Manual of Measures against Lake Eutrophication

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1. Introduction

The 21st century is anticipated as the century of environment. In this regard, it is crucial to remedy pollution and conserve resources, particular in respect with aqueous ecology, for fostering a healthy environment. Confronting this issue, which concerns not just Japan but the entire globe, will require creation of an international network. Japan has so far yielded substantial results from its various conservation projects, including those promoted through the ODA, although any project targeted at a single specific country and its results usually fail to be generalized more widespreadly. Consequently, demand grew greatly for a versatile anti-eutrophication manual/handbook suitable for lakes situated in tropical, subtropical, temperate, and frigid zones, which covers water environment safety, qualitative and quantitative preservation of water resources, as well as the characteristics of, and control measures for algae bloom. In other words, such a handbook should serve the vital function as the foundation for Japan to provide international environmental support to developing nations. With this in mind, those in the national and local governments, industry, NGOs and other organizations, who deal with overseas trainees and technical transfer for environmental remediation and conservation, could learn about (1) the past, present, and future of eutrophication, (2) eutrophication-related past developments and future directions of administration, organization/systems, control measures, monitoring, and standard setting, and (3) ideal systems utilization, regulation standards, and measuring/monitoring methods concerning eutrophication control, both domestically and globally, in order to implement practical and specific anti-eutrophication measures.

Right now at this moment, various lakes around the globe are suffering from the critical bloom of hazardous algae that generate microcystins and other substances more toxic than potassium cyanide. For this reason, the World Health Organization (WHO) boosted its efforts to control microcystin by designating it as one of the organic constituents regulated by its Guidelines for Drinking Water Quality. This example is sufficient to understand the importance of this Technology Transfer Handbook on Eutrophication Control of Lakes.

Based on the above background, the “Technology Transfer Handbook on Eutrophication Control of Lakes” covers the mechanism of lake eutrophication and its environmental impact, the present situation of lake eutrophication and its control measures both in Japan and in developing nations, new global challenges concerning lakes, the Lake Kasumigaura Cleanup Project as the core of the eutrophication control policy in Japan, proper transfer projects for Japanese technologies, aqueous environment remediation technology applicable to developing nations, administrative measures to arrest eutrophication, techniques and hints for lake survey, and future challenges and prospects.

2. Lake Eutrophication Mechanism and its Environmental Impact

This chapter introduces the problems generated by algae bloom, red tide and blue tide in lakes, inland seas and inner bays, the eutrophication mechanism, pollutant load sources, water sources, and the impact of eutrophication on agriculture and recreation.

2-1 Problems concerning Water Supply, Landscape, Fishery, Agriculture and Other Issues Caused by Eutrophication

2-1-1 Water Supply

(1) Inhibition through the Coagulation Process

Elimination of suspended solids (SS) from raw water taken from eutrophic lakes and reservoirs requires the coagulation process. Coagulants, such as aluminum sulfate, will have to be increased proportionately to the SS proliferation. Growth of algae inhibits coagulation by raising the pH level. For this reason, algae proliferation not only requires coagulants in quantity, but also may hinder the coagulation process. In addition, the green algae that form the water bloom tend to float, which means that they may flow out rather than settle.

(2) Trihalomethane Production

Pre-chlorination is sometimes practiced to ensure sufficient chlorine disinfection by averting the obstacles to coagulation and filtering. In this process, hypochlorous acid (HC1O) reacts with organic matters derived from algae to form trihalomethanes (chloroform, bromodichloromethane, dibromochloromethane, and bromoform) that are suspected of being carcinogens. Animal tests have demonstrated that, among them, chloroform and bromodichloromethane are carcinogenic, which suggest that they are very likely to be so for humans. The Waterworks Law stipulates the Water Quality Standards of Drinking Water for all four substances as well as their total value (total trihalomethanes) as 0.1 mg/*l*.

(3) Clogging of Filter Basins and Screens

Algae bloom triggered by eutrophication clogs the filter basins and screens. The clogging-causing algae are not limited to Cyanophyceae known as forming water bloom: outbreaks of Bacillariophtceae, such as *Synedra* and *Melosira* genera, are also found to cause blocking.

(4) Odor and Taste Impairment

Algae outbreaks caused by eutrophication can impart unpleasant odors to drinking water. Some are effused by algae directly; others are produced through the decomposing process of dead algae, effected by actinomycetes and bacteria. The algae-produced odors are caused by 2-MIB (2-Methylisoborneol) and Geosmin, which are found to be effused respectively by *Phormidium tenue*, *Oscillatoria* and *Anabaena* genera.

(5) Iron and Manganese Problem

A massive amount of microscopically small algae spawned by eutrophication, when dead, settle out on the bottom to undergo bacterial decomposition. As a result, the bottom layer becomes anaerobic, causing iron and manganese elution from the bottom sludge. These metals in the tap water can stain laundries and impair the water taste. Consequently, they need to be eliminated through a water purification process. Among the water-coloring metals, the Water Quality Standard of Drinking Water under the Waterworks Law in Japan regulates manganese and aluminum as the Items Relating to the Comfortableness of Water Quality. Furthermore, the WHO Guidelines for Drinking Water Quality sets guideline values for aluminum, copper, iron, and manganese.

2-1-2 Landscape and Recreation

Advancing eutrophication spawns the algae, which reduces the transparency by coloring the lakes green when dominated by blue-green algae and brown when dominated by diatoms. Such a phenomenon significantly disfigures the water environment. When the algae bloom forms a surface scum, the lake is unfit for recreation activities, such as swimming, water-skiing, and boating. The obvious reason is dangerousness due to the invisibility of the underwater. In addition, it is of great importance to remember the toxins released by Cyanophyceae which humans may be exposed to. An actual case is reported from England where soldiers became ill after canoe-training in water with a heavy bloom of Microcystis. Water bloom effuses a unique odor, which spoils the area for walks and hiking. Furthermore, foul odors from decomposing algae as well as the hydrogen sulfide smell from the anaerobic bottom layer caused by the decomposition deteriorates not only the recreational environment but also the living environment of the neighboring communities.

2-1-3 Agriculture and Fisheries

A certain degree of fertility has the favorable effect of raising the fish catch: the enhanced reproduction of algae consequently increases zooplanktons that feed fish. On the other hand, advanced eutrophication repels premium fish, such as salmon and trout, whose absence is filled by commercially valueless fish, thus degrading fishery profitability. Moreover, eutrophication affects the composition of predators and decomposers, transforming the biota into that viable within an over-fertile environment. In lakes and inner bays, eutrophication deprives the fish of their arena for reproduction by developing anoxic conditions: juvenile fish are vulnerable to external conditions which adult fish are resistant to. As a consequence, the fish population drops.

Water irrigated from eutrophic lakes and rivers has an adverse effect on crop production. Nitrogen in particular damages significantly by slashing the rice yield through overgrowth, lodging, poor maturation, and frequent pest outbreak. It is normally considered that 1 mg/*l* of nitrogen is harmless, whereas a level exceeding 5 mg/*l* causes grave problems.When mostly-toxigenic cyanobacteria bloom at the water sources in pasture, livestock may develop health disorders by drinking infested water. Cases of a lethal cyanobacterial intoxication of livestock including cattle, sheep, pigs, and fowl have been reported from Australia and the U.S.

2-2 Characteristics of Algae Spawn by Eutrophication

(1) *Microcystis* Genus

Among the *Microcystis* group, *M. aeruginosa, M. flos-aquae, M. viridis,* and *M. wesenbergii* emerge in lakes and reservoirs that provide raw water for water works. *M. aeruginos* and *M. flos-aquae* in particular bloom in heavily-polluted water areas. A representative of the *Microcystis* species, *M. aeruginosa* (shown in Photo 2-2-1), has a cell of 3-7 μm in diameter with a gas vesicle, which renders the alga floating. It is characterized by an amorphous colony of gelatinoid-coated cells. This genus can be described as suspending cyanobacteria emerging in heavily over-fertile lakes around the world. Being resistant to organic pollutants, the *Microcystis* quite frequently appear in aerated lagoons. They proliferate in summer, and form a water-bloom mat on the water surface. Grave concern has arisen from the problems caused by *Microcystis* species, such as offensive odor/taste and suppressed coagulation of dispersed cells through their reaction with chlorine in the water purification process. Furthermore, they produce microcystin that causes liver disorder in humans and animals. The water from the *Microcystis*-infected source needs particular attention to ensure the removal of microcystin through the purification process.

Photo 2-2-1 Micrograph of *Microcystis aeruginosa*

(2) *Anabaena* Genus

Among the *Anabaena* genus, *A. spiroides, A. macrospora, A. circinalis,* and *A. flos-aquae* emerge in lakes and reservoirs that supply raw water for water works. A representative of the *Anabaena* species, *A. spiroides* (shown in Photo 2-2-2), has a cell of 4.5-10 μm in diameter with its vegetative cell linked together to form a chain. This species is characterized by its idioblast of ϕ 4.5-10 μm globe among the cells, an intracellular gas vesicle, and its regular spiral shape. This is also called nostac, which commonly appear in polluted lakes in various regions. Being a suspending Cyanophyceae, this alga often forms water bloom. The chlorination in the purification process disperses the cells of the *Anabaena* species, which easily pass through the filter basins and thus cause problems. Some *Anabaena* algae effuse

Photo 2-2-2 Micrograph of *Anabaena spiroides*

fungus smell, and others release hepatotoxic microcystin and neurotoxic anatoxins. This genus is also known as nitrogen-fixing cyanobacteria.

(3) *Oscillatoria* Genus

Among the *Oscillatoria* genus (shown in Photo 2-2-3), *O. tenuis* and *O. agardhii* emerge in lakes and reservoirs that supply raw water for water works. A representative of the *Oscillatoria* species *O. tenuis* has a cell of 2-5 μm in length and 2.5-3 μm in width, with a cell length approximately double its width. *Oscillatoria* is a typical filamentous cyanobacterium occurring as a single trichome or a colony of accumulated trichomes. In the past, the dominant species in summer in Lake Kasumigaura was the *Microcystis*, which has been replaced by the *Oscillatoria* since 1987. Being reproductive under low temperatures, *Oscillatoria* algae appear even in winter and deteriorate the water quality. Proliferation of these species undermines coagulation in the water purification process, and consequently causes problems since they pass through the filter basins. Many of the *Oscillatoria* algae discharge fusty odors. Some also release hepatotoxic microcystin.

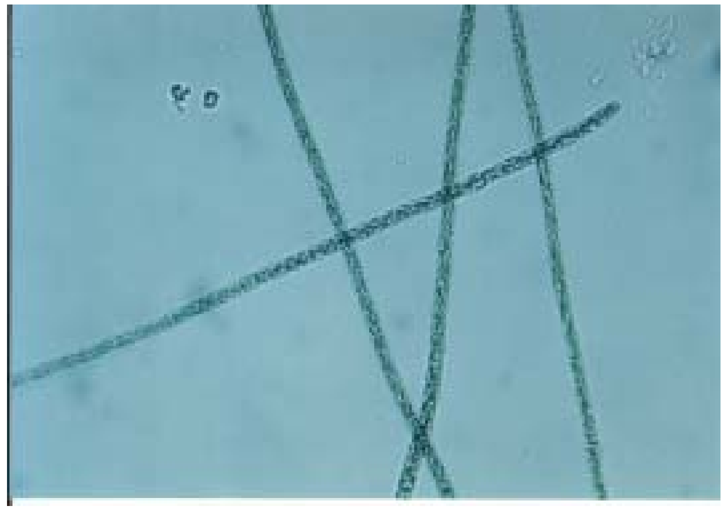

Photo 2-2-3 Micrograph of *Oscillatoria* sp.

(4) *Phormidium* Genus

Among the *Phormidium* genus, *P. tenue* and *P. mucicola* emerge in lakes and reservoirs that supply raw water for water works. A representative of the *Phormidium* species, *P. tenue* (shown in Photo 2-2-4), has a cell of 2.5-5 μm in length and 1-2 μm in width. This species are characterized by its sheathed cell, cell connections with no constrictions, a cell length three to four times the size of its width, and by indigo-colored cell. Though looking similar to the *Oscillatoria* genus, the *Phormidium* can be identified by its mucoid sheath. Being a saprobic cyanobacterium, *P. tenue* commonly occur in lakes either by attaching to gravels in the water areas or floating in the water. Being a major contributor to imparting a fusty odor to the drinking water, this alga is a targeted substance in the water purification process.

Photo 2-2-4 Micrograph of *Phormidium* sp.(center)

2-3 Eutrophication Mechanism

Nitrogen and phosphorus are essential elements for the algae, bacteria, protozoa, metazoa, and Pisces that comprise the hydrospheric ecosystem. Excessive inflow of these elements, however, eutrophicates lakes and sea areas. Efforts to remedy the organic pollution of water areas in Japan always focused on abating the biochemical oxygen demand (BOD) level of household and industrial wastewaters. As a result, organic pollution was positively relieved. At the same time, however, the influx of nitrogen and phosphate exempt from the wastewater treatment process raised their concentrations in the public water areas, which triggered frequent outbreak of Microcystis and red tide (see Fig. 2-3-1).

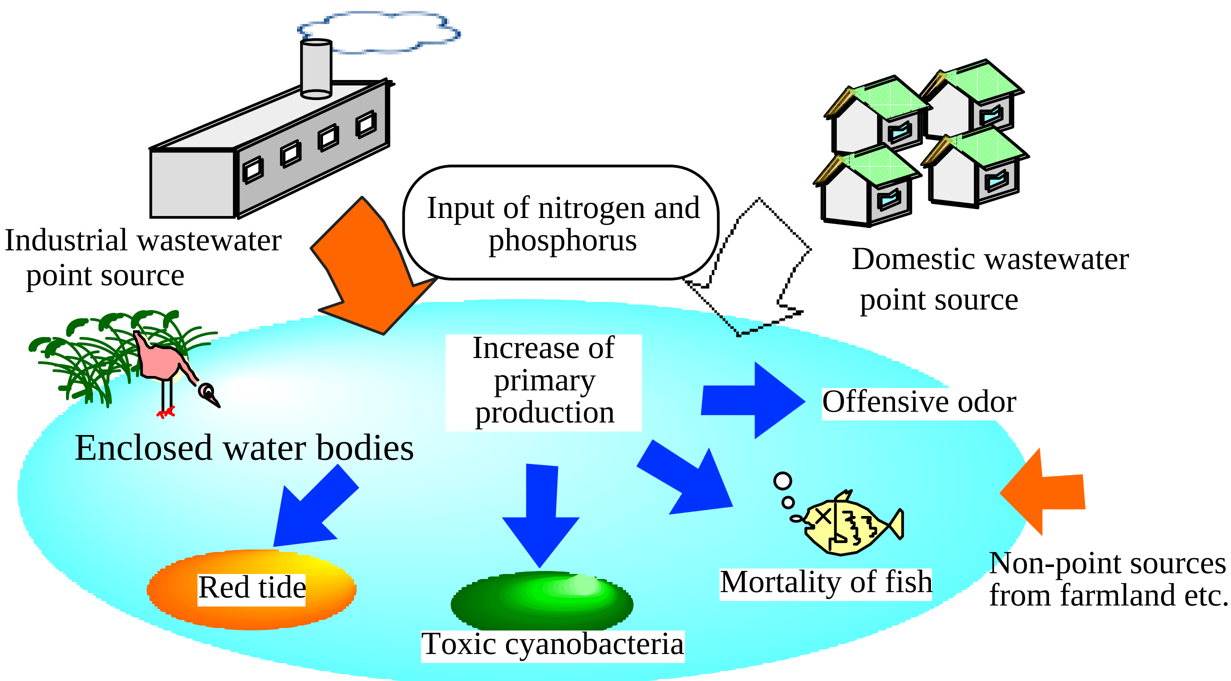

Fig. 2-3-1 Eutrophication prosesses

Algae bloom extensively in eutrophic lakes and reservoirs, such as Lake Kasumigaura, Lake Teganuma, Lake Inbanuma, and Lake Suwa in Japan, mainly in the summer. The major constituent of algae bloom is cyanobacteria represented by *Microcystis*, *Anabaena*, and *Oscillatoria* genera. Under the right temperature and light conditions, these algae propagate through absorbing nitrogen from nitric and ammonium ions and phosphorus from phosphate ions. Nutritive salts are provided to algae mainly by influx from influent rivers, recurrence from the bottom layer associated with the bacterial decomposition of excreta and zooplankton, elution from the bottom sludge, and rainfall. The reproductive rate of algae greatly depends on optical intensity, water temperature, and nitrogen and phosphorus concentrations. In addition to blue-green algae, green algae and diatoms emerge in hypertrophic lakes and reservoirs, where the dominant species changes by the season. Such a changeover takes place because each algae species has different reproductive properties respecting the nutritive salt concentration, the illumination, and the temperature, which determine the most suitable algae to dominate under changing environmental conditions. The blue-green algae are found not to generally dominate under an oligotrophic environment, because their reproductivity is low or null in the oligotrophic water. It was reported that *Microcystis*, a typical cyanobacterium, dominates the lakes when the total nitrogen and the total phosphorus are over 0.5 mg/*l* and over 0.08 mg/*l*, respectively.

In Japan 211 lakes were surveyed, with nitrogen and phosphorus concentrations as parameters, to clarify the elements that determine the dominant species. The results of this study reported that more lakes are dominated by the Cyanophyceae when total nitrogen and total phosphorus respectively exceed 0.39 mg/*l* and 0.035 mg/*l*. Temperature is also an important environmental factor for cyanobacterial reproduction: a typical blue-green alga *Microcystis* that constitutes water bloom becomes a dominant species mostly around summer.

Due to their shape, e.g., colonies of cells as for *Microcystis* and filamentous shape as for *Oscillatoria*, the blue-green algae are not susceptible to being eaten by zooplankton, which is also a contributing factor for the algae to dominate. Furthermore, cyanobacteria can float due to their intracellular gas vesicles. When they dominate the lake, the blue-green algae cluster on the surface, which sharply attenuates the underwater sunlight to block the insolation of other algae. Such a floating property accelerates the domination of the cyanobacteria, unless wind or other phenomena stirs the lake.

2-4 Pollutant Sources (Point and Non-Point) for Eutrophication and the Significance of Control Measures

2-4-1 Point-Source and Non-Point-Source Loads

The typical suppliers of nitrogen and phosphate to the public water areas, such as lakes, sea areas, and rivers, are effluent and its treated wastewater from factories and other industries, households, livestock, and fish farms, where the pollutant source can be located. In addition to these pinpointed ones, pollutants flow in from unlocated sources such as the influx from urban areas, spillage from industrial waste treatment facilities, leakage from illegally dumped waste, excrement associated with pasturage, and the influx from forests, farmlands, golf courses, and other areas. The common pollutants among many of these sources are organic matters, nitrogen and phosphate. The former type of pollutant source is called point source, whereas the latter is called non-point source.

2-4-2 Varieties of Point Sources and their Control

The point-source load is a pollutant discharged from the pinpointed pollution source. Since the point sources are already located, it is possible to control the pollutant loads from these sources. Among the point sources are sewage treatment water, treated industrial wastewater, household effluent, livestock wastewater, and fish farming water. Point-source effluent such as sewage treatment water and industrial wastewater is regulated under set effluent standards in various countries.

Among the point sources, the highest pollution load comes from household effluent. The basic units of organic materials, nitrogen, and phosphorus derived from miscellaneous household effluent (domestic wastewater exclusive of excrement) are set as 27 g/person/day for BOD, 2 g/person/day for total nitrogen (TN), and 0.4 g/person/day for total phosphorus (TP), respectively (shown in Fig. 2-4-1). At the same time, the basic units of the same substances derived from excrement are set as 13 g/person/day for BOD, 8 g/person/day for TN, and 0.6 g/person/day for TP, respectively. It is clearly demonstrated that the nitrogen and phosphorus loads from excrement are higher. For this reason, the influx of untreated domestic wastewater from areas without either a sewerage treatment system or private sewerage treatment tanks imposes such a heavy point-source load.

