learning error of back propagation with reconstructions. The horizontal axis is learning-iterations. Even if it decreases hidden-layer neurons number from 4 to 1, there are no serious changes in the back propagation learning. That is, 3 neurons are unnecessary. The emulation functions are sigmoid- and linear-functions for hidden- and output-layers, respectively. When the functions are adopted, the whole of the neural network functions as a finite expansion. Therefore,

the learning error is not converged to 0, but it is close to a small value.

Fig. 5 shows DO value of the Hungary Donau and the output of a neural network in CQSAR. The standard deviation was 0.0252.

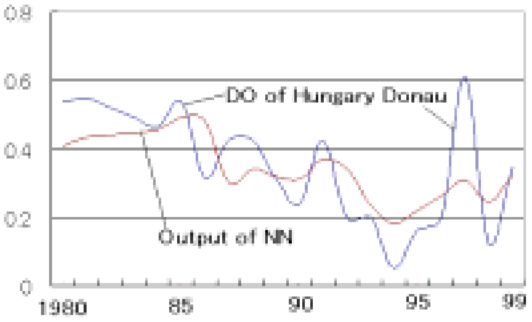

Fig. 5 DO of the Hungary Donau and output DO of a neural network in CQSAR. Both DOs are dimension-less. They are scaled in [0.05, 0.95], because of speed-up learning.

Selected connection weights between neurons are listed in Table 3.

Table 3 Connection weights between neurons. They are represented as ratios, and they have no unit.

descriptors	weight_matrix
dam construction	-9
dam lake	-16
the Morava	0
the Austria Donau	13

In Table 3, contribution of dam lakes, construction, and the Austria Donau is found. That of the Czech Morava is not found.

Environmental groups (MMF, Donau circle) assert that water quality of the Hungary Donau has deteriorated since 1980. For the DO value, their assertion is supported by the CQSAR calculation. However, it is insufficient to accept the assertion on the result only. We should investigate other indexes.

3.4 The Rhein basin system

The Rhein is a continent river that flows with Switzerland, the Germany, and the Netherlands. Fig. 6 shows that German Rhein and rivers in the Netherlands domains (Lobith, Mass Delta) are becoming pure in 20 years. The domain in Switzerland is the upper region and it is satisfactory to water quality now and past.

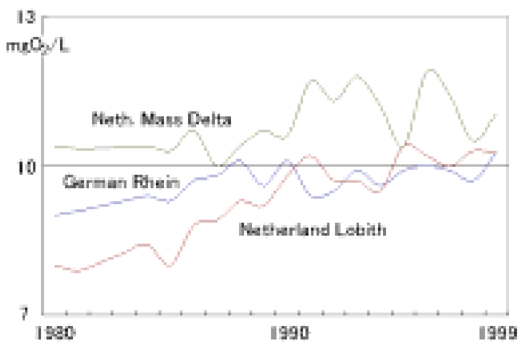

Fig. 6 DOs changes of the Rhein, the Lobith, and Mass Delta.

The Rhein s terminal in the Netherlands Mass Delta has high DO values, where is the lower region. The Do values are equal to that of upper region of another river, i.e., Tama River in Japan. We are impressed by the fact. Because, purification functions in river flood fields are imagined to be powerful.

The DOs of the Lobith and Germany Rhein are improved about 2 or 1 [mg/L] in 20 years. The improvement is more remarkable than the Donau. It is not purer over the Donau but same as. Considering the Rhein flows through many big cities, the purifying disposal would be extra-ordinary. We believe the disposal is based on the river re-naturalized policy.

3.5 The Guadal uivir, the Gedi , and the Seine

The DO values of the Guadalquivir (Spain), the Gediz (Turkey), and the Seine are in Fig. 7. The DO values at the present are lower than those at every region of another river.

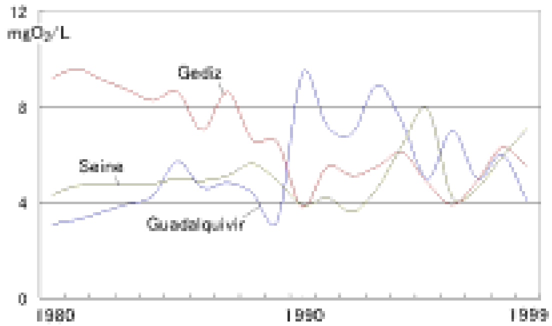

Fig. 7 DO changes of the Guadalquivir, the Gediz, and the Seine.

The Gediz s contamination becomes worse around 1988, and it is not recovered still now. It is same level in the lower region of Tama River (Japan) at 20 years ago. The Seine was polluted, which was improved during 20 years, slightly. So, the Seine is in undesirable level, now. The Guadalquivir was polluted till 1989. Improvement of 4-5 [mg/L] is found around 1990-4, whose cause is not understood. The observations are changed much, in the term. It seems to be strange. The river is contaminated again after the term. Considering those data, it is apprehensive in whether purifications are implemented effectively in the 3 rivers.

