

Urban-Hinterland Interaction : Urban Wastes and the Ecosystem of Lake Suwa

Tokio OKINO *

Since 1977, we, members of the Ecosystem Dynamics Research Group of Japan, have been conducting research in Environmental Science in pursuit of the better harmony between natural and human life. We belong to a small group that studies some specific areas with closed waters such as, to mention only the lake areas, the areas of Lake Kasumigaura and Lake Suwa, both of which are the typical eutrophic lakes in Japan, and the area of Lake Biwa, which is one of the mesotrophic lakes as well as the biggest lake of Japan, and, lastly, Lake Nakanoumi, a brackish lake, where some construction work is going on to change into a fresh water lake.

Today I'm going to talk about the Lake Suwa area, where there is a large scale sewerage construction plan underway to clean the eutrophicated lake. Lake Suwa is one of the most eutrophicated lakes in Japan, but at the same time it is the lake about which a great amount of research materials have been accumulated since the beginning of the 20th century. Around that time, this lake was categorized as a mesotrophic lake but gradually the trophic level became higher as the human activities in the watershed area, such as agriculture, tourism, the manufacturing of silk, precision products and brewage, became more active. In addition to that the population increased constantly. Since the 1960's the high growth of Japanese economy has exerted a great influence upon Lake Suwa and brought about such a change in the water condition that it is now classified as a hypertrophic lake. Every summer we can see what we call the water-bloom phenomenon caused by *Microcystis*, a kind of the blue-green algae, for quite a long period, from May to October.

In order to cope with this situation, the inhabitants

around the lake started to inquire into the possible measures to clean the lake in 1966, and with the help of the scientists and technicians, worked out a plan of waste water disposal through a sewage system, and finally in October 1979, part of the sewage plant started to operate.

The purpose of our research is to investigate and study the process of the recovery of this eutrophicated lake, to clarify the mechanism of the eutrophication and to preestimate, if possible, the future trophic level of Lake Suwa. This research is based upon the idea that the sewerage plan is a social experiment with a purpose of the recovery of the eutrophicated lake. At the same time our research intends to study how to feed the fruits of our research back to the community, and how to put the local governments, the inhabitants and the researchers into cooperation to attain our final purpose of improving the environment which is now a big social problems for us all. Since our research is still in progress, however, I cannot offer any definite conclusion.

Today I'll explain 1) the progress of eutrophication in Lake Suwa from 1900 to the present time, 2) the present nutrients loads in the watershed area, 3) the prospect of the future change in the lake water.

Photograph 1 is a panoramic view of Lake Suwa which I'm going to talk about today. In summer time it turns green all over as you can see in this picture (Photo. 2). There is so much blue-green algae in the water that the lake looks very like a grass land according to the remote sensing sent from an American Resource Satellite. The inhabitants around the lake call the algae "Aoko" or "the green powder", and the tourists who visit there sometimes mistake it for green paint illegally thrown in.

* Faculty of Science Shinshu University

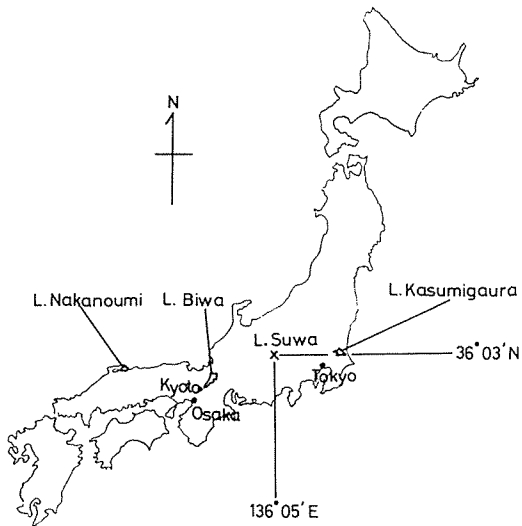


Fig. 1. The location of Lake Suwa and other watershed areas which we chose as the objects of our research.