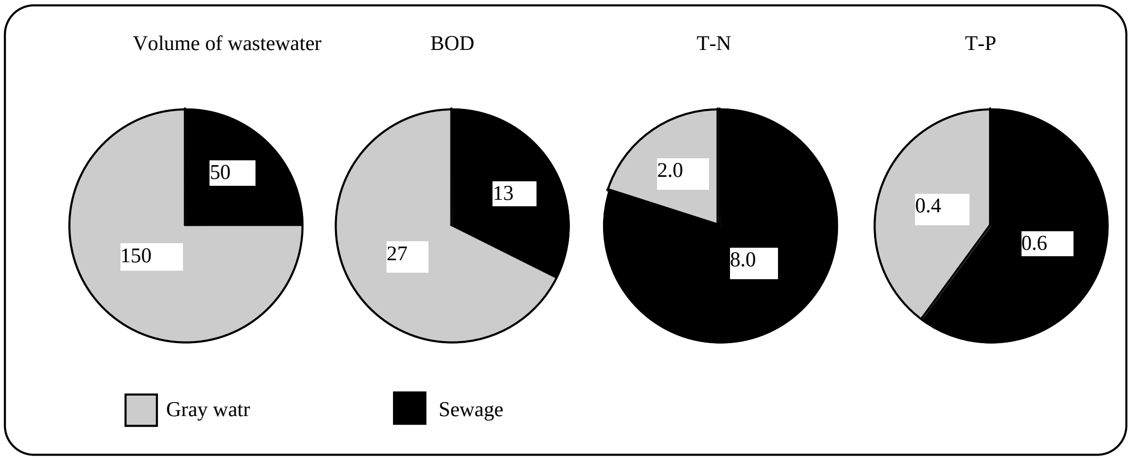

Fig. 2-4-1 Pollution sources from domestic water use
unit: Volume of wastewater(L・person^{-1}・day^{-1}) Others (g・person^{-1}・day^{-1})

When flowing into canals and rivers, improperly treated livestock excreta and washing water of farm corrals contaminates the water significantly. The pollutants drained from corrals are organic substances, nitrogen, and phosphorus. The basic load units per adult farm animal are presented in Table 2-4-1. The table shows that the excreta produced per head per day is 5.4 kg by pigs and 50 kg by cattle, both of which are much larger than 1.5 kg by human. Livestock wastewater is characterized by a high contamination load, a substantial share of pollutants as feces, high pollutant concentrations, biological treatability, high nitrogen concentrations, and a strongly offensive odor. Pre-elimination of feces at farm corrals can significantly cut down the pollutant concentrations in livestock wastewater. Some water areas suffer from a high pollutant load derived from fisheries, such as fish farming. The contaminants originating from fish cultivation with net cages are organic matters, nitrogen, and phosphorus eluted from the fish foods.

Table 2-4-1 Basic Units of Livestock Pollution Loads

Livestock	BOD (g/d)	N (g/d)	P (g/d)
Pig	130	37	14.7
Cattle	800	290	54

At Lake Kasumigaura, the contamination loads originating from carp breeding shares 7.4 % of the COD, 8.3 % of the nitrogen, and 20.3 % of the phosphorus, which manifests a larger percentage in the phosphorus figure. In the said lake, the pollution loads from point sources account for 55 % in the organic matters (COD), 58 % in the nitrogen, and 77 % in the phosphorus, which also indicates a higher share in the phosphorus load (see Fig. 2-4-2).

Breakdown of the point sources shows that the highest share is from household effluent, which commands 45 % of the phosphorus load. As for the organic matter and nitrogen, livestock effluent accounts for approximately 10 %, the second largest after household wastewater. Among the phosphorus sources, the fisheries drain is the second largest, sharing approximately 20 %, after the household effluent. The survey at Lake Biwa showed similar results, where the point sources accounted for 53.1 %, 45.3 %, and 68.4 % of organic matters (COD), nitrogen, and phosphorus, respectively, demonstrating a higher share in the phosphorus load just as in Lake Kasumigaura.

It is needless to say that the most crucial measure to control the pollutants from the point sources is wastewater treatment at source, which includes sewer system development, widespread installation of private sewage systems in the areas where a sewer service is unavailable, and the development of decontamination facilities for various industrial wastewaters. Many countries around the globe, including Japan, set effluent standards to control the point-sourced pollutants. The Japanese standards for eutrophicating nitrogen and phosphorus, however, are 120 mg/*l* and 16 mg/*l*, respectively, much too lenient against the actual nitrogen and phosphorus concentrations in water areas to prevent eutrophication. When such a nationwide uniform standard is inadequate to achieve a healthy environment, each prefecture can tighten standards by enacting its own ordinance for standards. For example, the Ordinance to Prevent Eutrophication of Lake Kasumigaura sets add-on standards for nitrogen and phosphorus, as shown in Table 2-4-2. The levels of nitrogen and phosphorus standards depend on the industry, the business size, and establishment year (pre- or post-ordinance). The tightened nitrogen and phosphorus standards for large-scale sewage treatment plants are 15 mg/l^{-1} and 0.5 mg/*l*, respectively, which are much more rigorous than the nationwide uniform effluent standards of 120 mg/*l* and 16 mg/*l*.

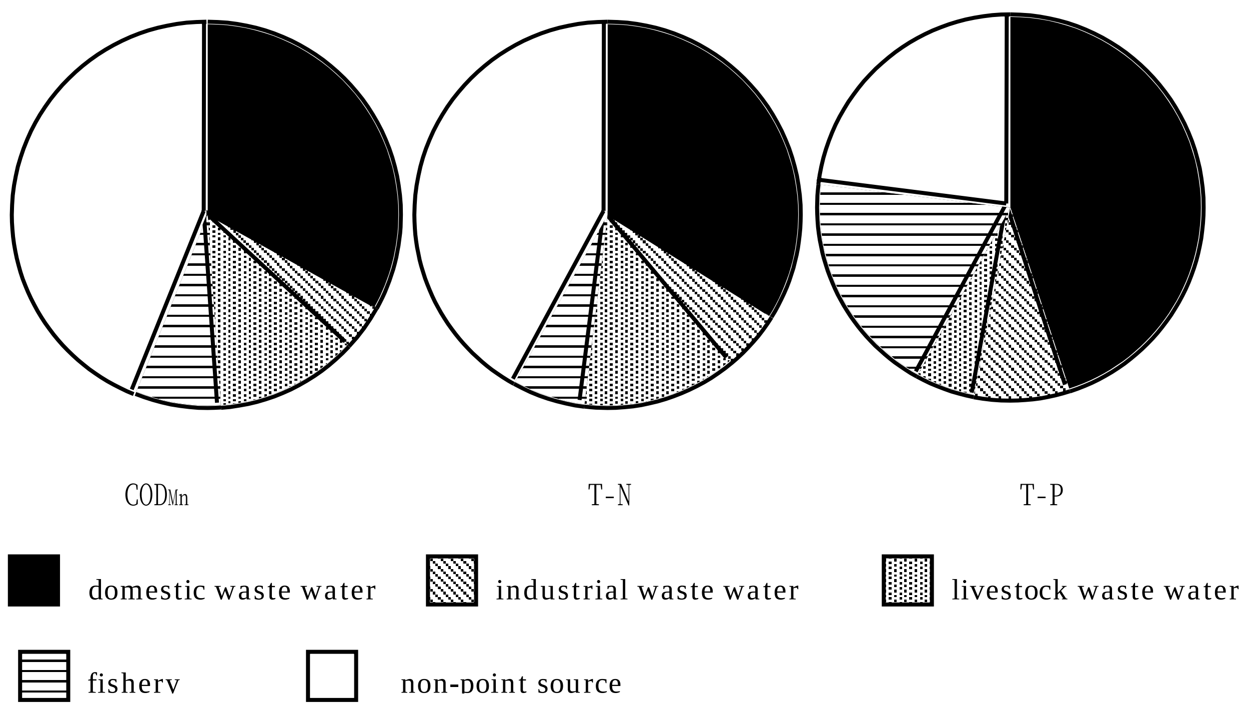

Fig. 2-4-2 Pollution source of Lake Kasumigaura

Table 2-4-2 Voluntary control standards based on the eutrophication control regulation of Lake Kasumigaura

		new		existing	
classifications	Volume of effluent(m^3 day^{-1})	N	P	N	P
Food manufacturing industry	20≦V≦50	20	2	25	4
	50≦V≦500	15	1.5	20	3
	500＜V	10	1	15	2
Metal products manufacturing industry	20≦V≦50	20	2	30	3
	50≦V≦500	15	1	20	2
	500＜V	10	0.5	15	1
Other manufacturing industry	20≦V≦50	12	1	15	1.5
	50≦V≦500	10	0.5	12	1.2
	500＜V	8	0.5	10	1
Livestock industry	20≦V≦50	25	3	50	5
	50≦V≦500	15	2	40	5
	500＜V	10	1	30	3
Sewerage	20≦V≦100000	20	1	20	1
	100000＜V	15	0.5	15	0.5
Sewage disposal	20≦V	10	1	20	2
Septic tank	20≦V	15	2	20	4
Other industry	20≦V≦50	20	3	30	4
	50≦V≦500	15	2	25	4
	500＜V	10	1	20	3

Kitchen wastewater contains a massive amount of organic matters and SS, providing a large share of the contaminants from household effluent. In this sense, household effluent control, in particular from kitchen wastewater, plays a vital role in conserving the water environment. Against this backdrop, the Water Pollution Control Law was amended in 1990, which defined the responsibility of both administration and citizens concerning the domestic wastewater control by introducing tighter control measures. Household wastewater is closely related to everyday life. For this reason, the revised law suggested various practical measures at every kitchen, such as not to drain waste oil but to dispose of it as a solid waste by impregnating it with paper or solidifying it with commercially available coagulant, to stop directly draining the food garbage and kitchen refuse by filtering them out by a sink-corner basket or a drainer bag at the kitchen sink outlet, and to avoid excessive use of detergents. These measures in the kitchen are part of the environmental conservation campaign participated in by citizens, and they are considered to potentially reduce the pollutant load by

30-50 %. In Japan, the government's responsibility is legislated as designation of the important areas for domestic wastewater measures and formulation of a promotion plan for domestic wastewater measures. The important area for domestic wastewater measures is the area designated by the Governors of the prefectures when they recognize that it is particularly necessary to promote the implementation of measures for domestic wastewater. Municipalities designated as the important areas for domestic wastewater measures shall draw up the Plan for Promotion of Implementation of Domestic Wastewater Measures.

Effluent concentration regulation alone is not sufficient to remedy an expansive closed water area; it requires reduction of the total volume of pollution loads. On this account, a total effluent control system was institutionalized through the 1978 amendment of the Water pollution Control Law and the Law Concerning Special Measures for Conservation of the Environment of the Seto Inland Sea, aiming to reduce the total pollutant volume in such areas. Under this system, Tokyo Bay, Ise Bay, and Seto Inland Sea were specified as targets of standardized measures for effective pollution load reduction in order to control the total pollutant volume to within certain limits. The System was implemented in four sets of programs. On all four occasions, the system regulated COD only, where the figures of internal products by nitrogen and phosphorus were not reduced with any effect. Against this backdrop, a new fifth total effluent control system now regulates nitrogen and phosphorus as well.

The composition and concentration of organic matters, nitrogen, and phosphorus in the factory and other industrial effluent substantially differs from business to business. Organic wastewater is generally treated with activated sludge. For the organic wastewater with hazardous components, the coagulating sediment method and neutralization are first applied to eliminate the noxious matters, after which the wastewater is biologically treated, such as by the activated sludge method. Inorganic wastewater with toxic matters undergoes treatment by the coagulating sediment method and chemical treatment. In Japan, private sewage treatment systems at individual households is now under more stringent regulations: Tsuchiura City in Ibaraki Prefecture further limits the effluent from septic tanks at individual detached houses down to BOD 10 mg/*l*, T-N 10 mg/*l*, and T-P 1 mg/*l*.

2-4-3 Varieties of Non-Point Sources and their Control

Non-point sources are those that are not categorized by their point source: non-point sources include farmlands, forests, and urban areas (see Fig. 2-4-3). It is called non-point because the sources spread areawide: such as outflow of fertilizers and agrochemicals from farmlands; rainfall containing atmospheric pollutants; pollutants such as exhaust gases, particulates and industrial dusts accumulated on the roofs, roads, and grounds of urban areas; outflow from animal excreta and bodies and fallen leaves; heavy metal outflow from mining areas; and effluent of contaminants from forests. The non-point pollutant sources are not pinpointed, but are spread all over the catchment area of water bodies. Pollutants from these sources escape from the sewage treatment in the watershed, and flow into influent rivers or directly into the lakes via canals or groundwater. The exact outflow points are unspecified, which makes it generally difficult to control them. The problematic pollutants from the non-point sources that load the water areas include organic materials, nitrogen, phosphorus, and agrochemicals. Some of the important factors of the non-point-source loads that flow into the watershed are, for instance, natural phosphate eluted from the soil in the basin and nitrogen and phosphate fed as fertilizer to farmland. Typical land use patterns that facilitate non-point pollutant sources are stock farming, forestry, and agriculture. In addition, soil and topsoil erosions trigger a massive nitrogen and phosphorus influx. Since the point sources are easier to control, implementation of measures against them tends to proceed smoothly. In this case, the non-point sources come to share a relatively larger portion of the pollutants, raising the

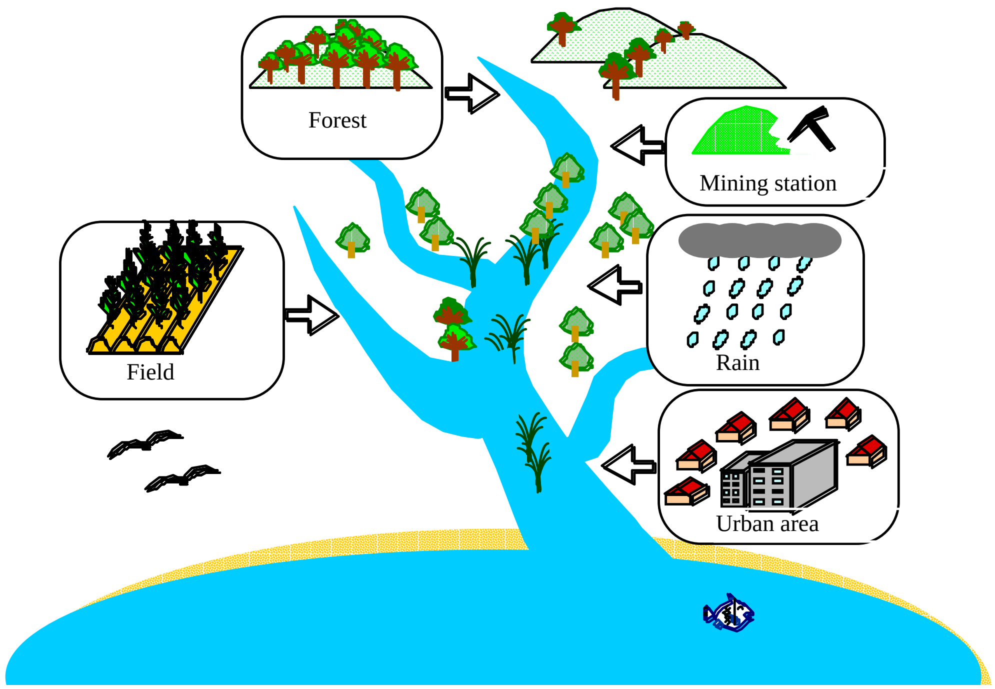

Fig. 2-4-3 Non-point sources

importance of control measures for these sources. Nevertheless, pollutants from non-point sources flow from numerous outflow points into rivers and lakes, which makes their control a severe challenge. Ensuring safe water use and a sustainable water environment requires a stepwise approach: first, to hydrologically understand and analyze the actual qualitative, quantitative, and environmental states of water, such as contaminant levels, pollution load volumes, water volume, rainfall, and geographic conditions, in order to set an effective target for water area remedy and conservation, and then to formulate and implement a strategy to reduce the pollutant loads before their influx into the water area.

Forest conservation plays a vital role in arresting the pollution load on the water area. Forest functions as flood regulator, drought reliever, climate and temperature moderator, water purifier, and global warming mitigator though CO^2 absorption. Yet forests, especially in the tropical developing countries, have continued to diminish/deteriorate. Being often attributable to social and economic factors of communities, such as overpopulation, economic difficulties, and land use, deforestation remains a difficult problem to prevent. The non-point sources are now considered to account for about 20 % of the total pollution load, although more accurate inventory should potentially raise its share. For this reason, it is crucial to implement more rigorous and efficient control over the non-point sources in the future.

In Lake Kasumigaura, the pollution loads from point sources account for 44 % in the organic matters (COD), 42 % in the nitrogen, and 23 % in the phosphorus, which demonstrates the higher share in the organic and nitrogen loads (see Fig. 2-4-2). Smaller phosphorus figures are attributed to their adsorption into the soil when penetrating through it. Formulation of a water pollution control strategy essentially requires the determination of influx volumes and the variety of pollutants from each source. As a result, the loads per area are calculated concerning organic matters, nitrogen, and phosphorus from the non-point sources (Table 2-4-3). The table illuminates the larger loads from urban areas than those from any other area. As a due course, urbanization in catchment areas increases the pollution loads from non-point sources. To be more specific, urbanization accelerates eutrophication. In a paddy field, the nitrate nitrogen concentration in the groundwater around it increases during the fertilizing period in summer. It rises up to 13 mg/*l* in June, whereas the figure in January is below 2 mg/*l*. Paddies can denitrify the nitrate nitrogen to a certain degree, due to less fertilization needs and the formation of an anaerobic layer by the water covering the field. On the contrary, a dry field, as a non-point source, imposes large pollution loads due to lack of denitrification attributed to its substantial fertilization needs and the absence of an anaerobic layer. Vegetables, which are harvested in the middle of their growth, leave more load-imposing nitrogen in the soil than rice that is harvested after being fully grown. Samples of calculated load volumes from nitric fertilizer, livestock waste, and household effluent penetrating into the groundwater are shown in Table 2-4-4.

Table 2-4-3 Basic Units Used for Determining the Pollution Load from the Non-Point Sources in Lake Kasumigaura

Item	Paddy Field	Dry Field	Forest / Mountain	Golf Course	Rainfall (Lake Surface)	Urban Areas
COD	7.19	2.45	3.83	3.83	6.95	15.3
TN	2.4	2.34	1.56	1.56	3.08	2.4
TP	0.095	0.116	0.054	0.0	0.13	0.18

The Plan for the Preservation of Lakes and Marsh Water Quality in Lake Kasumigaura lists three strategic approaches for non-point pollution source control: promotion of eco-friendly agriculture; restriction of pollutant load outflow from urban areas; and proper forest management. Promotion of eco-friendly agriculture requires publicizing the current condition of Lake Kasumigaura and disseminating its decontamination to those engaged in agriculture through PR campaigns for implementing load abatement measures in partnership with farmers. At the same time, low input sustainable agriculture is to be implemented, in balance with productivity, where consideration is given to mitigation of the environmental loads, such as chemical fertilizers and agrochemicals, through soil formation and reasonable crop rotation. Specific techniques for load reduction list rightsizing the fertilization based on soil test results and promoting

Table 2-4-4 Nitrogen sources into ground water

	Fertilizati	Sewage from livestock		House discharging effluent through night soil treatment system into ground
		Pig	Cattle	
Amountof nitrogen discharged	135 kg・ha^{-1}・$year^{-1}$	37 g・$head^{-1}$ ・day^{-1}	290 g・$head^{-1}$ ・day^{-1}	6 g・$person^{-1}$ ・day^{-1}
Load to ground water	34 kg ・ ha^{-1} ・	3.4 kg・$head^{-1}$・$year^{-1}$	26 kg ・ $head^{-1}$ ・	1.6 kg ・ $person^{-1}$ ・

Amount of nitrogen fertilization was calculated as average amount of Japanese field.
Nitrogen loads into ground water were calculated by 25% leaching into ground water for fertilization and livestock.
Nitrogen load was calculated for livestock as no nitrogen in sewage was removed.
Nitrogen load from house discharging effluent through night soil treatment system into ground was based on the experiment of soil trench system located in lysimeter treating 50 L・m^{-2} ・day^{-1} effluent from night soil treatment system.

the use of both slow-release and anti-elution fertilizers, among which the most important is optimal fertilization. As for urban area, PR and dissemination campaigns are to be undertaken to establish a partnership with the community members in cleaning gutters and residential areas to reduce the contaminant outflow from rain. In addition, storm-water reservoirs for flood control and other pools are to be properly managed. Another important measure is to reserve as many wide green spaces as possible in newly developed areas. Proper forest management means to reduce the pollutant outflow by rain from soil erosion and degradation in the deteriorated forests (foothill and plain forest). Since a properly managed forest substantially contributes to reducing the rainfall load and boosting the water source rechargeability, forest management and enhancement are identified to play a crucial role in non-point contamination source control in the Lake Kasumigaura watershed. Nitrogen and phosphorus from farmland and forestry can be reduced with effect by the land use that minimizes the fertilizer drainage associated with soil erosion and rainfall.