4. ODs OF DONAU, SEINU, T AMES

4.1 OD values of the Donau

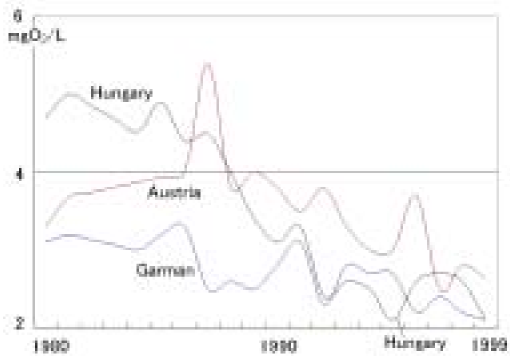

Fig. 8 BOD changes of the Donau.

The BOD of the Germany Donau is improved in these 20 years. The Austria Donau is polluted till 1987, and it is improved gradually after 1988. We believe the cause is re-naturalization. The Hungary Donau is improved straightly till 1992; after that, the improvement is stopped at the level of 1994. The water qualities of the 3 rivers are in a same level now, which are not so bad status.

We pay an attention that the water quality of down-stream Hungary is better than upstream Austria after 1988. Since BOD is an index that indicates self-purification power for organic compounds in rivers, it is accepted. The example can be used to determine a policy to purify rivers.

The BOD of Hungary Donau is not so bad, which is contrast with the DO-index.

4.2 Relation of water uality and dam construction

The DO of the Hungary Donau indicates bad effects of dams construction; however, the BOD doesn t do. We investigated the reason by using CQSAR. We used 4 kinds of descriptors, which are 2 kinds of dummy-data for dams construction, and others are BOD-values of the Austria Donau and the Morava. By reconstructions in CQSAR, the number of hidden layer s neurons is reduced to 1, and the standard deviation between the Hungary Donau s BOD and outputs of the neural network is 0.0115.

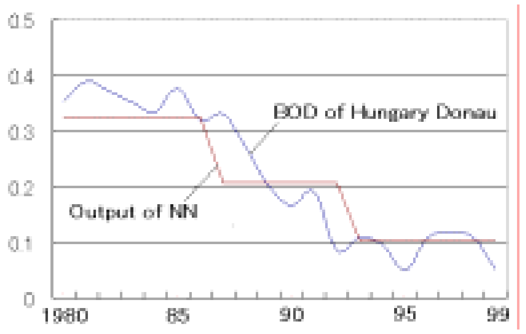

Fig. 9 BODs of the Hungary Donau and outputs of CQSAR.

CQSAR s neural network is learned by 4 descriptors, which are 2 kinds of dummy-data for dams construction, and others are BODs of the Austria Donau and the Morava. The outputs are like as a step-function; that is, the Hungary Donau s BOD depends on the dams.

Table 4 shows connection weights between the descriptors and outputs neurons.

Table 4 Connections among input/output neurons (no unit)

descriptors	weight_matrix
dam construction	-8
dam lake	-18
the Morava	0
the Austria Donau	0

Table 4 shows that BOD values of the Hungary Donau depend on dams construction and the lakes. BODs of the Austria Donau and Morava are not contributed. Because, the BOD of the Morava is high, and the pattern of the BOD changes of the Austria Donau is different from the Hungary Donau.

The BOD of the Hungary Donau have improved since 1980. It seems to be improved by dams construction. It is derived by resemblance of patterns on a scaling process; therefore, it doesn t always means the causality of phenomena. This is a boundary of the CQSAR.

Environmental groups have said relations of dams construction and water quality aggravation; however, the CQSAR doesn t support it. It may be related for BOD value not to be suitable for the water quality of lakes (appropriate index is COD). Or, it may be shown that organic compounds were decomposed in the dam lakes.

4.4 OD Values of the Seine and the Thames

BOD values of the Rhein are not listed in OECD reports [2]. We hope the data are published officially, which are necessary to research the re-naturalization.

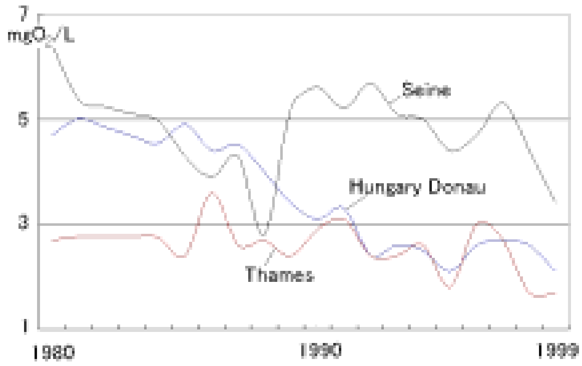

Fig. 10 BOD changes of the Seine and the Thames.