Here you can see the location of Lake Suwa, and other watershed areas which we also chose as the objects of our research (Fig.1). The location of Lake Kasumigaura is about 60 km north east of Tokyo, the second largest lake in Japan, it is also suffering from the eutrophication phenomena. Lake Biwa is the largest lake in Japan, about 100 meters deep in its deepest place, a very important lake as the source of water supply for Kyoto, Osaka and other areas. However, it has also been suffering from eutrophication for years. The red water phenomenon caused by *Uroglena*, a kind of Chrysomonadida, and the problem of bad smell of service water are among the signs of eutrophication. Lake Nakanoumi is a brackish lake draining itself into the Sea of Japan. Now, they are planning to turn it into fresh water lake by building a gate at the debouchment to prevent the sea water from coming in.

Now, Lake Suwa of which I'm going to talk about today, is a lake situated in the center of Japan Proper. To say more accurately, it is situated in the 163rd degree of east longitude, and 36th degree of north latitude. This is in the tectonic belt crossing the Japanese Islands, and Lake Suwa is one of the tectonic lakes at the cliff on the west side of the belt. Although it is surrounded by the mountains and situated in a relatively high land of 759 meters above sea level, it is an

extremely eutrophicated lake as you saw in the photograph 2. It is a very shallow lake with the area of 13.30km². The length of its shore line is about 16km, maximum depth of it is 6.5 meters, the mean depth is 4.1 meters, but the layer of sedimentation is reported to be more 200 meters deep. About 20 small rivers and streams flow into the lake from the watershed, but the Tenryu River is the only one outlet. The renewal time of the lake water is about 50 days. Now I'll show you how Lake Suwa has undergone changes in the past 80 years in the following figures.

Since the first scientific research of the lake was conducted by Dr. Akamaro Tanaka in the 1910's, a considerable number of scientists have carried on the investigations. The diagram of Fig.2 based upon their studies shows the change of transparency of the lake water. The upper line indicates the maximum numerical value of each year. As you can see from this diagram, the maximum transparency was about 3 meters and the minimum was about 1 meter in the 1910's, but about 1960 they suddenly began to decline, and in the summers of the 1970's, they almost reached 0 cm.

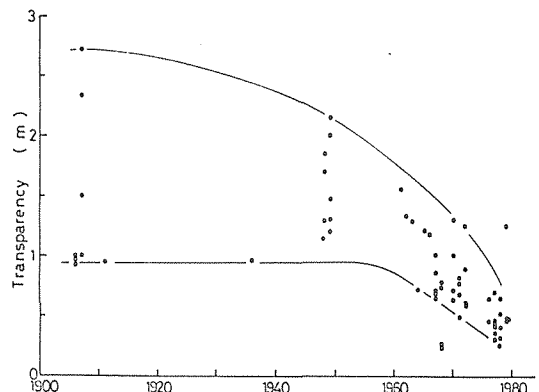


Fig. 2. The process of the change of transparency in Lake Suwa since the 1900's.

(quote from a report by H. Hayashi and others, 1980)

1960 was the year when Japan adopted the high economic growth policy and our economic activities were rapidly accelerated. The decline of transparency coincided with the decrease of the dissolved oxygen content at the bottom layer in the summer time, which caused the decrease in shrimps and shells. However, it is very interesting that in recent years, the discharge of

oxygen from great amount of *Microcystis* has resulted in the reverse phenomenon, that is, the recovery of the conditions of oxygen at the bottom layer.

Next, I'll show you the present conditions of the watershed area of Lake Suwa. As you saw in the Photo. 1 of the panoramic view of the lake, the urban areas are located very close to the shore line, and those urban areas contain quite a number of manufactories connected with precision machinery industry and food industry. Moreover, there are many hotels and restaurants around the lake, because this area attracts many

tourists on account of its hot springs.

On the other hand, 70 % of the watershed area with the size of 512 km², is covered with forests and grass lands, 18 % with cultivated fields (Fig 3). The main components of the forests are summer green broad leaved forests and artificial larch forests, but in the area higher than 2,000 meters above sea level grow subalpine coniferous forests. We measured the matter balance of organic matter, nitrogen and phosphorus in each of these three kinds of forests as part of the research on the eutrophication of the lake.