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3 The present conditions and eutrophication measures in lakes in Japan

There are many designated lakes as well as other lakes in this country, but the closed nature (retention time), water depth, water temperature and catchment area load vary. Therefore, the eutrophication characteristics in lakes also vary as do opinions on the measures for tackling the problem. In this chapter, based on these points mentioned above, the present conditions of eutrophication in lakes in this country are described. For each lake, (1) the characteristics of catchment areas, (2) the water quality in lakes, the characteristics of biota, (3) the problems of the present situation and prospects for measures are described.

3-1 Lake Kasumigaura

3-1-1 Characteristics of the catchment area/lake

Lake Kasumigaura is an inland sea-lake belonging to the Tonegawa River system that flows through the Kanto Plain, and the lake is situated on the left bank of the lower reaches of the Tonegawa River, a low-lying area in the southeast part of Ibaraki prefecture. The water area is about 220 km^2, so it has the second largest area after Lake Biwa in this country. Moreover, the pondage is about 850 million m^3, which is larger than the total pondage of the multipurpose dam that was constructed in the upper reaches of the Tonegawa River. About six thousand years ago, Lake Kasumigaura was part of the inlet connected to the present upper reaches of the Tonegawa River, Lake Inba and Lake Tega. Over the centuries, the mouth of the river became blocked by earth and sand that was carried from the upper reaches, and it is said that the lake more or less assumed its present shape about 1,500-2,000 years ago, becoming a freshwater lake around 1638 during the Edo period. Lake Kasumigaura is a very young lake when compared to Lake Biwa that was said to have formed about four millions years ago, and it is naturally sensitive to surrounding

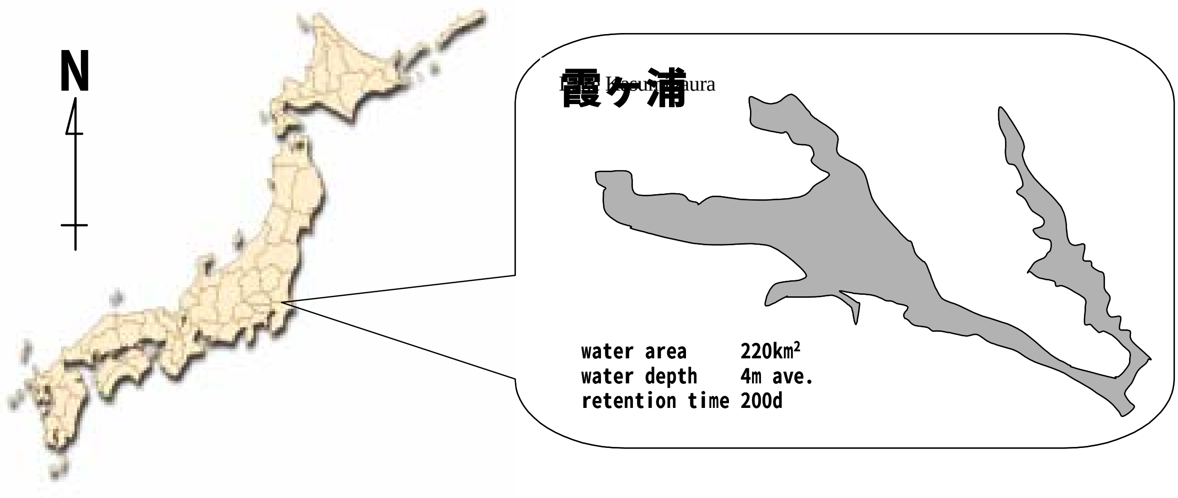

Fig 3-1-1 Overview of Lake Kasumigaura
Fig 3-1-1 Overview of

environmental changes. In recent years, in particular, large-scale development projects and a lot of regional development works have taken place in areas where development is possible such as the flat metropolitan catchment areas. As the plentiful lake water is a valuable water resource, Lake Kasumigaura plays an important role and has various uses as a water source including an irrigation water supply, domestic water supply, industrial water supply and inland water fisheries as well as recreation places, such as yachting and fishing, together with the experience of a remarkable anthropogenesis. However, Lake Kasumigaura has the characteristic tendency to accelerate water pollution due to eutrophication from its natural conditions; for example, Lake Kasumigaura is very shallow, the average water depth is about 4 m (the maximum is 7 m), the retention time (about 200 days) is long and the catchment area is large when compared to the volume of lake water. Therefore, for large-scale development sufficient consideration must be given to the water quality and conservation of the ecosystem together with the adjustment of extensive interests.

3-1-2 The present conditions of the lake

Lake Kasumigaura, as shown in Figure 3-1-1, is a natural lake under the control of Ibaraki prefecture. The water area is 220 $km^{2,}$ the pondage is 850 million $m^{3,}$ the maximum water depth is 7 m, the average water depth is 4 m, the basin area is 2,135 km^2, the catchment area population is 964,000, the average retention time is 200 days and it fronts a total of 21 cities, towns and villages, such as Tsuchiura City. The population density per pondage of a million m^3 is 1,126 and the population density per basin area of 1 km^2 is 448. The water is used for the public water supply, irrigation water supply, industrial water supply, fisheries, fishing and boating. The level of the environmental standard under the Plan for the Preservation of Lakes and Marsh Water Quality is COD: 3 mg/*l*., T-N: 0.4 mg/*l*., T-P: 0.03 mg/*l*., but the water quality in 1996 was COD: 10 mg/*l*., T-N: 1.1 mg/*l*., T-P: 0.14 mg/*l*. in Nishiura, COD: 8.7 mg/*l*., T-N: 0.71 mg/*l*., T-P: 0.086 mg/*l*. in Kitaura and COD: 8.8 mg/*l*., T-N: 0.75 mg/*l*., T-P: 0.090 mg/*l*. in the Hitachitone River. This lake was previously used as a lake resort, but was closed in 1973 due to the acceleration of water pollution. It is one of the lakes in Japan in which a lot of research has been conductedfor many years on the water quality and the organisms of Lake Kasumigaura, but even this is by no means sufficient. Recently, research has been specially focused on the transition of water-bloom formative algae. In the past, outbreaks of water-bloom from mainly *Microcystis* and *Anabaena* had occurred every summer, but for the past several years, *Oscillatoria* and *Phormidium* that emerge throughout the year have become dominant. The reason for this transition has not been made clear, but it is indicated that the changes in the quality of the inflow load from the catchment area might affect the transition.

3-1-3 The present situation of measures

The Conservation of Lakes and Marsh Water Quality Measures Project includes the enlightenment project for purification in Kasumigaura, the domestic drainage canal purification measures promotion project, the water-bloom disposal measures project, the river environmental improvement project, the Lake Kasumigaura_catchment area paddy fields self-purifying function improvement emergency measures project, the environmental preservation livestock establishment guidance project and the Lake Kasumigaura and Kitaura purification measures project. Furthermore, Tsuchiura Biopark was established at Tsuchiura Port, and this park functions as a place for both water purification and connecting the residents and the waterside. "The 6th International Conference on the Conservation and Management of Lakes - Kasumigaura '95" was held in October 1995 with an attendance of 8,200 participants from 75 foreign countries, under the theme of "Harmonizing Human Life with Lakes - Towards the Sustainable Use of Lakes and Reservoirs." There, residents, researchers, companies and administrators met together for discussion and presentation of the results of their research. This was a landmark international conference as there was an intense exchange of opinions among the participants. Through the discussions at this conference, the present conditions and problems of lakes around the world were made clear, and people related to the preservation of lake environments became aware of the importance of cooperation and the necessity for international cooperation. "The declaration of Kasumigaura," action guideline for the 21st century, was adopted, and it became a great opportunity for heightening interest in the environmental issues of lakes in Japan. In addition, since April 2001, an independent administrative agency, the National Institute for Environmental Studies Bioecoengineering Research Facility, has been established at Kasumigaura lakeside, and its function as a place for the international and scholarly transmission of information is greatly expected.

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3-2 Lake Biwa

3-2-1 Characteristics of the catchment area / lake

Lake Biwa with its long history of about five million years is a natural treasury of over 1,000 species of aquatic organisms. The water is used not only for water sources including the public water supply, industrial water supply and the irrigation water supply of about 14 million people in areas such as Keihanshin, but also for resort places including a swimming area and a place for the marine products industry. Furthermore, it was designated as a registered wetlands under the "Ramsar Convention (Convention on Wetlands of International Importance Especially as a Waterfowl Habitat) " in June 1993, and its significance as a habitat for a variety of organisms was recognized once again. Lake Biwa is one of the lakes known as an "ancient lake," in which stream dwellers evolved originally, and its ecological system was fixed by its endemic species throughout its long history. In fact, endemic species of fish, such as crucian carp (*Carassius auratus grandoculis*), *Gnathopogon caerulescens* and the Lake Biwa catfish, which evolved in the unique environment of the lake, exist in Lake Biwa. Thirteen species out of 53 species of fish living in Lake Biwa are endemic species, and a dozen or so species of endemic shellfish, called *Semisulcospira,* can also be found. Climatically and geographically, Lake Biwa is a great natural puddle. Climatically, the southern part of Lake Biwa adopts the Pacific coast climate and has a lot of rain both in the rainy season and the typhoon season. On the other hand, the northern part of Lake Biwa adopts the Japan Sea coast climate and has a lot of snow in winter. Therefore, this area has heavy rainfall throughout the year on average, besides being surrounded by mountains, in which the water is constantly flowing from over 400 rivers and watercourses, and then out into the Seta River only. This specialty leads to its value as a natural puddle of Lake Biwa.

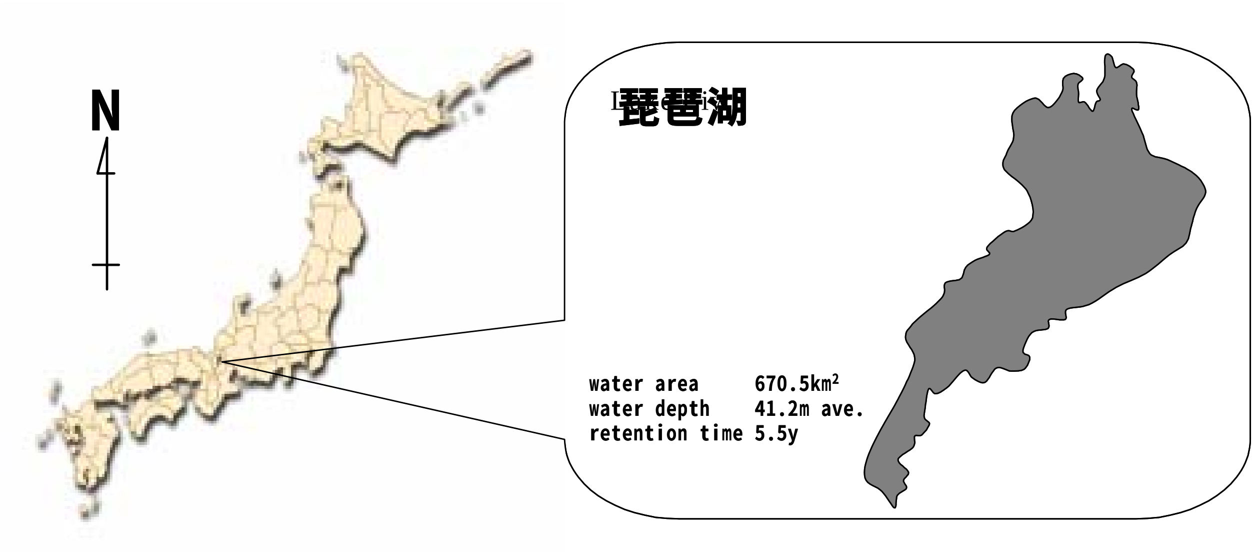

図3-2-1 琵琶湖の概要

Fig 3-2-1 Overview of Lake Biwa

3-2-2 The present conditions of the lake

Lake Biwa, as shown in Figure 3-2-1, is a natural lake under the control of Shiga prefecture, and the water area is 670.5 km^2, the pondage is 27,500 million m^3, the maximum water depth is 130.6 m, the average water depth is 41.2 m, the basin area is 3,174 km^2, the catchment area population is 1,219,000, the average retention time is 5.5 years and it fronts 21 cities and towns, such as Otsu City. The population density per pondage of a million m^3 is 44 and the population density per basin area of 1 km^2 is 381. The water is used as a public water supply, irrigation water supply, industrial water supply, for fisheries, bathing, fishing, sightseeing, boating and natural environment protection. The level of the environmental standard under the Plan for the Preservation of Lakes and Marsh Water Quality is COD: 1 mg/*l*., T-N: 0.2 mg/*l*., T-P: 0.01 mg/*l*., but the water quality in the year of 1996 was COD: 2.5 mg/*l*., T-N: 0.34 mg/*l*., T-P: 0.007 mg/*l*. in the Northern Lake, and COD: 3.0 mg/*l*., T-N: 0.42 mg/*l*., T-P: 0.018 mg/*l*. in the Southern Lake. Freshwater red tide and algal-bloom start to bloom every summer, and create difficulties for water use and deterioration of the landscape. Since the 1960s, water pollution has been accelerated mainly in the Southern Lake with the increase of industrial effluent and household wastewater flowing into Lake Biwa. The pollution finally spread over the whole of Lake Biwa, with eutrophication being remarkable in the 1970s. There was a particular outbreak of freshwater red tide caused by *Uroglena americana* in Lake Biwa in 1977 for the first time, and an outbreak of algal-bloom on the west coast of the Southern Lake in 1983. Since then, there have been outbreaks of, freshwater red tide almost every year except in 1986, 1997 and 1998, and algal-bloom outbreaks except in 1984. Mass multiplication of picoplankton that is classified as the blue-green algae *Synechococcus* was also observed over the whole of Lake Biwa in 1989. Looking at the transition of COD, which is a typical parameter of organic pollution in lakes, it temporarily showed a tendency to decrease in the early 1980s in Lake Biwa, but since then it has shown a tendency to increase gradually. The COD of the Northern Lake is 2-3 times higher than the level of the environmental standard and the COD of the Southern Lake is 3-4 times higher than the level of the environmental standard, so both levels drastically exceed the level of the environmental standard every year.

3-2-3 The present situation of measures

Lake Biwa has a large inflow pollution load amount derived from area sources among the designated lakes. In Lake Biwa, the inflow pollution load amount has decreased by the implementation of measures under the Lake Law, but the water quality has not yet been improved. The reasons for this include the following: (1) the retention time is long (about 5 years), and the change of the inflow load amount does not immediately reflect changes of the water quality, (2) the load amount estimated by the area sources including agricultural land might very likely be underestimated, (3) the increase of nitrogen and the phosphorus effluent load amount due to the changes from a pit latrine to a septic tank, (4) based on the calculation of the load amount, it is assumed that the residential pollutant load per unit production has not changed, but there is in fact the possibility of an increase, (5) the load amount from the bottom sludge is not decreased immediately, so a time lag is observed. However, if measures had not been taken, the inflow load amount would clearly have been increased. In 1995 when the measures were taken, the load amount of COD: 20%, T-N: 20% and T-P: 31% was reduced.

The Conservation of Lakes and Marsh Water Quality Measures includes the water quality conservation facilities improvement project, the joint treatment plant installation project, the small-scale wastewater facilities in agricultural villages improvement project, the waterweed harvesting project, the Southern Lake Water quality Improvement measures project, the enforcement of ordinance to reed community preservation, the enforcement of ordinance to household wastewater measures promotion and the Northern Lake organic pollution measures. To preserve reeds at the lakeshore, especially in Shiga, the “Ordinance to Preserve the Reed Community in Lake Biwa in Shiga Prefecture” was adopted in 1992, and projects that protect the community at the lakeshore under the specification of reed community preservation areas and raise reed communities are being conducted. Taking into consideration that the wetlands are designated under the Ramsar Convention, the water purification ability of botanical reeds is not sufficient to merit evaluation, but the role of the reed field as a cradle of organisms is very important. Furthermore, the 1st World Lakes Conference was held here in 1982, and the 9th World Lakes Conference under the slogan of “Building Partnerships between Citizens and Local Governments for Sustainable Lake Management” was held at Lake Biwa in November 2001.

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3-3 Lake Suwa

3-3-1 Characteristics of the catchment area / lake

Lake Suwa is located in the middle of Nagano Prefecture, and its water area is the largest in the prefecture. Moreover, the lake is typical of the eutrophic lakes in Japan.　Lake Suwa is situated at an altitude of 759 m above sea level, and located away from large cities, but it is known that eutrophication is accelerated earlier in inland highland lakes.　This is a very shallow lake and the present water area is 13.3 km^2, the maximum water depth is up to 6.5 m, the average water depth is about 4 m, but the thickness of the lake bottom cumulus deposit is over 200 m and it consists of earth and sand carried from the surroundings through rivers, the carcasses of organisms and diatom organic ooze produced in the lake.　There is a lot of earth and sand flowing into the cumulus deposit from outside of the lake, because major mountains surrounding the lake are volcanoes including Yatsugatake.　It is supposed from the muddiness of influent rivers during rainfall that earth and sand presently flow out of agricultural land at the foot of mountains on a plateau, and a lot of earth and sand flow into Lake Suwa.　The lakeshore line is less irregular due to artificial repairs, and its extension length is about 16 km.　The total influent rivers into the lake are considered to

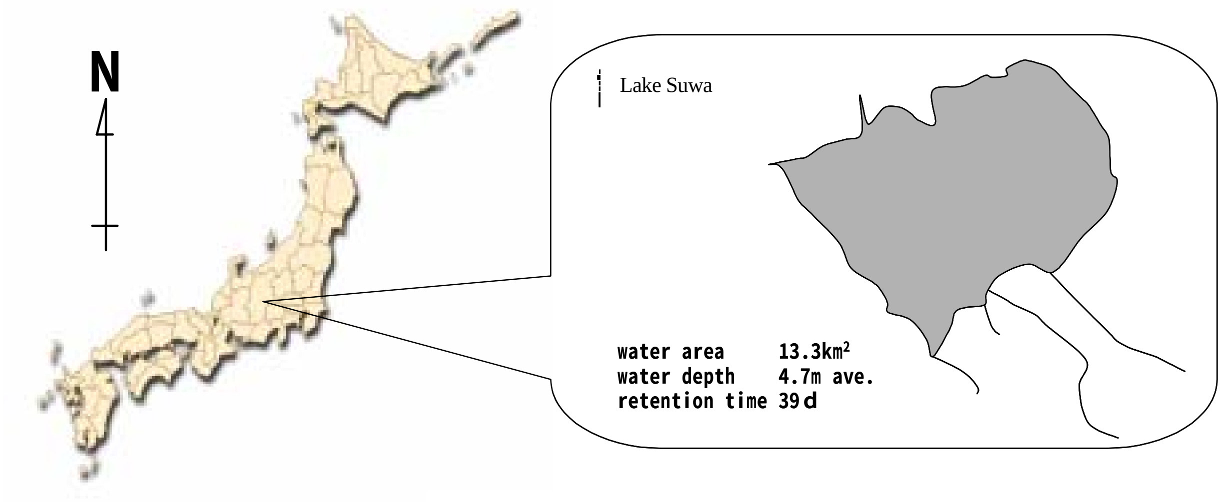

Fig.3-3-1 Overview of Lake Suwa
図 3-3-1　諏訪湖の概要

number 31, but many of them are irrigation canals and small canals, and the main influent rivers are the Yokokawa River, the Togawa River, the Kakumagawa River, the Kamikawa River, the Miyagawa River and the Shinkawa River. The only effluent river to flow out of the west part of the lake is the Tenryu River, which flows into the Pacific Ocean in Shizuoka through Inatani.

3-3-2 The present conditions of the lake

Lake Suwa, as shown in Figure 3-3-1, is a natural lake under the control of Nagano prefecture, and the water area is 13.3 km^2, the pondage is 62.9 million m^3, the maximum water depth is 7.2 m, the average water depth is 4.7 m, the basin area is 531.8 km^2, the catchment area population is 182,000, the average retention time is 39 days and it is located in Suwa City. The population density per pondage of a million m^3 is 2,905 and the population density per basin area of 1 km^2 is 344. The water is used for the irrigation water supply, fisheries, fishing and boating. The level of the environmental standard under the Plan for the Preservation of Lakes and Marsh Water Quality is COD: 3 mg/*l*., T-N: 0.6mg/*l*., T-P: 0.05 mg/*l*., but the water quality in 1996 was COD: 11 mg/*l*., T-N: 1.0 mg/*l*., T-P: 0.094 mg/*l*. Algal-bloom outbreaks occur every summer and cause deterioration of the landscape and difficulties in water use. Scientifically, for three years from 1985 to 1987, a large-scale isolated water mass (mesocosm) experiment was conducted to determine whether any chain reactions occur in organisms and the environment when artificial changes are inflicted on the ecosystem in each water mass. Then, an analysis and examination were purposely conducted to investigate the mechanism of maintenance and changes in ecosystem stability.