The Seine have large BOD values, they indicate pollution. In a short term in 20 years, an observation is improved suddenly; i.e., in 1998-9. Same phenomenon is found in 1987-8. Since we have 20 observations only, we don t judge whether the improvement is true or passing accidents. Comparing the BOD with that of the Hangary Donau, we can see little improvement in the Seine. The BODs are in 3.1-4.2 [mg/L], which show water for industrial usage.

The Thames has small BOD values, 1.6-3.4 [mg/L]. It is rather pure water, as same as the latest Donau. However, the Thames is considerable contamination in the total-phosphorus (*cf.* section 5).

The BOD is an index that indicates contamination of decomposable organic compounds. It is evaluated by the consumed oxygen in standard conditions, but doesn t depend on whole amount of organic compounds. It is affected by salts and other uncertain causes. That is; the BOD is one side of the water quality. We have interest in the correlation between the BOD and temperature that controls microbe activity.

5. T-Ps of the DONAU, the SEINE, the T AMES

5.1 T-P of Germany-, Austria-, and ungary-Donau

We compared total phosphorus (T-P) of 3 Donau rivers of Germany, Austria, and Hungary; that is listed in Fig. 11.

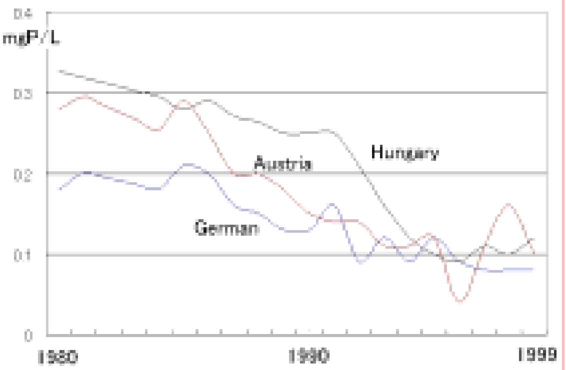

Fig. 11 T-P changes of Germany-, Austria-, Hungary-Donau.

The T-P values are in the order of Germany, Austria, and Hungary. It corresponds to the order of up, mid, down streams. We estimate that phosphorus cannot be decomposed soon like BOD. Therefore, the order is reasonable. The order is kept till 1994, and after that, it is disordered. The T-P of the Hungary Donau is about 0.1 [mg/L] now, which is 1/3 of 20 years ago. It satisfy the standard 0.175 in directive80/778/EEC. But, it is not for Japanese water supply, 0.01.

5.2 T-P of the Seine and the Thames

We compared the T-P of the Sene and the Thames; that is listed in Fig. 12.

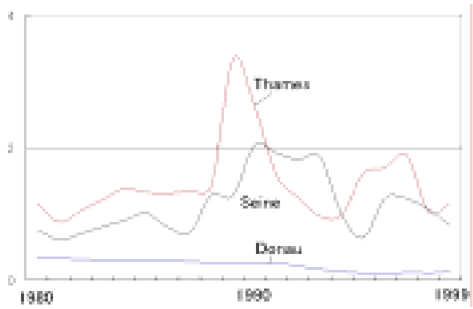

Fig. 12 T-P changes of the Seine, the Thames, the Donau.

The Thames and the Seine are polluted than the Donau in 20 years, which are not still improved now. It may be destiny that rivers through cities have large T-P values because of the difficulty of decomposing phosphorus.

. CONCLUSION

We interpolated defects in water quality data of European rivers, where the original was published by OECD. Using the complete dataset, we researched environmental conditions of rivers, and got the following results;

1. The BOD is not a suitable index in chill climate, which is used for judgment of water quality. The index should be used with T-P or T-N index. The BOD means demands of microbes; it doesn t correspond with the DO once in a while.

2. Water quality of rivers in Germany (the Rhein and the Donau) has been improved as for DO and BOD. The rivers have been re-naturalized. We believe that the effect is found in these indexes; however, the T-P isn t so much. The re-naturalization restores rivers generally, which is remarkable in the Austria Donau.

It is required to take proper measures against environmental pollutions. It is important to restore nature in rivers, which has been lost. We are sure the re-naturalization is a hopeful direction.

3. European rivers have self-purification function; we still find it in BOD data. Pollution caused by the Donau dams between Slovakia and Hundary is not so much for the BOD. The bad effect is found as stagnation of DO improvement in Hungary, which is derived by CQSAR calculations. Euclid s distances show that Hungary Donau s water doesn t depend on the upstream branches till 1988-9. We are sure that the dams make the situation. We are with anxiety about eutrophication of dam lakes and accumulation of sediment, which bring about in long operation.

4. We hope that purification measure of rivers is taken effectively in Spain and Turkey. About the water pollution of 2 rivers in the countries, the situation has become so aggravated that it can no longer be ignored.

We make appropriate measure for restoreing rivers and make the self-purification functions increase; then, the rivers will support population of cities. We have such expectation on investigations of the Donau and the Rhein. It is important that is derived by information technique, CQSAR.

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