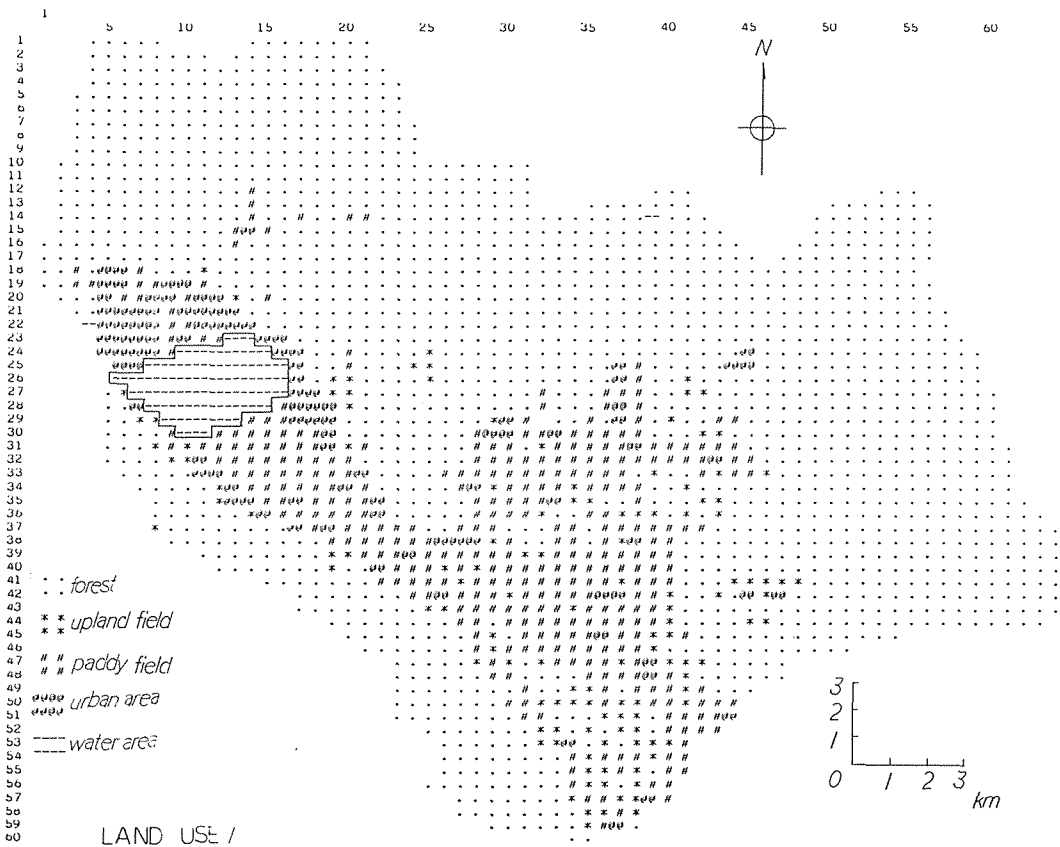


Fig. 3. The map of the land use in the watershed of Lake Suwa. (quote from M. Matsuda, unpublished.)

One-half of the cultivated land is rice fields, the other half is vegetable gardens. Especially for the vegetable gardens, they use a lot of fertilizers, and consequently the drainage of nitrogen ingredients has been a big problem. We measured the matter balance of nitrogen and phosphorus in the cultivated land, as we did in

the forests, and we made full use of the results for the present research.

I'll show you the seasonal changes of the standing crop of phytoplankton and the contents of nitrogen and phosphorus in 1977, so that you may understand the present conditions of eutrophication in Lake Suwa.

Here is the standing crop of phytoplankton indicated by the amount of chlorophyll-a (Fig. 4). It reaches the peak in spring and summer, owing to diatoms such as *Asterionella* and *Melosira* during the spring time, and owing to *Microcystis* in summer. The standing crop of the phytoplankton is about 200 mg/m³ in average on the basis of the amount of chlorophyll-a, and in some particular parts of the lake it reaches over 2000 mg/m³. Accordingly, the transparency in summer declines to 20–30 cm. In winter, the lake is usually frozen from the end of December to February but the transparency is no more than 1.5 meters.