3-3-3 The present situation of measures

The Preservation of Lakes and Marsh Water Quality Measures Project includes river-basin sewerage works, joint treatment plant maintenance (outside the area of the sewage system plan), bottom sludge dredging (for example, off Hama in Okaya City, off Shimosuwa Town and off Takashima in Suwa City) and the removal of suspended solids and waterweed (in cooperation with related cities, towns and villages, and various lobbies). Several mistakes can be observed in the original Lake Suwa purification plan. One of them is the dredging plan, adopted as one of the main plans. One reason for the plan is secondary pollution caused by aquatic plants; as a result of the pollution, the removal of aquatic plants along the shore was done effectively. However, it is clear that this action caused significant changes in the environment of Lake Suwa not only its water quality but also its biota. Fortunately, nationally and worldwide, the importance of coastal areas and the restoration of lakes as an ecosystem has become recognized, and the restoration plan for coastal areas can be progressed in Lake Suwa. Preservation of lakes is important not only for the water quality of the environment of organisms that inhabit lakes, but also for preservation of the shape of Lake Suwa itself, and its preservation as an ecosystem is possible only after the two are combined. The restoration still has to be progressed with trial and error, but it is expected that the experiments in Lake Suwa will be applied as one of the case studies.

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3-4 Lake Mikatagoko

3-4-1 Characteristics of the catchment area/lake

Lake Mikatagoko, in the southern part of Fukui Prefecture, is a lake community consisting of five lakes, Hyuga, Kugushi, Suigetsu, Suga and Mikata, and each lake has a close relationship hydraulically, because each lake is connected mutually by the Hyuga channel, the Hayase River, the Urami River, Saga Zuido, Seto and the Horikiri River, and eventually, to the ocean. Lake Mikatagoko originated from a pooling lake on a fault basin submerged by diastrophism about one million years ago, and it is said that Hyuga, Suigetsu, Suga and Mikata used to be freshwater lakes, respectively. On the other hand, it is said that Kugushi is a lake formed by closure with a bar. After that, to

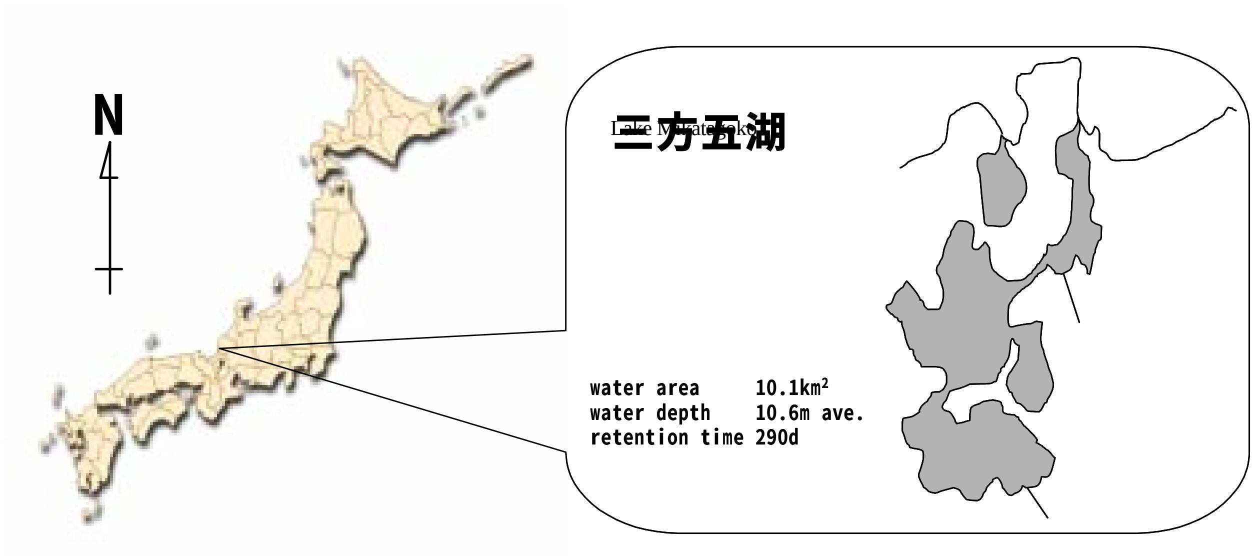

Fig 3-4-1 Overview of Lake Mikatagoko
図 3-4-1 三方五湖の概要

prevent overflowing by flood, the Hyuga channel and the Urami River were excavated in 1630 and in 1655 respectively, and Saga Zuido was dug and widened from 1933 to 1936, after which a large amount of seawater flowed into Lake Suigetsu. However, Saga Zuido was closed in 1978. At present, Hyuga is a saltwater lake that opens onto Wakasa Bay. Kugushi, Suigetsu and Suga are brackish-water lakes, and moreover Suigetsu is a partly circular lake with a halocline around a water depth of 10 m, and Suga is a sub-lake basin of Suigetsu. Mikata is a freshwater lake that has the role of the sedimentation of the earth, sand and pollutants from inflowing rivers. The main river that flows into Lake Mikatagoko is the Nanamegawa River that flows into Lake Mikata, but there are some others, such as agricultural effluent canals and the Ubanishi River that flows into the Bessho River, the Kannon River and the Kugushi River.

3-4-2 The present situation of the lake

Lake Mikatagoko, as shown in Figure 3-4-1, is under the control of Fukui prefecture, and the outline of the lake community that forms Lake Mikatagoko is as follows: For Lake Hyuga, the water area is 0.9 km^2, the average water depth is 14.3 m, the lake capacity is 12.87 million m^3 and the basin area is 2.2 km^2; for Lake Kugushi, the water area is 1.4 km^2, the average water depth is 1.8 m, the lake capacity is 2.52 million m^3 and the basin area is 15.8 km^2; for Lake Suigetsu, the water area is 4.3 km^2, the average water depth is 14.3 m, the lake capacity is 74.36 million m^3 and the basin area is 4.3 km^2; and for Lake Mikata, the water area is 3.6 km^2, the average water depth is 1.3 m, the lake capacity is 4.68 million m^3 and the basin area is 60.3 km^2. In Lake Mikatagoko taken as a whole, the water area is 10.1 km^2, the maximum water depth is 33.7 m, the average water depth is 10.6 m, the lake capacity is 107 million m^3, the basin area is 84.2 km^2, the catchment area population is 11,300 and the average retention time is 290 days. The lake lies between the two towns of Mikata and Mihama, and the water quality in 1996 was COD: 5.0 mg/*l*., T-N: 0.64 mg/*l*. and T-P: 0.056 mg/*l*. Algal-bloom outbreaks occur from June to September every year and cause deterioration of the landscape and difficulties in water use. Component species of algal-bloom outbreaks in Lake Mikatagoko are known to belong to the following four species: genus *Microcystis*, genus *Anabaena*, genus *Oscillatoria* and genus *Aphanizomenon*.

3-4-3 The present situation of measures

The environmental standard of Lake Mikatagoko except for Hyuga was designated as type B in February 1977, because the water pollution due to eutrophication was accelerated (Lake Hyuga was designated as type A). Moreover, for the four lakes, the environmental standard related to nitrogen and phosphorus was designated as type IV in October 1987. At the designation, for Lake Mikata the temporary targeted value with the type designation was set at 0.61 mg/*l*., because it was not expected to achieve the type IV water quality of nitrogen quickly, so "An attempt will be made to achieve the temporary target step by step and the environmental standard as early as possible." The temporary target will be reconsidered every 5 years, so the water quality of the present state was set as the standard in 1992; taking into consideration that enforcement of the measures for conservation of the water quality was planned, the water quality estimation for the future (in 1997) was made, then reconsideration of the temporary target was examined. However, the proportion of the pollutant loads except for residential and industrial loads is high, and measures for the sewerage system are underway, so it was estimated that achieving the temporary target in 1997 would be difficult. Therefore, it was decided that the conventional temporary targeted value would remain unchanged, and the total measures for the achievement are continuing to progress. Measures for Water Quality to achieve the temporary target of the "Preservation of Lakes and Marsh Water Quality Comprehensive Measures Promotion Conference," organized in the 17th section of the prefectural office, were established, and various measures are being conducted as the keys to "source control," "measures for inflowing canals," "measures for inlakes" and "measures for lakesides." The Preservation of Lakes and Marsh Water Quality Measure Project includes a public sewerage improvement project (Mihama public sewerage: disposal population 7,560, the scheduled year of completion is 2020; Mikata special environment public sewerage: disposal population 4,550, the scheduled year of completion is 2016), an agricultural comprehensive improvement project, a rural community sewerage project (disposal population 1,020, the scheduled year of completion is 1999), an agricultural-recycled lake measures establishment promotion project (enlightenment on the prevention of fertilizing-outflow, the spread of fertilizing-planting machinery, the installment of a floating reef for aquatic plants) and a rivers purification project (dredging of Mikata).

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3-5 Lake Kojima

3-5-1 Characteristics of the catchment area/lake

Lake Kojima, located about 8 km south from the center of the Okayama city area, is an artificial lake that became a freshwater lake when the river mouth of Kojima bay was closed by the Ministry of Agriculture, Forestry and Fisheries. This measure was taken to prevent drought damage and salt water damage to agricultural products raised on reclaimed land that had prospered from the Edo era until 1963, and to reinforce the draining of reclaimed land and secure the safety of the reclaimed embankment. The construction work on the closed embankment began in

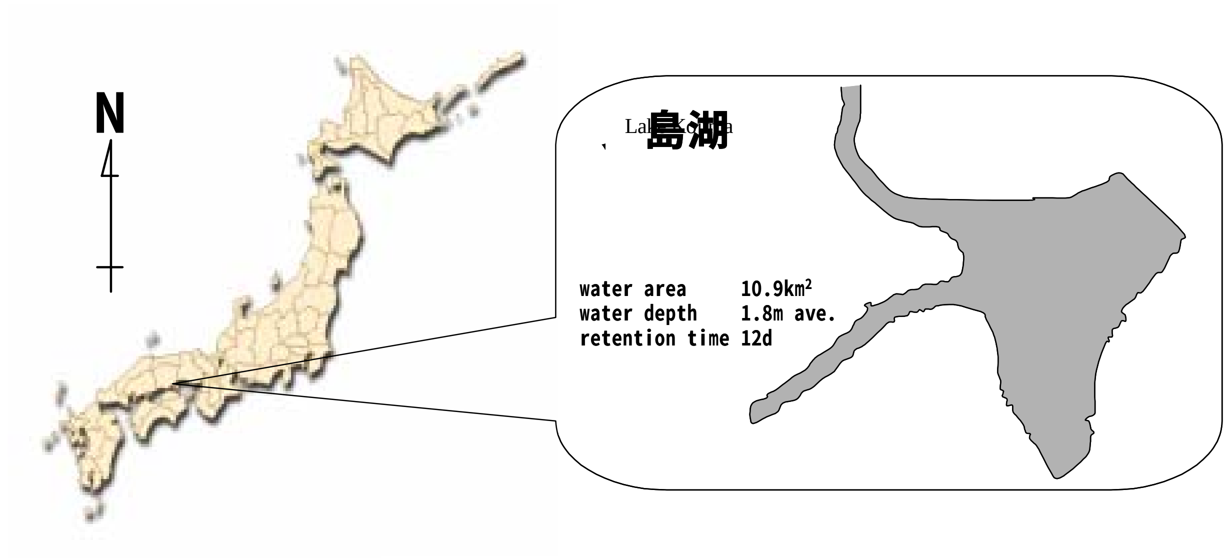

Fig.3-5-1 Overview of Lake Kojima
図 3-5-1 児島湖の概要

February 1951, the construction of the tide block was conducted in 1956, the embankment was constructed in 1959 and then the entire work of the embankment extending for 1,558 m was completed in March 1962. The water level is controlled by opening and closing the center sluice consisting of 6 gates and a distance of 24 m. When the standard water level of 80 cm in an irrigation period and 50 cm in a non-irrigation period is exceeded, control is exerted by discharging into Kojima bay at low tide. The Sasagase River and the Kurashiki River flow into Lake Kojima through both the city areas of Okayama and Kurashiki and its surrounding fields. Especially, the Kurashiki River flows into Lake Kojima through the fields of estuarial areas. As for the characteristics of Lake Kojima, it is entirely shallow except near the sluice and part of Kohoku, and the lake belongs to a shallow water lake. It has a small water area, many people, about one third of the prefectural population, live in the catchment area, the pollutant load ratio charges of 33,700 persons/million m^3 lake water and 3,070 ha/million m^3 lake water are the third highest next to Lake Tega and Lake Inba, and the lake becomes polluted easily. Moreover, the annual average retention time is as short as about 12 days.

3-5-2 The present conditions of the lake

Lake Kojima, as shown in Figure 3-5-1, is an artificial lake under the control of Okayama prefecture, and the water area is 10.9 km^2, the pondage is 26.1 million m^3, the maximum water depth is 9.0 m, the average water depth is 1.8 m, the basin area is 543.6 km^2, the catchment area population is 624,000, the average retention time is 12 days and it fronts eight cities, towns and villages, such as Okayama city, Kurashiki city, Tamano city, Sojya city, Nadasaki town, Hayashima town, Yamate village and Kaya town. The population density per pondage of a million m^3 is 23,895 and the population density per catchment area of 1 km^2 is 1,146. The water is used for an irrigation water supply and fisheries. The level of the environmental standard under the Plan for the Preservation of Lakes and Marsh Water Quality is COD: 5 mg/*l*., T-N: 1 mg/*l*., T-P: 0. 1 mg/*l*., but the water quality in 1996 was COD: 10 mg/*l*., T-N: 1.8 mg/*l*., T-P: 0.21 mg/*l*. Looking at the COD effluent amount to the catchment area by different sources, household wastewater with the urbanization accounts for 51.6%, then mountain forest, fields and live-stock account for 31.4%, plant effluent and business establishment effluent account for 17.0%, and T-N and T-P are shown as having almost the same effluent ratio as the COD by different sources. Being influenced by the source, the water quality has changed by about double the level of the environmental standard of 5 mg/*l*. of COD, the conformable rate of the environmental standard is 0% and the conditions of water pollution are extremely bad, so much so that it became the fifth worst lake in Japan in 1997. By adopting the environmental standard type V, T-N 1 mg/*l*. and T-P 0.1 mg/*l*., both T-N and T-P are changed by about double the level of the environmental standard such as COD. Lake Kojima became a closed water area in which water exchange is poor because of the closure of Kojima bay, and the concentration of nutrient salts, such as nitrogen and phosphorus is high. Thus, typical eutrophication is caused by a marked increase in the production of aquatic organisms, such as plankton, aquatic plants, benthos, fish/crustaceans due to the abundant growth of algal-bloom, freshwater red tide, Water Hyacinth and water lettuce. Freshwater red tide caused by *Euglena sanguinea* started to bloom in irrigation canals in the catchment area from 1994, indicating in particular that organic pollution was extremely accelerated, and the acceleration of eutrophication is suggested to have occurred throughout the entire catchment area with the algal-bloom caused by *Microcystis aeruginosa* and *Anabaena spiroides* in Lake Kojima.

3-5-3 The present situation of measures

For the water purification measures, the lake was designated as a designated lake based on the “Special Measures Act for the Preservation of Lakes and Marsh Water Quality” in December 1985, after which the “Plan for the Preservation of Lakes and Marsh Water Quality for Lake Kojima” was established in January 1987. Various measures of Water Quality Conservation were then promoted all together within the prefecture, related cities, towns and villages, and the residents in the catchment area. Recently, the “Ordinance for Lake Kojima environmental protection” was established in March 1991 to promote general measures for environmental preservation, which were not only for Water Quality Conservation, but also for nature conservation, landscape measures and environmental considerations. Then, the ordinance was enforced in September 1991. Furthermore, the second plan for the conservation of the water quality was formulated in March 1992, and it was decided to reconsider the plan every five years after that. Currently, the third plan for the conservation of water quality is underway. However, the water quality is around 10 mg/*l*. of COD, and it remains stable. It has been evaluated that the deterioration of the water quality could be prevented based on the plan for the conservation of the water quality, but that the targeted value of 8.8 mg/*l*. under the plan for the conservation of the water quality could not be achieved. The Conservation of Lake Water Quality

Measures Project includes improvement of the sewage system/rural community sewerage, an installation assistance project of a joint treatment plant, a household wastewater treatment facilities installation project, a waste disposal facilities improvement project, an animal waste disposal facilities improvement project, an artificial formation of tideland/reed field, the development of vegetation revetment, the installation of water purification facilities, a governmental comprehensive farmlands disaster prevention project, the Lake Kojima catchment area environmental preservation measures promotion conference, the Lake Kojima catchment area water quality conservation Foundation and the Lake Kojima catchment area environmental preservation monthly publication event.

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3-6 Lake Nojiri

3-6-1 Characteristics of the catchment area/lake

Lake Nojiri is located in the Joshinetsu highland national park, and has been used as a summer resort for a long time. The lake is said to have originated from the eruption or volcanic activity of Mt. Kurohime.

3-6-2 The present conditions of the lake

Lake Nojiri, as shown in Figure 3-6-1, is a natural lake under the control of Nagano prefecture, and the water area is 4.56 km^2, the pondage is 9.6 million m^3, the maximum water depth is 38.5 m, the average water depth is 21.0 m, the basin area is 185.3 km^2, the catchment area population is 2,500, the average retention time is 738 days and it is located in Shinano town in Kamiminochigun. The population density per pondage of a million m^3 is 26 and the population density per catchment area of 1 km^2 is 13. The water is used for the public water supply, irrigation water supply, power generation water supply, fisheries and sightseeing. The water quality is said to be better than average,

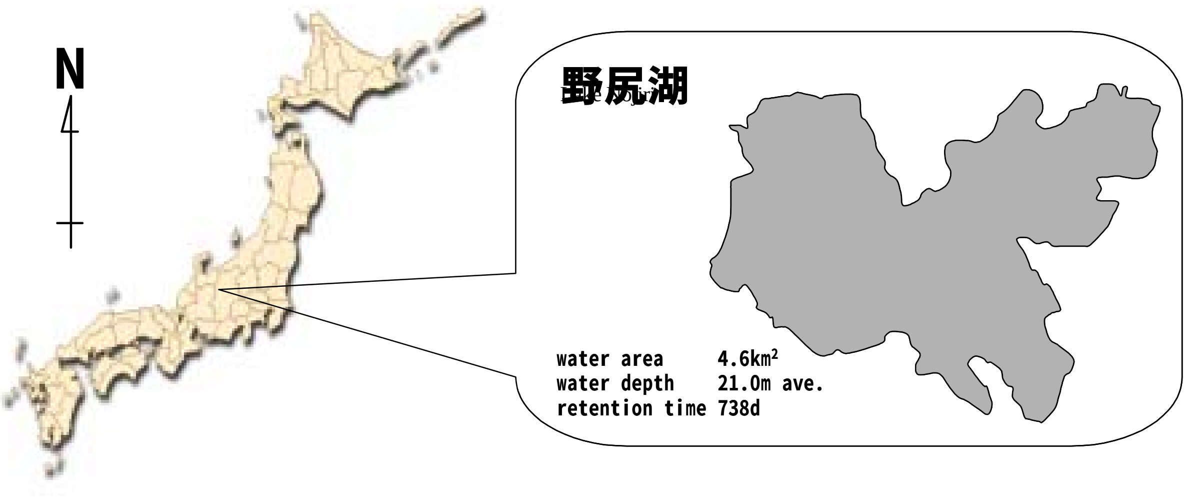

図 3-6-1 野尻湖の概要
Fig 3-6-1 Overview of Lake Nojiri

but freshwater red tide bloomed in 1988, and the development of eutrophication has been a concern ever since then. Therefore, the lake was designated by the Special Measures Act for the Preservation of Lakes and Marsh Water Quality in 1994, and comprehensive purification measures are being enforced. The level of the environmental standard under the Plan for the Preservation of Lakes and Marsh Water Quality is COD: 1 mg/*l*., T-P: 0.005 mg/*l*., but the water quality in 1996 was COD: 2.1 mg/*l*., T-P: 0.005 mg/*l*.

3-6-3 The present situation of measures

Conservation of the Lake Water Quality Measures Project includes public sewerage maintenance (partly started in 1995), rural community wastewater treatment facilities improvement (Kokai area, partly started in 1994), water purification by reed field (conducted at inflowing rivers), a joint treatment plant/clarification tank installation project (Shinano town, outside the sewerage system area, installation assistance) and the dissemination of environmentally-conserved agriculture (the dissemination of paddy field stripe fertilizing-planting machinery, appropriate control of the paddy field surface water).

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3-7 Lake Tega

3-7-1 Characteristics of the catchment area/lake

Lake Tega is located in the northwestern part of Chiba prefecture and belongs to the Tone River system. It is an important water source for the irrigation water supply and an inland water fisheries facility, but the water quality of COD, the parameter of organic pollution, has been at the worst level of all lakes in Japan since 1974 due to the progression of pollution. The current Lake Tega is a small shallow lake, and the water area is 650 ha, the water capacity is 5.6 million m^3 and the average water depth is 0.86 m, but many citizens visit its water side for relaxation on weekends, and more than 8.4 hundred thousand people have visited the Lake Tega public water square, "Mizunoyakata" established in 1991, over the past eight years. Furthermore, currently 22 parties belong to the "Joint association of the beautiful Lake Tega appreciation society," established by resident organizations in the Lake Tega catchment area in 1995. Lake Tega is polluted, but is one of the small number of tasteful lakes remaining in the suburbs of the Tokyo metropolitan area. Restoring Lake Tega to its former glory will lead to the reclamation of hometowns that have been lost over the past few years. Lake Tega plays an important role as a symbol of the community in this area.

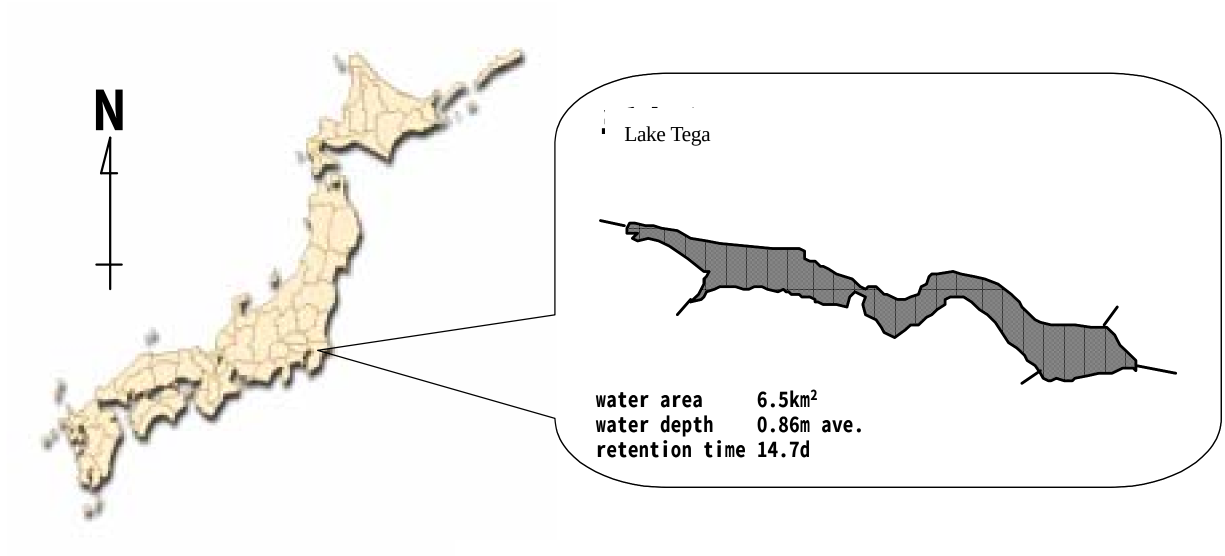

Fig.3-7-1 Overview of Lake Tega

図3-7-1 手賀沼の概要

3-7-2 The present conditions of the lake

Lake Tega, as shown in Figure 3-7-1, is a natural lake under the control of Chiba prefecture, and the water area is 6.5 km^2, the pondage is 5.6 million m^3, the maximum water depth is 3.8 m, the average water depth is 0.86 m, the basin area is 150.2 km^2, the catchment area population is 465,000, the average retention time is 13.9 days and it fronts 2 cities and 3 towns, such as Kashiwa city, Abiko city, Shonan town, Shiroi town and Inzai town. The population density per pondage of a million m^3 is 83,036 and the population density per catchment area of 1 km^2 is 3,096. The water is used for an irrigation water supply, fisheries, fishing and boating. The water area was once 12 km^2, but it was reduced to 6.5 km^2 as a result of the reclamation project conducted from 1954 to 1968. The level of the environmental standard under the Plan for the Preservation of Lakes and Marsh Water Quality is COD: 5 mg/*l*., T-N: 1 mg/*l*., T-P: 0.1 mg/*l*., but the water quality in 1996 was COD: 24 mg/*l*., T-N: 4.5 mg/*l*., T-P:0. 49 mg/*l*. Algal-bloom caused mainly by *Microcystis aeruginosa* and *Anabaena affinis* starts to bloom from June to October every year, and it has a harmful influence on the recreational function through deterioration of the landscape.

3-7-3 The present situation of measures

Lake Tega is a lake that has a high residential load ratio among the designated lakes. In spite of the decrease of the inflow load amount through measures taken in Lake Tega as well as in Lake Biwa, the effect is not reflected in the water quality. The reasons may include the following: (1) The retention time is short and the lake is influenced by the water quality of inflowing rivers. However, a change in the water quality of inflowing rivers has not been observed, so the decrease in the load amount is caused by the decrease in the water amount of inflowing rivers; (2) The nutrient load from the bottom sludge is heavy. In Lake Tega, the water quality of the influent has to be considered, and the introduction of purifying water is necessary as a purification measure. Moreover, there are actually no effective measures for the nutrient load from the bottom sludge, so the development of technologies is expected.

A lot of purification measures, such as residential wastewater measures, industrial wastewater measures, direct purification measures for river / lake and area sources measures have been enforced in Lake Tega. It can be said that sewerage system development has been the most effective among these measures, but the water purification effect has not actually been immediately apparent because as the sewerage system user population increases, the population in the catchment area also increases at the same time. In Chiba prefecture, in an attempt to drastically improve the water quality in Lake Tega, new measures that have been added to the purification measures in the Plan for the Preservation of Lakes and Marsh Water Quality have been examined. On examination, it is difficult to recover the water quality in Lake Tega to the environmental standard (COD: 5 mg/ *l*) for the moment, so COD: 10 mg/ *l* that was the water quality before the drastic deterioration around 1970 was established as a provisional target. The Lake Tega river basin sewerage plan was set on eight cities and towns in the catchment area in 1972, and treatment was started in part of the areas in 1981. Treated wastewater is discharged directly into the Tone River, so the effluent load amount of the sewerage system user population to Lake Tega becomes zero, and the purification effect is high. Furthermore, the Kitachiba water conveyance project is a project that supplies a city water supply from the Tone River to the Edo River and conducts a purification water supply into Lake Tega up to 10 m^3/s. Its construction was started in 1974 and it finally reached the final stage of real water conduction in 2000. Examination of the water conduction began in March 1999. The test result shows that if a water conveyance of 5-10 m^3/s is conducted for 5-10 days continuously, it will be expected to achieve COD: 10 mg/*l*. Thus, this project has quite good prospects, although the water conveyance of the purification water supply is conditional and it includes uncertain factors because continuous water conveyance is impossible. Moreover, measures have been taken to establish purification facilities for the river water as the principal objective to remove the phosphorus that causes the bloom of phytoplankton. The result obtained is that a one third reduction of the current phosphorus inflow load amount is required to achieve the estimated COD: 10 mg/*l*. Taking the progress of the sewerage system in the future and the beginning of Kitachiba water conveyance into consideration, the decision was made to construct facilities with a total of 35,000 m^3/day in four areas of sewerage system underdevelopment in the upstream catchment area of the Obori River and the Otsu River, and the construction of the first facilities began in 1999.

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3-8 Lake Naka-umi/Lake Shinji

3-8-1 Characteristics of the catchment area / lake

Lake Naka-umi and Lake Shinji, situated at the foot of the mountains in the Shimane peninsula and the mountains region of Chugoku, are located in part of the river mouth of the Hii River, the source of which is the mountains region of Chugoku, and which is a brackish-water lake passing through the Sakai channel into the Sea of Japan (Miho bay). Independently, the water area of each lake constitutes the fifth and the seventh largest area, respectively in Japan, but the joined area connected by 7 km of the Ohashi River exceeds the largest brackish-water lake, Lake Saroma (the water area is 151.9 km^2) in the country. Similar to ancient mythology stated in “The description of the natural

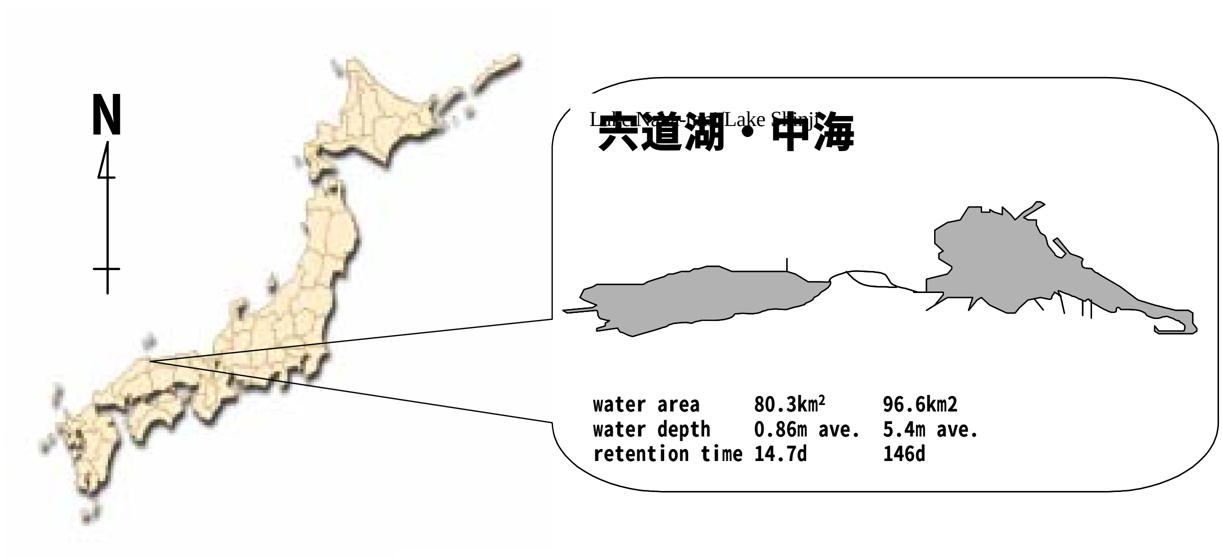

Fig 3-8-1 Overview of Lake Naka-umi/Lake Shinji

図3-8-1 中海・宍道湖の概要

features of Izumo," a project called "Kunihiki of Showa" was started. This was the "Governmental Lake Naka-umi Land Reform Project," which was related to the desalination and reclamation of Lake Shinji and Lake Naka-umi that began in 1963. Arguments about the project still continue over the reclamation of the Honjo building construction area, which is the last area that has been planned for reclamation for over forty years. In addition, it has become well known as an aquaculture base for corbicula, which are shipped to the whole country.

3-8-2 The present situation of lake

Lake Naka-umi, as shown in Figure 3-8-1, is a natural lake under the control of Tottori and Shimane prefectures, and the water area is 86.2 km^2, the pondage is 521 million m^3, the maximum water depth is 8.4 m, the average water depth is 5.4 m, the basin area is 590.1 km^2, the catchment area population is 161,200, the average retention time is 146 days and it fronts 4 cities and 3 towns, such as Yonago city, Sakaiminato city, Matsue city, Yasugi city, Mihonoseki town, Higashi-Izumo town and Yatsuka town. The population density per pondage of a million m^3 is 300 and the population density per catchment area of 1 km^2 is 265. The water is used for fisheries, an industrial water supply, sightseeing and fishing. With the development of socio-economical activities, the water quality environmental standard has not been secured since 1973, and the level of the environmental standard under the Plan for the Preservation of Lakes and Marsh Water Quality is COD: 3 mg/*l*., T-N: 0.4 mg/*l*., T-P: 0.03 mg/*l*., but the water quality in 1996 was COD: 7.5 mg/*l*., T-N: 1.0 mg/*l*., T-P: 0.1 mg/*l*. On the other hand, Lake Shinji is a natural lake under the control of Shimane prefecture, and the water area is 80.3 km^2, the pondage is 366 million m^3, the maximum water depth is 6.4 m, the average water depth is 4.5 m, the basin area is 1289.1 km^2, the catchment area population is 271,800, the average retention time is 110 days and it fronts 2 cities and 3 towns, such as Matsue city, Hirata city, Tamayu town, Shinji town and Hiigawa town. The population density per pondage of a million m^3 is 743 and the population density per catchment area of 1 km^2 is 211. The water is used for fisheries, an industrial water supply, sightseeing and fishing. With the development of socio-economical activities, the water quality environmental standard has not been secured since 1973, and the level of the environmental standard under the Plan for the Preservation of Lakes and Marsh Water Quality is COD: 3 mg/*l*., T-N: 0.4 mg/*l*., T-P: 0.03 mg/*l*., but the water quality in 1996 was COD: 4.7 mg/*l*., T-N: 0.56 mg/*l*., T-P: 0.053 mg/*l*.

3-8-3 The present situation of measures

Lake Naka-umi was designated by the Special Measures Act for the Preservation of Lakes and Marsh Water Quality in 1988, and based on the measures, the Plan for the Preservation of Lakes and Marsh Water Quality was settled in1989. This was followed by the second plan, which was settled in 1994, after which measures for the Conservation of the Water Quality were planned for its comprehensive and systematic promotion. The outline of the main measures for the Plan for the Preservation of Lakes and Marsh Water Quality includes sewerage system development (the increase of the dissemination rate: from 27% to 35%, used together with 4 cities and 2 towns, and conduit construction in 1 town and 1 village), small-scale wastewater facilities in agricultural villages (used together with 10 areas, the construction of a conduit and water treatment plant in 6 areas), purification measures for inflowing rivers (an environmental lake shore development project, river bed dredging, the former Kamo River purification water supply introduction project), direct purification of lakes (bottom sludge dredging, cover sand, artificial formation of seaweed beds), the spread of small-sized joint treatment plants (734 plants for 3 cities, 2 towns and 1 village), Measures for Miscellaneous Household Effluent (assistance to the community residents' enlightenment project, attaining 100% installation rate of fine strainer), agricultural area measures (the spread of fertilizing-planting machinery), measures related to the live-stock industry (appropriate treatment of excrement by composting facilities installation) and factory business establishment of wastewater measures (technical service and financing related to the prevention of pollution).　Lake Shinji was designated by the Special Measures Act for the Preservation of Lakes and Marsh Water Quality in 1988, and based on the measures, the Plan for the Preservation of Lakes and Marsh Water Quality was settled in 1989. This was followed by the second plan, which was settled in1994, after which measures for the conservation of water quality were planned for its comprehensive and systematic promotion.　The outline of the main measures for the Plan for the Preservation of Lakes and Marsh Water Quality includes sewerage system development (the increase of the dissemination rate: from 26% to 42%, used together with 2 cities and 4 towns, and conduit construction in 4 towns), small-scale wastewater facilities in agricultural villages (used together in 20 areas, the construction of a conduit and water treatment plant in 20 areas), a household wastewater polluted water channel direct purification project (conducted at 4 places in 2 cities), river improvement works projects (pseudo-natural bank development, river bed dredging, water weed removal), a small-sized joint treatment and purification plant improvement project (1,518 plants for 3 cities and 9 towns), the promotion of the Measures for Miscellaneous Household Effluent (assistance to the community residents' enlightenment project, attaining 100% installation rates of fine strainer), an environmental preservation agriculture promotion project (the spread of fertilizing-planting machinery), live-stock management environmental preservation comprehensive measures guidance (composting facilities installation) and factory business establishment of wastewater measures (technical service and financing related to the prevention of pollution).

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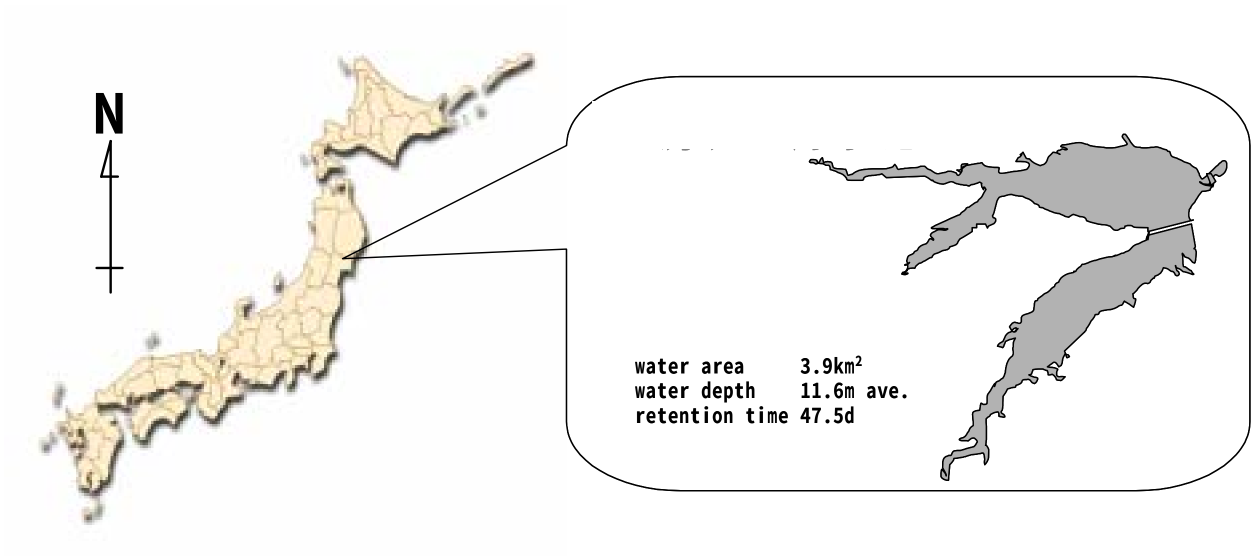
3-9 Kamafusa Damu-ko (Reservoir)

3-9-1 Characteristics of the catchment area / lake

Kamafusa Damu-ko (Reservoir) is a dammed lake that was constructed on the Goishi River, a branch of the Natori River System; the water source is the Miyagi and Yamagata prefecture borders, and it is located in Kawasaki-cho, 25 km southwest of Sendai.　The construction was completed in 1970 for flood measures due to the action of successive typhoons after the war and for the purpose of water use.　The dam takes the form of a linear gravity concrete dam, with a height of 45.5 m and a crest length of 177 m.　The geology of the dam site belongs to green tuff areas consisting of tuff and sandstone, but fossil seashells can be found on the lake shore, and an underground lignite mine is present. Kamafusa Damu-ko (Reservoir) is a multi-purpose reservoir, and used for flood-control as well as irrigation water for water use, a domestic water supply, an industrial water supply and a power generation water supply. The domestic water supply is especially supplied to 3 cities and 3 towns including Sendai City, after purification of the source water taken in directly from Kamafusa Damu-ko (Reservoir) at the Moniwa water purification plant. The amount is up to two hundred thousand liters a day. Furthermore, the Goishi River, a lower reach of the dam, is connected to the Natori River, and 44,000 m^3 of water is taken from a river channel at the Tomita water purification plant in the lower reaches of the Natori River. Up to 9,684m^3/s of irrigation water is used, industrial water up to a hundred thousand a day is used in a land industrial zone in Sendai, and in addition, 1,200 kW of electric power is generated with the maximum water use of 6.0 m^3/s. On the other hand, the areas around Kamafusa Damu-ko (Reservoir) play an important role as recreation spots. The peaks of Zao seen from a distance provide fine views, and there is a famous waterfall, Akino-otaki and many hot springs nearby. Furthermore, it is famous as a relaxation spot for citizens, for activities such as pond smelt fishing and outdoor sites. Michinoku-mori National Lakeside Park was opened as the tenth state park by the Ministry of Construction in 1980. It has become a large water park, which includes a vast flower garden, a variety of fountains and cascades, a public square that is a replica of one from the Jomon period, a forest for relaxation, a nature trail and a square for games and water. These were established in the 76-ha site, and recently, zones of culture and water have also been added. There are plans to expand the site to about 300 ha, including a campsite over the next few years.