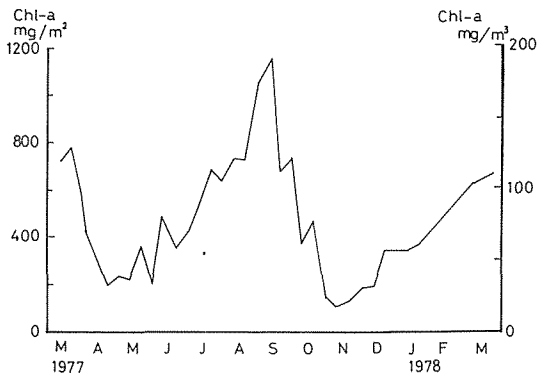


Fig. 4. The seasonal change of the chlorophyll amounts of Lake Suwa in 1977.

Here you can compare the seasonal changes of the amount of nitrogen with that of phosphorus in Lake Suwa.

The concentrations of the total nitrogen and total phosphorus remain all year round at such a high trophic level as 2–3 mg/L and 0.2–0.4 mg/L respectively, but most remarkable is the change of the both of concentrations in summer. As you can see in this diagram (Fig. 5), in recent years at the peaks of the growth of *Microcystis* in summer the amount of DIN (Dissolved Inorganic Nitrogen) has become extremely small. On the contrary, the amount of DIP (Dissolved Inorganic Phosphorus) tends to remain unchanged. The decrease of DIN is considered to be caused by the absorption of phytoplankton judging from the fact that at that time of the year PON (Particulate Organic Nitrogen) and POP (Particulate Organic Phosphorus) have increased a great deal (Fig. 6). The disappearance of DIN is an evidence that the growth of phytoplanktons in the

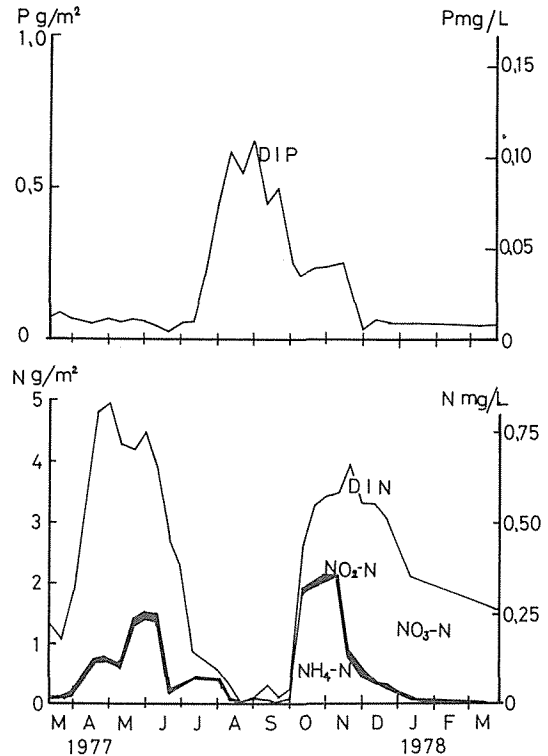


Fig. 5. The seasonal changes of the concentration of total inorganic nitrogen and phosphate phosphorus of Lake Suwa in 1977. (quote from the papers by N. Nakamoto (1978) and Y. Watanabe and others (1980).)

summer is controlled by nitrogen. Accordingly, Lake Suwa at the present time is understood to be a lake of the nitrogen limiting type. This is ascertained by the bioassay method (Nakamoto, 1980), too.

However, ten years ago when IBP (International Biological Program) research was carried out here. Lake Suwa obviously belonged to the phosphorus limiting type. This means that Lake Suwa has changed from the phosphorus limiting type to the nitrogen limiting type. It is clear, therefore, that the cause of the eutrophication of the lake is the drainage of the great amount of nutrients from the watershed area. So we collected the basic data by studying from what parts of the watershed area nitrogen and phosphorus come into the lake, and how much they are.