3-9-2 The present conditions of the lake

Kamafusa Damu-ko (Reservoir), as shown in Figure 3-9-1, is an artificial lake under the control of Miyagi prefecture, and the water area is 3.9 km^2, the pondage is 3.9 million m^3, the maximum water depth is 43.6 m, the average water depth is 11.6 m, the basin area is 191.4 km^2, the catchment area population is 8,900 and the average retention time is 47.5 days. The population density per pondage of a million m^3 is 46 and the population density per catchment area of 1 km^2 is 1.9. The level of the environmental standard under the Plan for the Preservation of Lakes and Marsh Water Quality is COD: 1 mg/*l*., T-P: 0.01 mg/*l*., but the water quality in 1996 was COD: 2.4 mg/*l*., T-P: 0.017 mg/*l*. By looking at the annual changes of the recent water quality, the average of *Kalium permanganicum* consumption is 4.3 mg/*l*., and it is especially high from summer to winter. This tendency did not change after the dam construction. NO_3-N is 0.58 mg/*l*. on average, while T-P is 0.015 mg/*l*. When the nutritional state of Kamafusa Damu-ko (Reservoir) is indicated by the modified Carlson index, the level is close to the level of the South Lake of Lake Biwa, and the result of a decision by Forsberg-Ryding shows Chl.a, the eutrophic state for transparency, the mesotrophic state for T-N and T-P. Furthermore, Kamafusa Damu-ko (Reservoir) is in the Tohoku district, and notorious as a dam lake that causes the problem of mold odor, which creates a bad smell in the domestic water supply not only in summer but also in winter. The mold odor of Kamafusa Damu-ko (Reservoir) was observed from the year following the dam construction, and 2-methyl-isoborneal produced by *Phormidium tenue* is considered to be a causative substance. Two air pumping pipes were installed by the Ministry of Construction in June 1984 as a measure against the mold odor, then more pipes were built in September 1984, in 1987 and 1989; 9 pipes are working at present. The population size of the mold odor producing algae, *P. tenue* has been drastically decreased and after the installation of the air pumping pipes, the mold smell is only observed periodically. Kamafusa Damu-ko (Reservoir) has been regarded as a successful case of water quality improvement with air pumping pipes all over the country. However, the occurrence of the mold odor has begun to be observed again since the winter of 1996, and the areas are suffering from mold odor problems throughout the year.

3-9-3 The present situation of measures

The Conservation of Lakes and Marsh Water Quality Measures Project includes sewerage system development projects (the increase of dissemination rate: from 49% to 58%, the administrative population in the designated area is 8,858, the population in the treatment area is 5,336), a joint treatment and purification plant installation promotion project (sharing the difference with a single type purification plant, 109 plants were installed), a miscellaneous wastewater simple purification plant installation promotion project (a subsidy for the area outside the sewerage system plan, 53 plants were installed), a stripe fertilizing machinery introduction project (regulated by the Law for paddy field fertilization, assistance with the purchase costs, 80 plants were introduced), aeration circulation with air pumping pipes, the installation of purification facilities between grits (water purification in the lakeside park), a live-stock environmental measures project (compulsory fermentation treatment facilities, compost facilities, human waste treatment facilities, maintenance of agricultural machines) and the establishment of the Kamafusa Dam Conservation of Water Quality Measures Promotion Council (started in 1989). For the removal of mold odor, powdered activated carbon is used at the Moniwa water purification plant and granular activated carbon is used at the Tomita water purification plant. Furthermore, the drastic change in the water level is considered to be one of the reasons for the mold odor, and the reduction of sedimentation in the Kamafusa Dam (Reservoir) is being attempted by the construction of sand stored dams in each of the inflowing rivers.

<Reference>

1) Japan Society on Water Environment, ed., *Water Environment in Japan vol.2 Tohoku Edition*, pp.232 (2000).

3-10 Isahaya Bay Balancing Reservoir

3-10-1 Characteristics of the catchment area / lake

Isahaya Bay, located in the center of Nagasaki prefecture, has become well known through the "Isahaya Bay Reclamation Project." "Blocking the tide" with a tide blocking dike in April 1997 was reported by the mass media; the scene of steel plates being dropped one after another was compared to a guillotine, chopping off the abundant organisms, which form the tideland ecosystem. Differences between the high and low tides of the Ariake Sea incorporating Isahaya Bay reach 5-6 m and with the tideland being developed on the coast, the history of reclamation projects is old and dates back to before 1690. The Isahaya Bay reclamation project mentioned above was started in 1989, and at first, its completion was planned for the year 2000, but completion has been postponed until the year 2006 due to various reasons. Blocking the tide by a tide blocking dike was conducted in April 1997, and the construction of the tide blocking dike, with a total length of 7.05 km and a dike levee crown true height of 7.0 m, was almost completed in October 1998. Because of that, the mouth of Isahaya Bay, all 3,550 ha, was closed and with the construction of the inside dike, a 1,840-ha dry area and 1,710-ha balancing reservoir were developed.

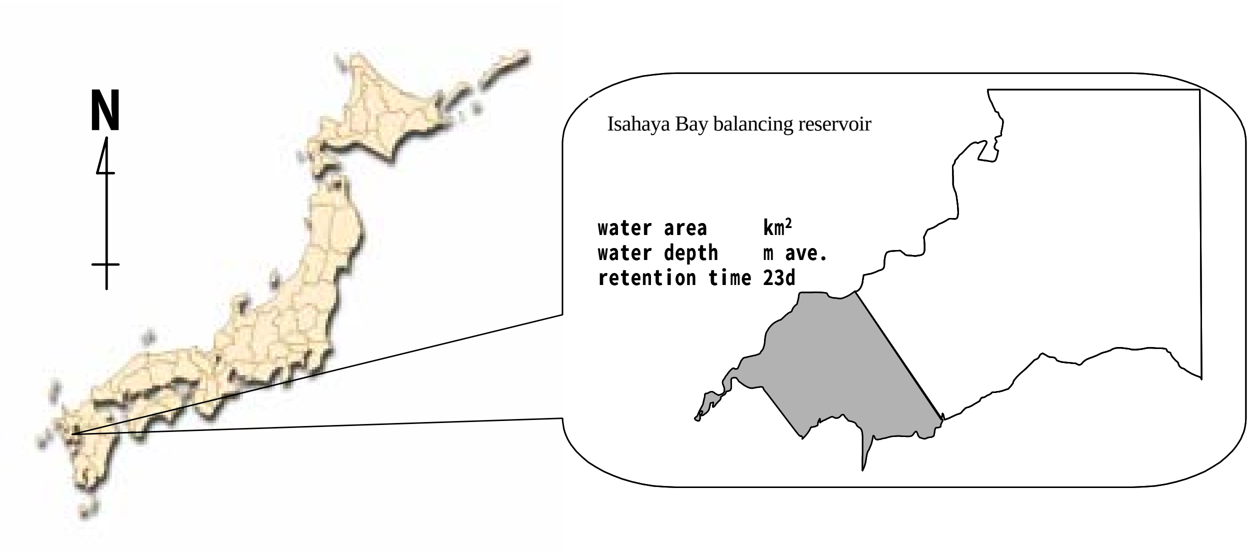


Fig 3-10-1 Overview of Isahaya Bay balancing reservoir

3-10-2 The present conditions of lake

, as shown in Figure 3-10-1, is under the control of Nagasaki prefecture, and the water area is 123.58 km^2, the river inflow level (the normal water level) is 249.3million m^3, the average retention time (in a normal water year) is 23 days and the rainfall on the surface of the lake is 64.78 million m^3. Based on the results of water quality monitoring for one year from the closure of the mouth of Isahaya Bay, desalting of the water area closed by the flood-control dike has rapidly progressed because of the decrease in salt concentration; that is, a decrease from 17,000 $mgCl^-/l$. before the closure to about 4,000 mg Cl^-/l. three months after the closure has been recognized. Moreover, looking at the average values, especially for COD that indicates the conditions of organic matter pollution, T-N that indicates the nutrient salts concentration and the T-P rise from 1998, it can be seen that COD is increased from 3 mg/*l*. from before the closure to 6-8 mg/*l*., T-N is increased from 0.2 mg/*l*. from before the closure to 1.5-2.0 mg/*l*. and T-P is increased from 0.03 mg/*l*. from before the closure to 0.20 mg/*l*.

3-10-3 The present situation of measures

For measures for conservation of the water quality of the balancing reservoir, the water quality conservation targeted value is set on environmental assessment; COD: below 5 mg/*l*., T-N: below 1 mg/*l*. and T-P: below 0.1 mg/*l*. are set. The estimated pollutant load on the balancing reservoir as of March 2001 was COD: 3,104 kg/day, T-N: 1,556 kg/day, T-P: 182 kg/day, and for COD the residential load (33.1%) and that originated in the source area (37.3%), for T-N the live-stock load (17.9%) and that originated in the source area (38.7%) and for T-P the residential (25.3%) and live-stock load (38.5%) are high. That is, the percentage of the load of area sources from the catchment area is large in the Isahaya Bay balancing reservoir, indicating that the measures for area sources in the catchment area are important while the water quality conservation in the balancing reservoir is being progressed. The examination of putting pollutant reduction using charcoal to practical use is being conducted in Isahaya, and the maintenance of the sewerage water supply is being progressed at the same time. On the other hand, bottom sludge measures by dredging, water purification with aquatic plants and the removal of waterweeds are being considered as purification measures for the balancing reservoir. As a concrete example of lake purification, a water area purification boat that is a free running algal-bloom increase prevention device was introduced, and it plays an active role in combination with stream current generation and ultrasonic technology.

<Reference>

1) Japan Society on Water Environment, ed., *Water Environment in Japan vol.7 Kyushu/Okinawa Edition*, pp.221（2000）.

4. State of Lake Eutrophication and its Control in Developing Nations

Lakes in developing nations are various. Located in almost every climatic zone, including the tropical, the subtropical, the temperate, and the frigid, those lakes differ considerably in their climatic conditions as well as in their economic location. Their detention days (how closed they are), the depth, the water temperature, the pollution loads from the catchment area, and other conditions are all dissimilar, which determine their respective conditions of eutrophication and its control strategy. Giving consideration to such conditions, this chapter will cover the state of lake eutrophication in some developing countries and perspectives for its control.

4-1 Lake Taihu

4-1-1 Characteristics of the Lake and its Watershed

Lake Taihu is located in Jiangsu Province of the People's Republic of China (see Fig. 4-1-1). The lake is in the downstream part of the Changiiang River near the estuary delta, and its altitude is 3.1 m above sea level. Situated at N 30º55'40" to 31º32'58" and E 119º53'32" to 120º36'10", the lake is known as the third largest freshwater lake in China, with a lake area of 2,427,800,000 m^2 and a capacity of 4,300,000,000 m^3. The Taihu is a typical shallow lake, with the mean and the maximum depths of 2 m and 4 m, respectively. Within the lake are 51 islands of varying sizes, which cover 89.7 km^2 in total. The largest of all is the 79-km^2 Mount West Dongting Island. Embracing some densely populated cities such as Wuxi City (population of 4.26 million) and Suzhou City (population of 5.72 million), the Taihu watershed has a population of approximately 30 million and a density of 900/km^2. Farmlands account to 39.6 % of the catchment area. The Lake is connected with 70 influent rivers and 224 effluent rivers. Taihu offers an annual fish catch of around 13,700 t. The inflow rate is 195 m^3/s and the hydraulic detention time in the lake is 0.79 year.

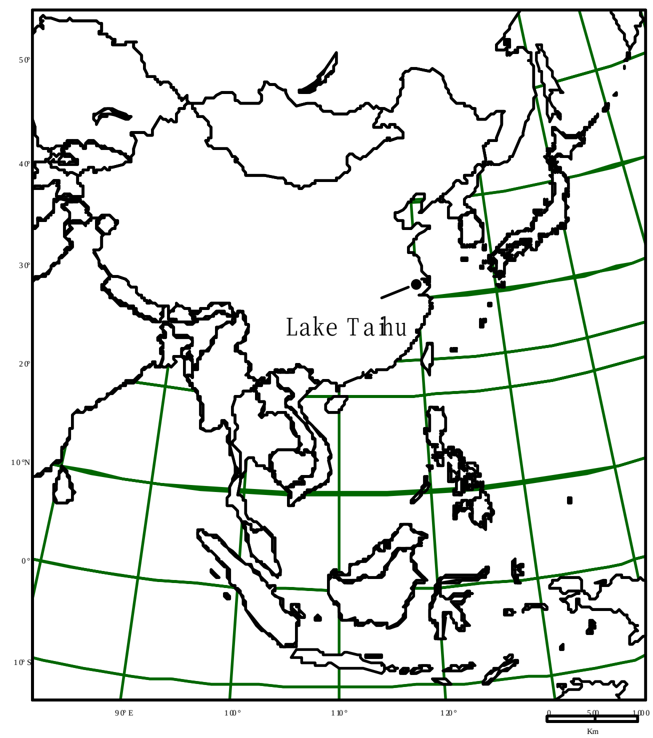


Fig.4-1-1 Situation of Lake Taihu

4-1-2 State of the Lake

Taihu Lake suffers from a surging pollution load from its catchment area, which imposes a serious environmental health problem. The major contamination sources are untreated household and industrial wastewater. The government of China designated the Taihu as the lake most prioritized for water environment remedy. The eutrophic state of the lake is not uniform, as seen in Fig. 4-1-2; the west of the lake called Xi Taihu and the northernmost area on the southeast of Wuxi City called Meilianghu, are particularly over-fertilized. The mesotrophic (relatively less eutrophic) areas in the lake are Huahu and Xuhu to the north of Mount West Dongting Island, which are sanctuarized as the spawning ground for daoyu with the breeding net cages installed in the area. Photo 4-1-1 illustrates the algae bloom layer on the surface of the lake, where a streaky ripple pattern of algae can be observed just as in the photograph when blown by the wind.

The average water quality figures of Taihu Lake are as follows: transparency 0.15-1.00 m (July to August); pH 8.0 (surface layer); suspended solid (SS) 50 mg/*l*; dissolved oxygen (DO) 9.56 mg/*l*; COD 1.04-5.21 mg/*l*; and NH_4-N 0.108 mg/*l*. All over the lake, cyanobacteria (*Microcystis aeruginosa aeruginosa*) bloom densely, whose concentration reaches 4.52 million colonies per liter in an accumulated area. Moreover, the toxic microcystin produced by this alga has exerted a serious deleterious effect on both human and livestock health, raising a grave social issue for many places in the world. The microcystins detected and reported in Lake Taihu are mainly microcystin-RR, microcystin-YR, and microcystin-LR. The total microcystin biomass was recorded as 0.57 μg/*l* inMeilianghu in the northernmost part of Taihu. Another report provided the estimated microcystin quantities in the algae-accumulated area as 219 μg/*l* for microcystin-RR, 120 μg/*l* for microcystin-YR, and 105 μg/*l* for microcystin-LR. Since the WHO guideline value of microcystin-LR in drinking water is set as 1 μg/*l*, the standing crop of microcystin derived from cyanobacteria in Lake Taihu is a matter of grave health concern.

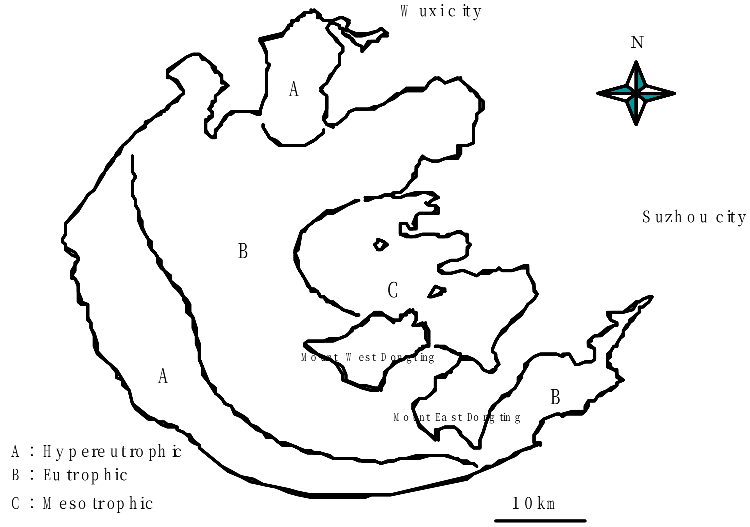


Fig.4-1-2 Trophic level of Lake Taihu

Photo 4-1-1 Scenery of Lake Taifu with algae

4-1-3 State of Control Measures and their Future Direction

Studies and observations have already revealed that Lake Taihu undergoes an abnormal cyanobacterial proliferation every year, and suffers from a consequentially high concentration of dissolved microcystin toxicity derived from the algae. For this reason, it is of an urgent necessity to implement toxin control measures, such as the biofilm method at water purification plants to decompose and eliminate the algae, and the activated carbon method to adsorb and remove the toxic substances.

It is needless to say that fundamental and drastic steps, including sewerage service development and widespread use of the advanced private sewage treatment system in the basin area, are most effective to reduce the pollution load flowing into the ailing Lake. At the same time, however, execution of these measures for every pollution source in its wide catchment area will require a phenomenal cost and time. At present, a tight regulation is imposed on the industrial effluent from large-scale business, a substantial pollutant source in the basin, in order to reduce the pollution load by combating the untreated wastewater. This remedy targeting larger businesses is working with effect. On the other hand, the household wastewater and the industrial wastewater from small businesses are drained without treatment, and the prompt installation of purification devices, such as an advanced private sewerage system, is unlikely to happen due to the lack of finance for the initial capital investment and the management/maintenance expenditure. As a control scheme for these contaminant sources, the spotlight now focuses on purification methods using eco-engineering techniques, which require only a low budget for capital investment and management/maintenance, and can still exert a substantial effect in reducing the pollution load. These methods, including the soil trench treatment and the hydrophyte planting purification method, are characterized by their effective use of ecology in the treatment process. Although they have the drawback of requiring a vast operation area, the most striking characteristic of these methods is their low initial investment and running costs. Effective budget use and sustainable techniques, such as these, have been receiving great attention as a practical scheme for ecosystem remediation.

Photo 4-1-2 Carriage of collected water hyacinth

Photo4-1-3 Carriage of collected submerged plants

A lake-wide project for collecting suspending plants like *Eichhonia crassipes* (water hyacinth) and submerged plants such as *Potamogeton malaianus* and *Vallisneria asiatica* (eelgrass) to utilize as livestock feed is also conducted. The photos 4-1-2 and 4-1-3 show the scenes of collecting and carrying the water hyacinth (the first) and the submerged plants such as *Potamogeton malaianus* and *Vallisneria asiatica* (the second). On one hand, water hyacinth collection is relatively carefree, because its resource is plentiful without any possible exhaustion due to overexploitation. On the other hand, the submerged plants such as *Potamogeton malaianus* and *Vallisneria asiatica* essentially require controlled collection in terms of resource management, due to their vital role as a habitat for juvenile fish and small crustaceans, including the water flea, and a spawning bed for adult fish.

4-2 Lake Dianchi

4-2-1 Characteristics of the Lake and its Watershed

Lake Dianchi lies in Yunnan Province of the People's Republic of China (see Fig. 4-2-1). Located on the Yunnan-Guizhou Plateau, the lake is 1,887 m above sea level. Covering 2,920 km^2 at N 24º29' to 25º28' and E 102º29' to 103º01', Dianchi is known as the sixth largest freshwater lake in China, with a length of 114 km, an average width of 25.6 km, and a maximum capacity of 1,593,100,000 m^3.The mean and maximum depths of China's sixth largest lake are 5.1 m and 11.3 m, respectively. This slim-shaped lake lies in a north-south direction reaching Kunming City (population of 3.47 million), the capital of Yunnan Province, on its north end. The catchment area covers 2,920 km^2, with a population density of around 690 per square kilometer. Over 14 big rivers, such as the Xinhe River (basin of 112.5 km^2), the Daqing River (basin of 205.2 km^2), the Chaihe River (basin of 256.4 km^2), and the Dongda River (basin of 180.4 km^2), flow into Lake Dianchi with their annual rate of inflow reaching 696,000,000m^3 in total.