The sources of nutrients in the watershed area are divided into 10 categories (Tab.1). Each basic figure is

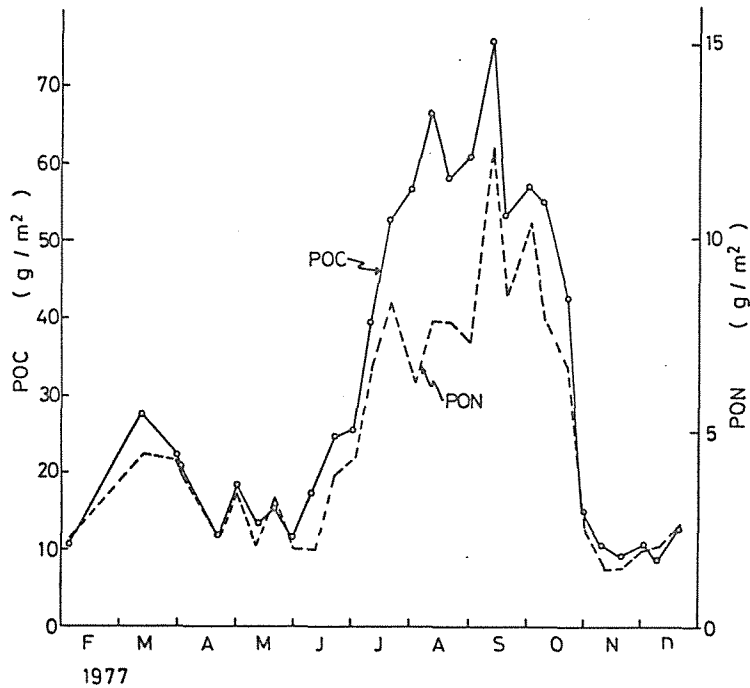


Fig. 6. The seasonal changes of the amounts of PON (Particulate Organic Nitrogen) and POC (Particulate Organic Carbon) of Lake Suwa in 1977. (quote from the data by Y. Watanabe and H. Hayashi)

	TN	TP	
Rainfall	36.5	1.4	g/ha-yr.
Forest	3.6	0.12	kg/ha-yr.
Field	28.	2.0	% against Fertilizer
Cattle	290	50	g/ind.day
(Pig)	40	25	
Hot spring	2.4	0.3	g/m³
Gas well	107.	1.7	g/m³
Resident	3.0	0.71	g/man-day
Tourist	6.7	0.43	g/man-day
Industry	from the water quality of waste water by each industry.		
Sanitary plant	11.4	0.62	g/man-day

Table 1. The basic figures of the sources of nitrogen and phosphorus in the watershed area of Lake Suwa. (Okino, T. and others, 1981)

almost unexceptionally based upon measuring in the watershed area of Lake Suwa. Those numerical values were obtained by the investigation and research by our project team. One of those categories, gas gush out of the lake and it is used as urban gas. As for the amounts

of drained nitrogen and phosphorus from fields we obtained these values by using lysimeters and other methods. These numerical values in the diagram indicate the effluent rates on the amounts of fertilization. I wish to emphasize here that the effluent rate of nitrogen reaches no less than 28% of the amounts of fertilization and one of the characteristics of this area is that the type of a drained nitrogen is nitrate.

Fig.7 shows the total amounts of nitrogen and phosphorus at each of the sources in the watershed area, as well as their influx amounts into the lake. TN indicates total nitrogen and TP indicates total phosphorus at each source. Fish culture is shown here separately, because it is practiced in the lake only for 150 days from May to October. As indicated here very clearly the main sources of TN are cultivated fields and sanitary plant. About 30% of TP is drained from the inhabitants' houses, which is of course, the greatest source of TP. To sum up, most of nitrogen sources are flat place as cultivated fields, while in the case of

phosphorus, the sources tend to be concentrated upon small points such as the inhabitants' house.

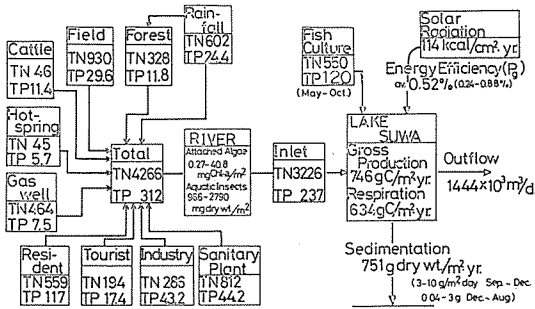


Fig. 7. The total amounts of nitrogen and phosphorus at each of the sources in the watershed area of Lake Suwa and the amounts of loads (kg/day) into the lake.

The construction of sewerage started in the urban sections in the Lake Suwa watershed area in 1971 in order to stop the progress of eutrophication caused by the nutrients loads from the watershed area, and eventually to recover the lake. The project area is shown in Fig.8. It covers 4,627 ha and about 190,000 inhabitants. Sewage will amount to 280,000 ton a day and it will be

treated according to the standard activated sludge method. The treated water is planned to be drained out into the Tenryu River which is the only outlet of Lake Suwa.

To what extent will Lake Suwa recover when the sewerage system is completed? In order to solve this problem we made a preestimate through simulation method. Here I'll show you the model we used for simulation study (Fig.9). Since Lake Suwa with its small depth and simple shore line, is considered to be of the complete mixture type, we used a box model which is divided into two layers. The influx water first comes into the lower layer, and then it exchanges with the water of the upper layer. Each of Layer is composed with 7 components. One of the features of the model is that the phytoplanktons are divided into two categories, that is, *Microcystis* which is characteristic of Lake Suwa and other kinds of phytoplanktons. *Microcystis* is easy to float because of its small specific gravity and it is difficult to be grazed by zooplanktons. These properties of *Microcystis* were incorporated into the model.

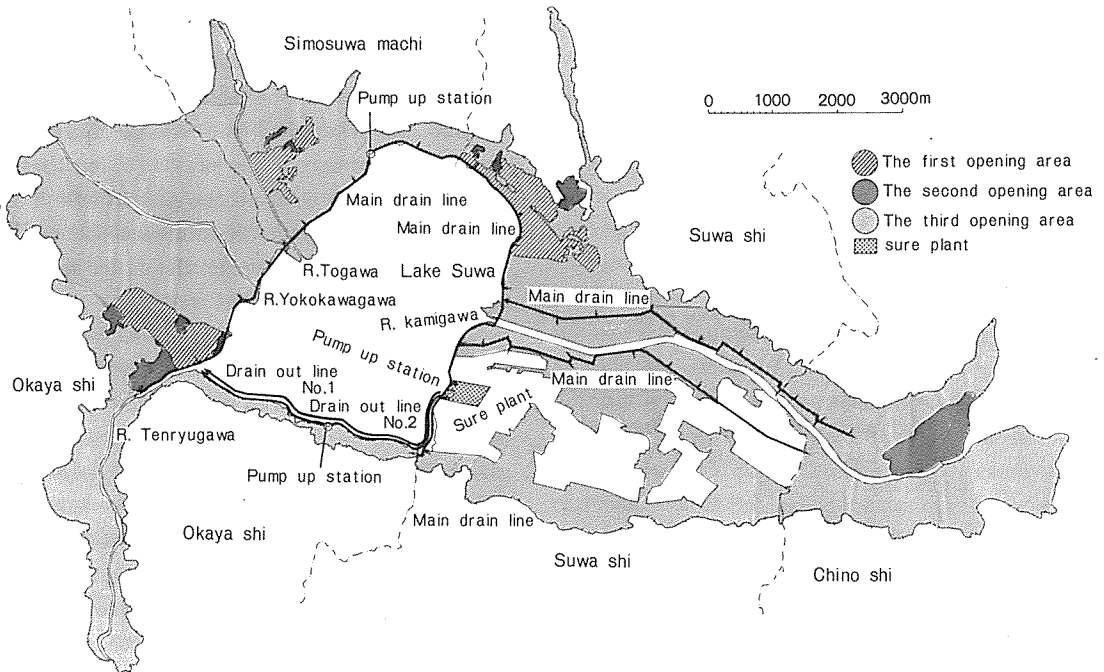


Fig. 8. The project area of sewerage system. (by pamphlet of the office of Nagano Prefecture)