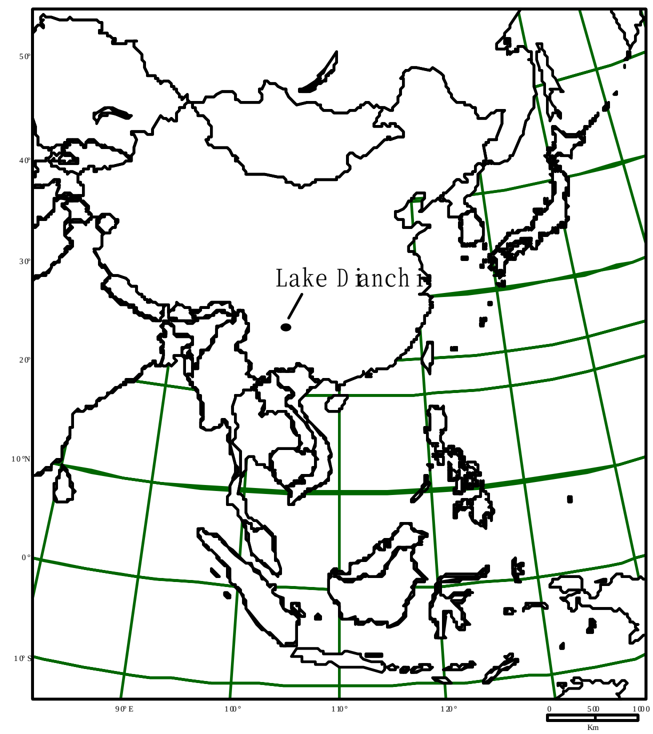


Fig. 4-2-1 Situation of Lake Dianchi

4-2-2 State of the Lake

Being slim in the north-south direction, Dianchi can be divided into Caohai (Inner Lake) of a constricted shape in the north and wide-shaped Outer Lake in the south. The effluent from the Kunming's urban area, which dominates the influent contamination load, first flows into the Inner Lake via the Daguan River, and then down to the Outer Lake. Because of such a flow route, the Inner Lake is more eutrophic than the Outer Lake; in fact, Caohai is a hypertrophic lake. The algae bloom is observed all across Lake Dianchi and, in particular, the surface of the Inner Lake is covered by dense cyanobacterial mats (shown in Photo 4-2-1). The water quality figures of Inner Lake and Outer Lake are, respectively, as follows: COD 15.7 mg/*l* and 6.5 mg/*l*; BOD 12 mg/*l* and 3.4 mg/*l*; TOC 12.4 mg/*l* and 8.3 mg/*l*; T-N 8.7 mg/*l* and 1.2 mg/*l*; and T-P 0.79 mg/*l* and 0.09 mg/*l*. These rates also manifest the severity of eutrophication in the

Inner Lake area. Across the Inner Lake, cyanobacteria (*Microcystis aeruginosa aeruginosa*) propagate densely, whose concentration reaches 3.95 million colonies per liter in an accumulated area. Phytoplankton of 87 genera in 39 families have been identified in the Inner and Outer Lakes in total, and the dominant species in both water areas are blue-green algae such as *Microcystis*, *Oscillatoria*, and *Anabaena*. The phytoplankton biomasses dominated by these cyanobacteria are 64,670,000 per liter in the Inner Lake and 13,649,000 per liter in the Outer Lake, the former reaching 4.7 times larger than that of the latter.The effluent from Kunming City accounts for a large portion of the pollution load into Lake Dianchi. Its basic units per capita per day are calculated as follows: CODcr 41.5 g; BOD 20.7 g; T-N 8.06 g; T-P 0.765 g; and SS of 19 g. Based on these figures, the annual pollution loads from Kunming in 1995 are estimated as 18,800 t for COD, 9,400 t for BOD, 3,700 t for T-N, 350 t for T-P, and 7,400 t for SS, which should have increased by the year 2000 up to 20,900 t for COD, 10,400 t for BOD, 4,100 t for T-N, 390 t for T-P, and 8,200 t for SS.


Photo 4-2-1 Lake Dianchi covered with cyanobacterial mats (Caohai)

4-2-3 State of Control Measures and their Future Direction

The eutrophication control measures in Lake Dianchi can be classified into on-site measures and administrative measures, and the former can be further divided into watershed management, point source management, non-point source management, and lake zone management. Some typical administrative measures are legislating effluent regulations, keeping accurate track of the state of pollution through monitoring, and publicizing the current state of contamination through PR campaigns. The specific approaches in the four on-site measures are as follows. The watershed management includes water conveyance from outside of the basin area. The point source management includes developing wastewater treatment facilities, recycling the effluent as a resource, and regulating the use of phosphate-containing detergents. The non-point source management includes expanding the recharging forests for the headwaters, reforestation to combat topsoil


Photo 4-2-2 Water hyacinth collection

erosion, and ensuring the observation of systematic and reasonable fertilization. The lake zone management includes promoting fishery, systematically expanding the hydrophyte biomass, and conducting direct aeration. These measures are characterized by an emphasis on household effluent in the point source management, and the stressed introduction of the eco-engineering approach that utilizes the abundant aquatic vegetation in the lake. Attention is being given to the hydrophyte utilization, which is currently under discussion for regional widespread application, as a low-cost and relatively maintenance-free treatment method. Water hyacinth, with its floating and exceedingly proliferative nature, often blocks the canals to such an extent that it hinders boat transportation. Such a nuisance of no value, when effectively used, can be converted into a reusable resource, which is offering an exciting prospective.

Photo 4-2-2 shows the scene of the water hyacinths that propagated so much to block the boat routes of the canals connected to the Inner Lake, and the collection of these using rafts. The recovered water plants are desiccated to serve as pulverized fertilizers as shown in Photo 4-2-3. Discussion is now proceeding over the pros and cons of this new method, including the costs, and hopes run high for rendering these otherwise worthless water hyacinth into a reusable resource.

Photo4-2-3 Fertilizer made by drying water hyacinth

Photo 4-2-4 shows the livestock feed made of the pelletized algae: the proliferated cyanobacteria were removed and collected from the lake by suction to make them into dehydrated cakes, which then were compressed and desiccated into solid pallets. Current research extends to the content rate of cyanobacteria by experiments with pigs, which evaluates the effective use of the propagated algae as a protein source for domestic animals in the future. In addition to the said water hyacinth project, discussion is also proceeding over the pros and cons of the cyanobacterial utilization method including the cost for commercializing the pellet feed, and hopes run high for this new

Photo 4-2-4 Livestock feed made of pelletized algae

method to recover a reusable resource.

4-3 Lake Erhai

4-3-1 Characteristics of the Lake and its Watershed

Lake Erhai lies in Yunnan Province of the People's Republic of China (see Fig. 4-3-1). Located on the Yunnan-Guizhou Plateau, the lake is 1,974 m above sea level. Covering 250 km^2 at N 25º25' to 26º16' and E 99º32' to 100º27', the Erhai is a freshwater lake with a north-south length of 42.5 km, an average width of 6.3 km, and the maximum capacity of 802,000,000 m^3.The Erhai basin, lying in the alpine region, embraces many forest zones. On the west coast of the lake is the Diancang Mountain range, a chain of 19 mountains with altitudes ranging from 3, 074 m to 4,122 m above sea level, which provide headsprings for 18 influent streams.The mean and maximum depths of Lake Erhai are 10.5 m and 21 m, respectively. This slim-shaped lake in a north-south direction, as shown in Fig. 4-3-2, neighbors some extensive urban areas, such as Xiaguan on its south and Dali on on its west.The Erhai is characterized by the counterclockwise surface current due to concurrent winds blown from different directions. The attenuation coefficient of the lake current ascribable to these winds was registered as 2.25×10^{-5} per second at the depth of 2 m.

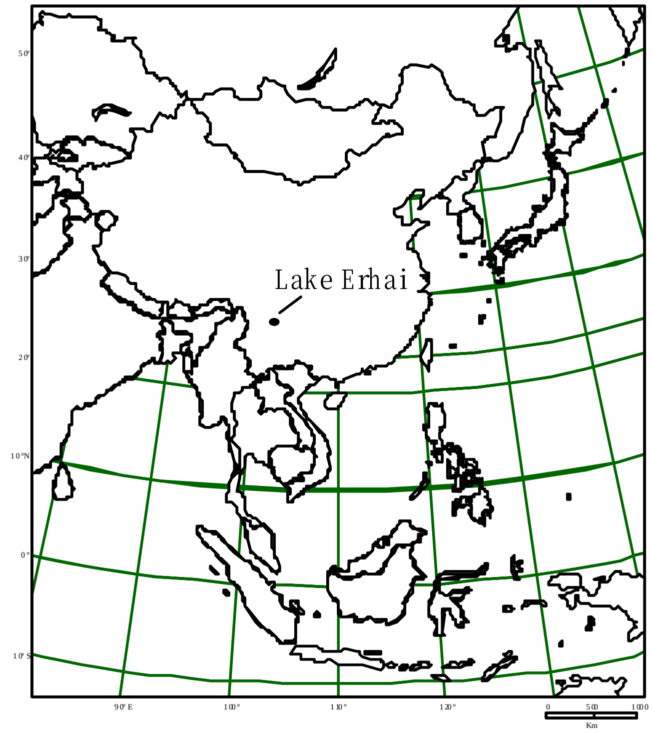


Fig.4-3-1 Situation of Lake Erhai

Fig.4-3-2 Drainage of Lake Erhai

4-3-2 State of the Lake

Encompassed by the mountain range, the catchment area of Lake Erhai can be classified into a forest zone (between 2,200 m and 3,000 m above sea level) and an alpine zone beyond the timberline (higher than 3,000 m). The major pollution sources for the lake are urban districts and farmlands developed like belts in the area between 1,974 m (lake surface altitude) and 2,200 m of altitude above sea level. Breakdown of the major land use patterns and their share in the basin is 19.8 % by forest, 24.8 % by shrubbery, 2.5 % by grassland, 9.5 % by paddy field, 9.5 % by watershed wetland, and 2.6 % by urban areas.

Photo 4-3-1 Algae bloom belts in Lake Erhai

The water quality figures of Lake Erhai are as follows: COD 2.8 mg/*l*; BOD 1.3 mg/*l*; T-N 0.31 mg/*l*; and T-P 0.018 mg/*l*. Judging from these average rates of water quality, the lake is clearer than other eutrophic lakes. Nevertheless, observation confirmed algae bloom belts in some parts of Lake Erhai due to the influx of household wastewater (see Photo 4-3-1). The most serious environmental issue surrounding Erhai at present is not eutrophication but depletion of the water resources incurred by its declining water level. Analysis during the period 1952 and 1988 showed that, for the 25 years prior to 1977, the average figures for the water level, the lake surface area, and the pondage were 1,974 m, over 255 km^2, and approximately 2.9 billion m^3, respectively. After 1977, however, the water level continued to fall to an average level of 1,972.3 m for the 12 years between 1977 and 1988, a decrease of 1.7 m from the former figure. As a consequence, the pondage decreased by 430 million m^3 to 2.49 billion m^3.

Depleting water resources has been posing a great damage to the waterfront vegetation zone, problematically reducing the once abundant hydrophyte biomass. Such considerable deterioration of the hydrophyte standing crop triggered various consequential problems, such as the loss of the spawning grounds for resource-providing fish and the extinction of numerous aquatic organisms that once inhabited the waterfront vegetation zone, hence developing into a serious social issue. The hydrophyte zone of Lake Erhai is renowned as the habitat of precious water plants, including *Potamogeton dentatus* which is endangered globally, which means that the threat of emergence and dry-out to these hydrophyte zones will directly unleash the extinction of these plants on the red data book from the earth.

Positioned in the alpine region, Lake Erhai is characterized by numerous forest zones in its basin. Deforestation in these areas, however, is apprehended to deteriorate the water retaining capacity. Although 11.4 % of the Diancang Mountain region on the west of the lake is still covered by forest, the forest area on the east coast has been developed into farmland and other forms of land use. The total average of the forest coverage accounts for 11.9 %, which is, in fact, mostly shared by sparse groves and coniferous forests. As a result, the issue here is the immensely receded share of the mature, deciduous broad-leaved forestry, a major contributor to recharging the springhead.

4-3-3 State of Control Measures and their Future Direction

The anti-eutrophication strategy focuses on implementing the regulative water quality standard. The effluent concentration criteria cap the T-N and T-P to 0.5 mg/*l* and 0.025 mg/*l*, respectively. At the same time, the western-Erhai water areas including Wanhua, Zhong He, Dali, and Xizhou, and the water area in the vicinity of Wase are designated as the specified areas for focused regulation, by enforcing the area-wide total pollutant control of annual nitrogen and phosphorus discharge as 1,254.48 t and 62.72 t, respectively.

As for arresting the diminishing water retaining capacity in the catchment area, a reforestation project is actively implemented to foster the regeneration of the forest vegetation. In addition, various degrees and types of management/control measures, including food input for fish farming and tourism and freight boats specifications, are undertaken in order to support the environmental conservation of Erhai Lake from multiple directions. The distinctive and most important measure among them is the protection and nurture of water plants. A diverse variety of submerged plants, such as *Potamogeton malaianus*, *P. dentatus*, *P. maackianus*, *P. crispus*, and *Ottelia alismoides*, flourish on the lake shore, and these in combination with emerging plants, such as reeds and water oats, and floating-leaved plants, such as water chestnuts, enormously contribute to the natural decontamination of the watershed. In Lake Erhai, the aquatic plants are actively protected and nurtured for not only the purpose of water purification, but also making use of them as a nursery of juvenile fish for the fishery and fish farming. As shown in Photo 4-3-2, the submerged plants are currently harvested to feed livestock without particular care. Such actions will need to be regulated to prioritize the conservation and nourishment of the hydrophyte resource. The future direction of Lake Erhai conservation lies in maximizing the use of the ecosystem to bring out its natural purification capacity, such as through the aforementioned hydrophyte protection and nourishment.

Photo 4-3-2 Submerged plants harvested in Lake Erhai

4-4 Lake Nong Han

4-4-1 Characteristics of the Lake and its Watershed

Lake Nong Han is located in Sakon Nakhon Province of the Kingdom of Thailand; more specifically, it is at N 17º12' and E 104º11', in Isan Region in the northeast of Thailand, and approximately 650 km to the northeast of Bangkok (see Fig. 4-4-1). Nong Han is an artificial lake created in 1946, with a surface area of 135.2 km^2, a mean depth of 2.0 m, a maximum depth of 3.0 m, and a maximum pondage of 267.7×10^6 m^3. Its catchment area covers about 1,653 km^2. The altitude of the filled lake surface is 156 m above sea level, and the lakeshore length extends to 115.6 m. As shown in Fig. 4-4-2, four major rivers flow in from the north and south of the lake, whereas the effluent river exits from the east. The lake provides irrigation water for farmlands, as well as a fishing ground that extensively contributes to the local fishery.

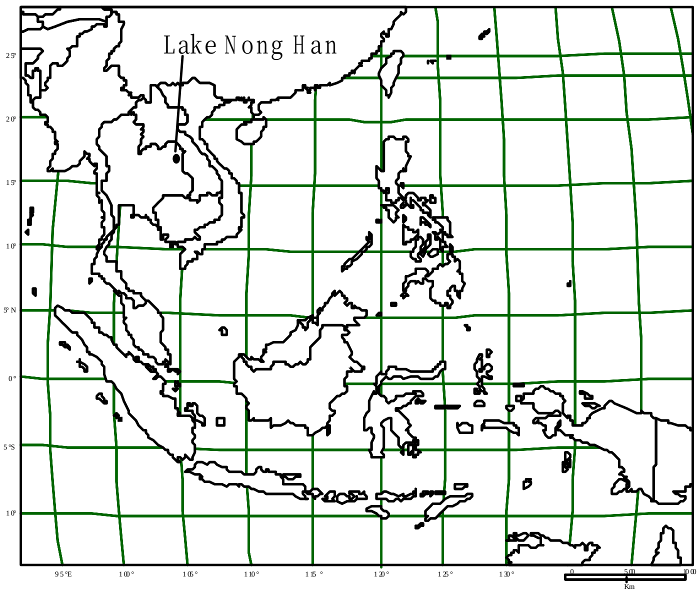


Fig.4-4-1 Situation of Lake Nong Han

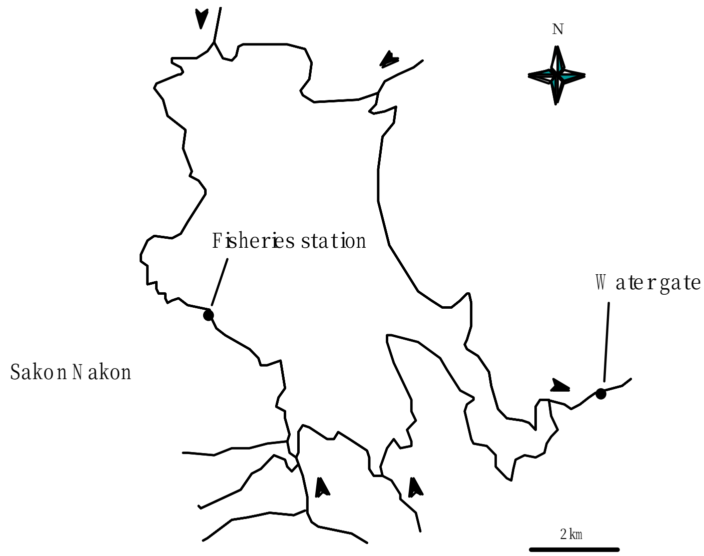


Fig.4-4-2 Drainage of Lake Nong Han

4-4-2 State of the Lake

Lake Nong Han suffers from advanced eutrophication due to household wastewater from the provincial capital Sakon Nakhon City (population of 27,000 as of 1991). The total pollution loads from the capital are estimated as 87.4 t/year for nitrogen and 24.6 t/year for phosphorus. Approximately 70 % of these loads allegedly flow into the lake without any treatment. Its basin population exclusive of Sakon Nakhon City is around 20,000 (as of 1991), and 10 % of the estimated total pollution loads (64.9 t/year for nitrogen and 18.3 t/year for phosphorus) are assumed to flow into the lake from that source. In addition, livestock wastewater, on a total pollution load basis, was estimated to be responsible for 613-t/year nitrogen and 456-t/year phosphorus. 10% of the effluent from the livestock industry is also untreated and flows directly into the lake. The influx pollution loads in total are calculated as 129 t/year for nitrogen and 64.8 t/year for phosphorus.

The water quality figures for July are as follows: chlorophyll concentration 2.92 μg/*l*; pH 7.3; transparency 74 cm; DO 6.9 mg/*l* on the surface and 5.7 mg/*l* on the bottom; NO_3-N 0.62 mg/*l*; PO_4-P 0.11 mg/*l*; water temperature of 30.9 ºC; alkalinity of 31.5 mg/*l*; and hardness of 39.3 mg/*l*. On the other hand, the water quality figures for October are as follows: chlorophyll concentration 5.57 μg/*l*; pH 5.9; transparency 93 cm; DO 6.7 mg/*l* on the surface and 5.2 mg/*l* on the bottom; NH_3-N 0.23 mg/*l*; NO_2-N 0.056 mg/*l*; NO_3-N of 1.5 mg/*l*; PO_4-P 0.43 mg/*l*; water temperature 28.7 ºC; alkalinity 25 mg/*l*; and hardness 17 mg/*l*.

Nong Han is a shallow lake on the whole, and the northern part is particularly so. Due to this, numerous submerged and emerging plants exuberate mainly on the bottom of the northern part. The lake also registers a large biomass of floating plants dominated by water hyacinths. The annual productions of these aquatic plants are estimated as 785,600 t of submerged plants and 714,950 t of floating plants. Observation has found that the advanced eutrophication triggered the algae bloom (*Microcystis aeruginosa aeruginosa*) on the lake surface. Photo 4-4-1 shows the landscape of Lake Nong Han with flourishing submerged plants.

As for the fishing resources, the fish biomass was calculated as 32.3 kg/ha. The dominant species are *Tetraodon leiurus* (Eyespot Puffer), *Ambasis siamensis*, and *Notopterus notopterus* (Asian Knifefish), which account for 31.5 %, 18.4 %, and 15.0 %, respectively, of the total fish biomass. Analysis of the ichthyofauna in Nong Han by the food habit reveals that carnivorous fish share the largest of the total fish biomass, amounting to 37.8 %.

Photo 4-4-1 Landscape of Lake Nong Han with submerged plants

4-4-3 State of Control Measures and their Future Direction

Lake Nong Han has been undergoing the algae bloom ascribable to eutrophication. The dominant species of such algae is *Microcystis aeruginosa aeruginosa*, a Cyanophyceae notorious for producing a toxic substance called microcystin. While no report has been made yet concerning the microcystin volume determined at Nong Han, various microcystin isomers, i.e., microcystin-RR, microcystin-LR, and microcystin-YR, have been detected at Bang Pra Reservoir (capacity: 1.17×10^6 m) in Chonburi Province in Thailand. The total microcystin concentration at the center of the reservoir was reported as 0.014 μg/*l* (as of November 1999). Since the water temperature goes above 30 ºC at Lake Nong Han with plenty nutritive salts under its eutrophic condition, it is expected that the advancing algae propagation will manifestly bring out the issue of microcystin of cyanobacterial origin.