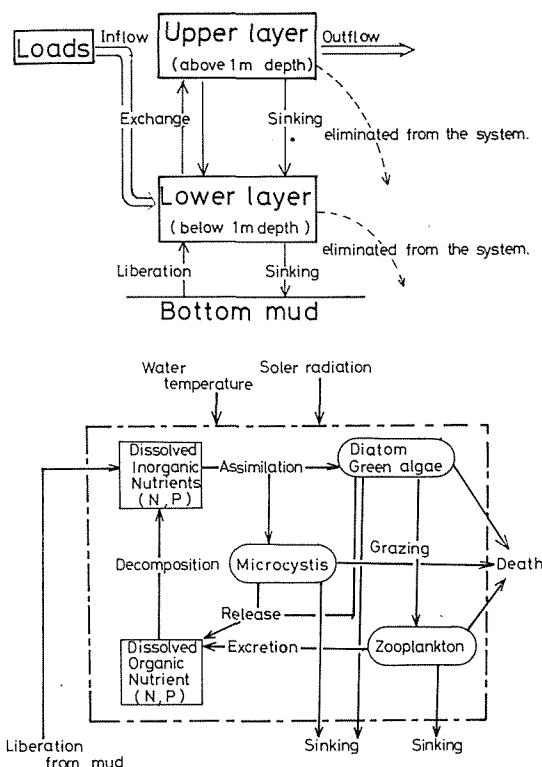


Fig. 9. The structure of the model and the components in the box of model used for simulation study. (Okino, T., S. Hiratsuka and T. Tanaka, 1981)

After we checked the model and corrected each parameter with consideration for the conditions of the lake in 1977, we made the following simulation study. First, we tried to simulate the change of the growth amounts of phytoplankton, especially *Microcystis*, by changing each load with the influx amounts of nitrogen and phosphorus in 1977 as its criterion. Fig. 10 shows the results of the simulation study. The broken line indicates the growth amount of *Microcystis*, the full line indicates the growth amount of other kinds of phytoplankton.

For example, the second diagram from the top of the left shows what will happen when TN stays unchanged, while TP is reduced to 50% of the present load. In this case, as you can see here, no great change takes place in the condition of the lake. On the other hand, the diagram on the right shows the case in which TN is reduced to 50%, while TP remains unchanged. In this case, we can recognize some change in the growth

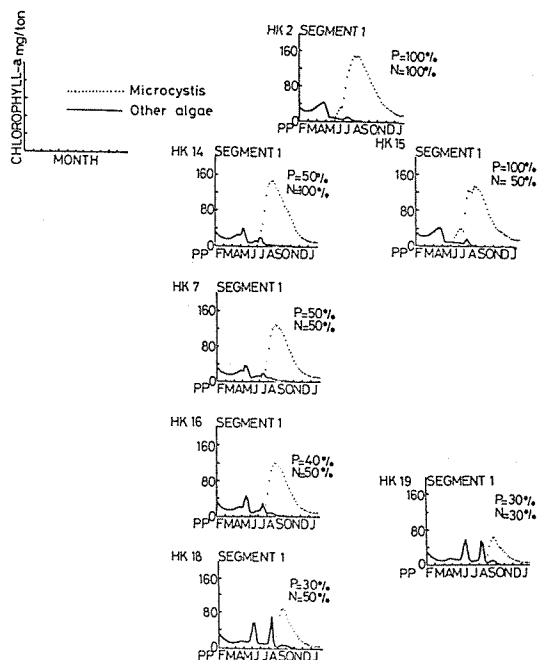


Fig. 10. The results of simulation study by changing each load with the influx amounts of nitrogen and phosphorus in 1977 as its criterion. (Okino, T. and others, 1981)

amount of *Microcystis*. These results of the simulation study suggest that Lake Suwa is of the nitrogen limiting type, as I pointed out before. The diagrams below them show what change will take place in the cases in which the greater percentage of TN and TP is reduced. Eventually, we estimated that in order to reduce the growth amount of *Microcystis* to the half of the present one, the reduction rate of TN should be about 50% and that of TP should be about 70%.

This diagram shows how far the recovery of the lake will be really accomplished by the concentration of sewerage. As indicated here in the diagram, it is estimated that about 50% of TN and 75% of TP will be collected when the sewerage construction plan now underway is completed. These rates are equivalent to the reduction rate which, as I showed you in Fig. 11, is necessary to limit the growth amount of *Microcystis* in summer to 50%.

If the plant works all right the transparency will improved from the present 20-30 cm upto 60-70 cm and the growth amount of *Microcystis* will be limited to 50%, but this is possible only when we can remove TN

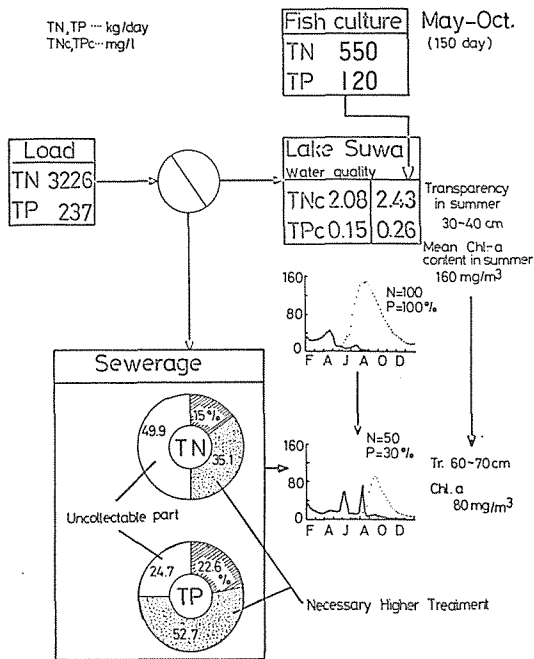


Fig. 11. This diagram shows how far the recovery of the lake will be really accomplished by the construction of sewerage (Okino, T. and others, 1981)

and TP by improving the present method of treatment. And this means the great increase of the cost of the plant construction and sewage treatment and inevitably the local governments require the consent and cooperation of the part of the inhabitants around the lake.

Although purification of the lake is an earnest wish of all the inhabitants around the lake, it is not easy to carry out the purification plan because it comprises not only scientific problems but also social problems. In order to cope with these social problems there are some attempts among the inhabitants as well as the local governments.

Lake Suwa has been a subject of pure scientific study for a long time. Recently, however, the pollution of the lake water has become a great social problem and a series of purification plans have been laid out mainly by the local governments. But in order to attain their object, they should secure the cooperation on the part of the inhabitants and in order to secure their cooperation, we have to inform them of the results of our scientific study as effectively as possible.

In the case of the Lake Suwa area, the inhabitants have been given sufficient information about the pollution of the lake through mass media. In order to carry out the purification plan, however, it is very important to convince them of why we have to clean the lake and how we can clean the lake. Fortunately, there are a number of civic activities for the purpose of adult education at the community centers of this area. As one of these adult education projects, each local government sponsors a series of open lectures on the present conditions of the water pollution to give the inhabitants the basic information on the lake. Moreover there are various kinds of "Clean the Lake" campaigns promoted by the civic groups and mass media.

Anyway it is very important for us researchers to give the accurate scientific information on the lake to the inhabitants so that they can realize that the purification of the lake is their own problem, and that they can make full use of it in their "Clean the Lake" campaigns.

Such are the projects and activities proceeding in and around Lake Suwa, a tiny lake on the earth. We, scientists, are still seeking for the best possible ways of doing research with the cooperation of the inhabitants around the lake, because our project is not only a scientific experiment but also a great social experiment for us all.

ACKNOWLEDGMENT and POSTSCRIPT

I am pleased to acknowledge the considerable assistance of Dr. M. Iida and Prof. Dr. H. Kurasawa. This paper is the manuscript of An International Scientific Conference and Exhibit, under the general theme "Ecology in practice: establishing a scientific basis for land management" held on Unesco Headquarters, Paris, from 22 to 29 September 1981, under the joint sponsorship of Unesco and the International Council of Scientific Unions (ICSU).

REFERENCE

- Kurasawa, H. and others (1978-1981) Progress Report of the Watershed Ecosystem Study in Lake Suwa, No.1-No. 7. (in Japanese).
- Watanabe, Y., M. Yamamoto, H. Hayashi, T. Okino and T. Tanaka (1980) Seasonal changes of the various nitrogen fractions in Lake Suwa. Rep. Suwa Hydrobiol. Station Shinshu Univ., No.3, 47-52. (in Japanese).