Lake Nong Han is characterized by its ichthyofauna dominated by carnivorous fish; these fish, such as Eyespot Puffer, account for 38 % of the total fish biomass. In parallel, the planktotrophic fish eaten by the carnivorous fish share around 19 % of the total fish biomass, which indicates that the planktotrophic fish has a secure habitat. The field research at the lake confirmed that a wide range of hydrophyte vegetation was actually secured, which revealed that the lake-wide production of such water plants reached to 1,588,120 t/year. The habitat for these hydrophytes serves not only as the nursery for juvenile planktotrophic fish, but also as an enormous contributor to maintaining the biomass of large crustaceans such as water fleas that are reported to substantially help improve water transparency.

It is needless to say that the most efficient way to address the ever-expanding influx load is a drastic measure, namely the development of influent wastewater purification plants, although they require phenomenal construction and maintenance/operation costs. At the same time, facilitation of the lake's self-purification function by using its ecosystem has been offering great hope. Lake Nong Han, in particular, embraces large communities of submerged plants, such as *Potamogeton malaianus, Potamogeton crispus,* and *Vallisneria asiatica,* all across the lake including their normal habitat lakeshore, and hopes run high for the utilization of these communities as an arena for water purification. Conservation and nourishment of the existing aquatic vegetation for boosting the hydrophyte biomass will share an important aspect of the Lake Nong Han purification strategy as a method to bring out a high decontamination effect with low running costs.

4-5 Lake Kwan Phayao

4-5-1 Characteristics of the Lake and its Watershed

Lake Kwan Phayao is located in Phayao Province of the Kingdom of Thailand; more specifically, it is at N 19º10' and E 99º53', and approximately 730 km to the north of the capital Bangkok (see Fig. 4-5-1). The Kwan Phayao is an artificial lake created in 1938 on a 2-km^2 pond around which a weir was built. Its dimensional properties are: a surface area of 23.46 km^2, a mean depth of 2.03 m, a maximum depth of 4.5 m, and a maximum pondage of 47.68 × 10^6 m^3. The altitude of the filled lake surface is 391.5 m above sea level, and the lakeshore length extends to 25.3 m. As shown in Fig. 4-5-2, the shape of Lake Kwan Phayao is quite simple due to its origin as a dammed river that runs near downtown Phayao City. The lake provides irrigation water for farmlands, as well as a fishing ground that extensively contributes to the local fishery.

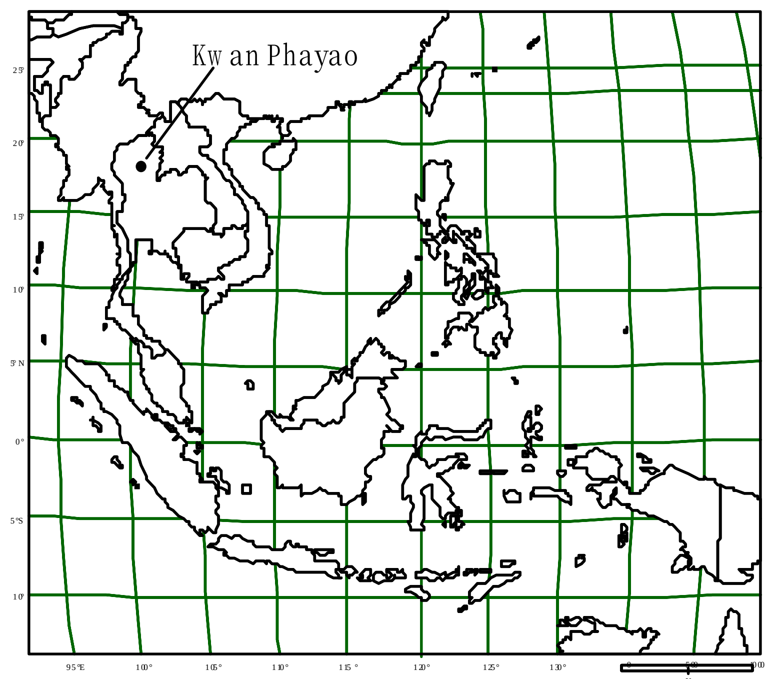


Fig.4-5-1 Situation of Kwan Phayao

4-5-2 State of the Lake

Lake Kwan Phayao suffers from advanced eutrophication due to the untreated wastewater flowing in from its catchment area. The major pollution sources are livestock effluent from the basin and household wastewater from Phayao City (population of 26,000 as of 1991). The total pollution loads from the city are estimated as 82.6 t/year of nitrogen and 23.2 t/year of phosphorus. Due to the lack of the wastewater treatment facilities within the catchment area, which includes Phayao City, approximately 10 % of the total loads flow into the lake without any purification processes. In addition, the livestock wastewater, on a total pollution load basis, was estimated to be responsible for 171-t/year nitrogen and 129-t/year phosphorus. 10% of the effluent from the livestock industry is also untreated and directly flows into the lake. The influx pollution loads in total are calculated as 77.4 t/year for nitrogen and 29.9 t/year for phosphorus.

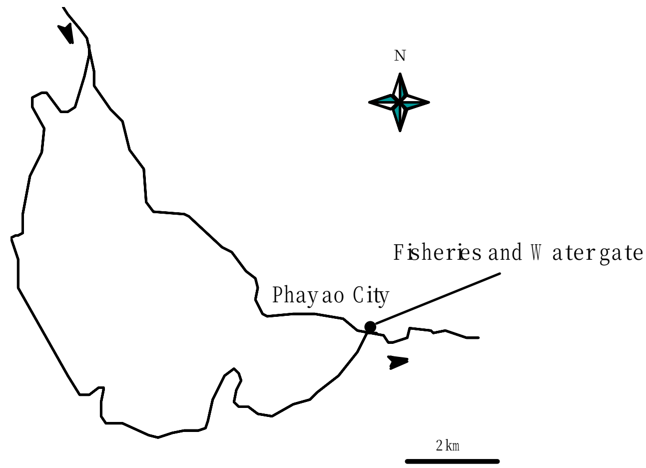


Fig.4-5-2 Drainage of Kwan Phayao

The water quality figures in July are as follows: chlorophyll concentration of 5.24 μg/*l*; pH 7.4; transparency 73 cm; DO 6.1 mg/*l* on the surface and 5.3 mg/*l* on the bottom; NO_3-N 0.19 mg/*l*; PO_4-P 0.035 mg/*l*; water temperature 30.2 ºC; alkalinity 34.3 mg/*l*; and hardness 34.7 mg/*l*. On the other hand, the water quality figures in October are as follows: chlorophyll concentration 3.74 μg/*l*; pH 6.0; transparency 140 cm; DO 6.0 mg/*l* on the surface and 3.5 mg/*l* on the bottom; NH_3-N 0.27 mg/*l*; NO_2-N 0.020 mg/*l*; NO_3-N 1.7 mg/*l*; PO_4-P 0.020 mg/*l*; water temperature 27.7 ºC; alkalinity 41 mg/*l*; and hardness 35 mg/*l*.

The Kwan Phayao is a shallow lake with a maximum depth of 4.5 m and its bottom conical from an easy grade. Due to this shape, numerous submerged and emerging plants exuberate on the bottom gently sloping from the lakeshore to the center. The lake also registers a large biomass of floating plants dominated by water hyacinths, which accumulate near the sluice drifted by the gentle current. The annual productions of these aquatic plants are estimated as 67,670 t of submerged plants and 34,000 t of floating plants.

As for the fishing resources, the fish biomass was calculated as 166 kg/ha. The dominant species are *Tilapia nilotica* (tilapia), *Pristolepsis fasciata*, and *Notopterus notopterus* (Asian Knifefish), which account for 53.6 %, 19.7 %, and 9.4 %, respectively, in the total fish biomass. Analysis of the ichthyofauna in Lake Kwan Phayao by the food habit reveals that the herbivorous fish share the largest of the total fish biomass, amounting to 55.7 %.

4-5-3 State of Control Measures and their Future Direction

Among the pollution load into Lake Kwan Phayao, application of aerated lagoon purification to the household wastewater from Phayao City is now under discussion. Phayao City is the only place with a relatively large urban area within the Kwan Phayao basin. No sewerage systems or wastewater treatment facilities have yet been developed in the city, and consequently, the untreated household effluent flows straight into the lake. For these reasons, the aerated lagoon should be able to significantly reduce the pollution loads from the household effluent. The lagoon, when developed, is expected to remove 35-85 % of the influent ammonia nitrogen. In spite of its drawback of requiring a vast site and a long retention time, decontamination with an oxidation pond can work effectively as a low construction and maintenance cost method in an area such as that of Lake Kwan Phayao basin where a relatively ample amount of land remains available.

For the non-point sources such as the livestock effluent, enhanced natural self-purification is considered most effective, either on the influent process or after having flown into the lake. Specifically, water plants are to be planted in the lake and canals in its basin, which raises expectations that they will exert a substantial effect. Planting high-market-value vegetables such as *phak bung* (swamp cabbage) can encourage the residents to regularly harvest the plants, which eliminates the danger of re-elution of nutritive salts from the dead plants. Consensus with the community members plays an important role in promoting and implementing this method, which also lets the community know the significant contribution of the water plants to the lake purification.

4-6 Lake Bung Boraped

4-6-1 Characteristics of the Lake and its Watershed

Lake Bung Boraped is located in Nakhon Sawan Province of the Kingdom of Thailand; more specifically, it is at N 15º42’ and E 100º15’, and approximately 250 km to the northeast of Bangkok (see Fig. 4-6-1). Lake Bung Boraped is an artificial lake created in 1926, with a surface area of 204.5 km^2, a mean depth of 1.4 m, a maximum depth of 5.0 m, and a maximum pondage of 218.2×10^6 m^3. The altitude of the filled lake surface is 23 m above sea level, and the lakeshore length extends to 62.5 m. As shown in Fig. 4-6-2, it is a slim lake in an east-west direction, due to its origin as a dammed river. The lake provides irrigation water for farmlands, as well as a fishing ground that extensively contributes to the local fishery.

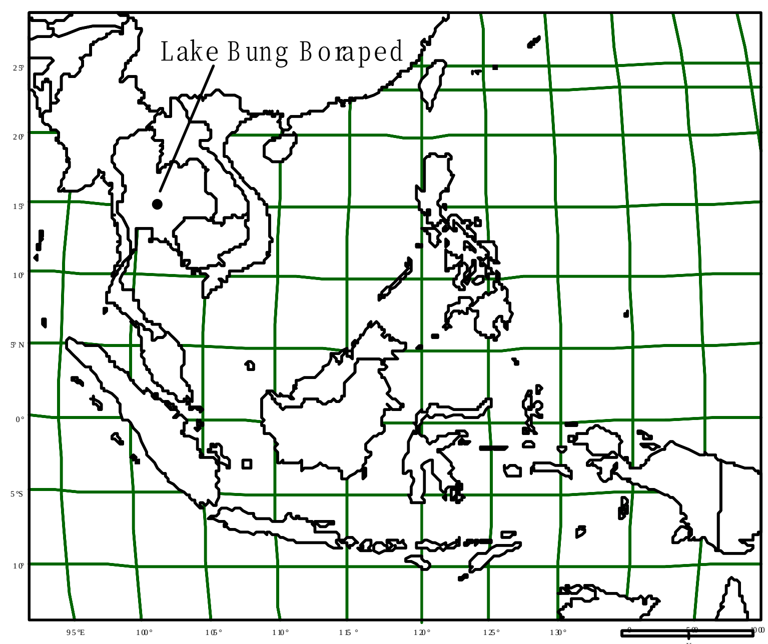


Fig.4-6-1 Situation of Lake Bung Boraped

4-6-2 State of the Lake

Much of the Lake Bung Boraped basin is used for lotus farms. The lotus farming needs massive spraying of pesticide, influx of which adversely affects the water quality and kills fishing resources. The provincial capital, Nakhon Sawan City is far away from the lake, making it free from influent urban pollution loads. The population around the lake is only about 6,800, with a population density in its catchment area as low as 92.2 /km^2. The total household pollution loads from the catchment area are estimated as 21.8 t/year of nitrogen and 6.1 t/year of phosphorus. Approximately 10 % of these total loads flow into the lake without any purification processes. In addition, the livestock wastewater, on a total pollution load basis, was estimated to be responsible for 149-t/year nitrogen and 107-t/year phosphorus. Approximately 10 % of these total loads also flow into the lake without any purification processes. The influx pollution loads in total are calculated as 14.9 t /year for nitrogen and 10.7 t /year for phosphorus. The water quality figures in July are as follows: chlorophyll concentration 4.12 μg/*l*; pH 6.6; transparency 109 cm; DO 5.4 mg/*l* on the surface and 4.0 mg/*l* on the bottom; NO_3-N of 0.55 mg/*l*; PO_4-P of 0.051 mg/*l*; water temperature 28.6 ºC; alkalinity 101.6 mg/*l*; and hardness 81.8 mg/*l*. On the other hand, the water quality figures in October are as follows: chlorophyll concentration 4.54 μg/*l*; pH 5.8; transparency 157 cm; DO 5.7 mg/*l* on the surface and 4.7 mg/*l* on the bottom; NH_3-N 0.43 mg/*l*; NO_2-N of 0.075 mg/*l*; NO_3-N of 1.4 mg/*l*; PO_4-P 0.51 mg/*l*; water temperature 30.1 ºC; alkalinity 61 mg/*l*; and hardness 48 mg/*l*.

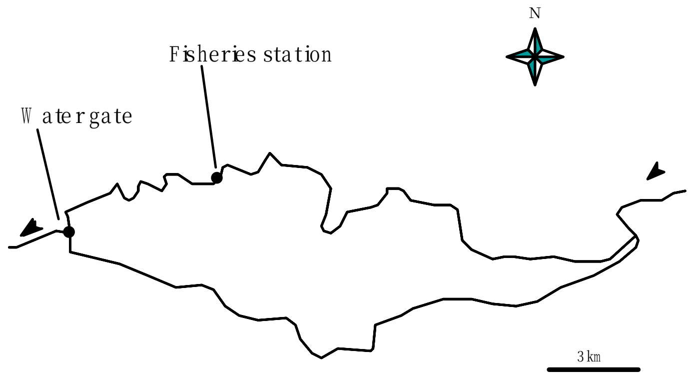


Fig.4-6-2 Drainage of Lake Bung Boraped

Lake Bung Boraped can be divided into three parts in general: the shallow and narrow eastern part that is the influent area with the lake bottom gently sloping toward the west; the water mass area in the center; and the western part near the sluice gate with a large community of submerged plants. The influent eastern area is characterized by the large biomass of waterfront emerging plants, whereas the central part and the western part near the sluice enjoy flourishing submerged and floating-leaved plants. The lake also registers a massive biomass of floating plants, mainly water hyacinths, scattered all across the lake. The annual productions of these aquatic plants are estimated as 529,000 t of submerged plants, 325,620 t of floating plants, and 200,800 t of emerging plants. The annual production of all the water plants totals 1,190,420 t.

As for the fishing resources, the fish biomass was calculated as 84.2 kg/ha. The dominant species are *Pristolepsis fasciata*, *Notopterus notopterus* (Asian Knifefish), and *Osteochei hasselti*, which account for 35.6 %, 22.4 %, and 12.8 %, respectively, in the total fish biomass. Analysis of the ichthyofauna in Lake Bung Boraped by the food habit reveals that the insectivorous fish share the largest of the total fish biomass, amounting to 58.0 %.

4-6-3 State of Control Measures and their Future Direction

Lake Bung Boraped is characterized by its catchment area free from a large urban area, which prioritizes non-point source control over point source management. As for the pesticides for lotus farming, it is unrealistic to request self-restraint in the use of chemicals; the stress is laid on rightsizing the use of agrochemicals to stop the influx of the surplus.The lake’s distinctive characteristic, the ichthyofauna dominated by entomophagous fish, suggests that the elimination of nutritive salts via fishing work significantly well. To be more specific, the fish catch out of the lake can effectively remove the nutritive salts and organic matters in the fish accumulated and concentrated through the food chain process whereby the fish eats the aquatic insects that eat animalcules, algae, and small fish, while such fishing practice itself can be incorporated into the life of human beings as a viable vocation sharing a part of an industry. Since fishery has already been conducted at the lake, boosting the catch volume is the most efficient way for nutrient reduction. In practicing this control method, the lake's entomophagous-fish-dominated ichthyofauna should be taken into account: the biomass of aquatic insects that feed these fish needs increasing by reserving a large habitat for water insects. Reservation of a larger habitat for these insects vitally requires abundant water plants, which suggests a direction of water decontamination at Lake Bung Boraped toward an enhanced hydrophyte biomass.

4-7 Laguna de Bay

4-7-1 Characteristics of the Lake and its Watershed

Laguna de Bay is located between Rizal Province and Laguna Province on the central part of Luzon Island in the Republic of the Philippines; more specifically, it is at N 14º02-05' and E 121º00-05', east of Manila Bay, and approximately 40 km to the southeast of the capital Manila (see Fig. 4-7-1). Also known as Lake Bay, Laguna de Bay is the largest lake in the country. The lake, which used to be part of Manila Bay, is a creation of volcanic activities at the lake-south area, where the deposited lava separated the lake from the bay. It is now a brackish lake, mixed with seawater. 21 rivers of different sizes, such as Pasig River through the Metropolitan Manila, flow into Laguna de Bay. As shown in Fig. 4-7-2, the lake has a complex shape with the north-south-long Talim Island lying on the center and two large peninsulas protruded from the northern shore into the lake. With a considerably high volume of volcanic sediments deposited on its bottom, the lake is maximum 7.3 m deep, 2.8 m deep in average, and holds maximum $3{,}200 \times 10^6$ m^3. The altitude of the lake surface is 1.8 m above sea level, and the lakeshore length extends to 220 km. The catchment area of 3,820 km^2 is shared 41 % by natural vegetation as forests, 52 % by farmlands, and 6.5 % by others. The area embraces the population of 2.381 million, with a population density of approximately 713 /km^2. The lake provides irrigation water for farmlands, as well as a fishing ground that extensively contributes to the local fishery.

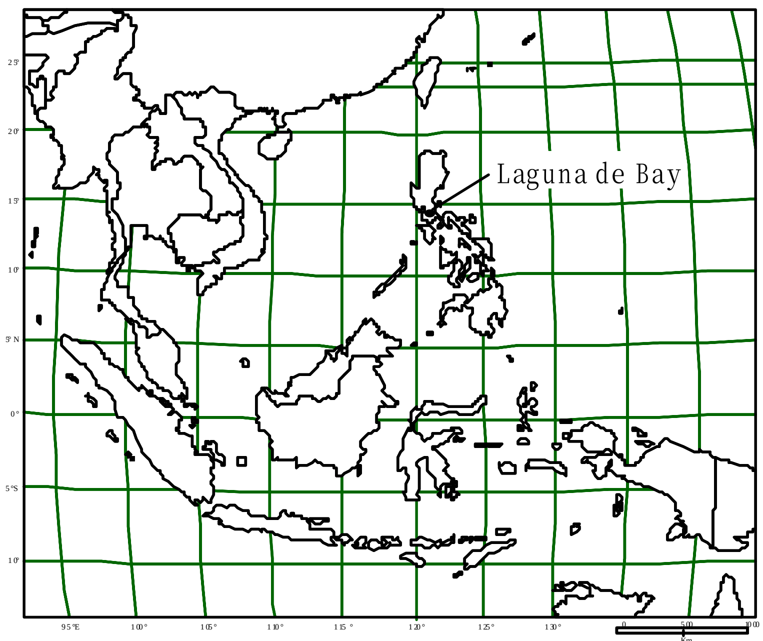


Fig.4-7-1 Situation of Laguna de Bay

4-7-2 State of the Lake

The contaminant load into Laguna de Bay can be divided by their origin: 40 % from agriculture, 30 % from factories and other businesses, and 30 % from households. In addition to the household effluent from Metro Manila flowing in through Pasig River, the influent load from other urban areas around the lake, such as Pasig on the north and Santa Cruz on the southeast, is increasing year by year. The industrial pollutant loads are mostly ascribable to effluents from food processing firms, pig farms, slaughterhouses, dyeing and textile factories, and paper and pulp mills. Fish farming, such as of tilapia, is raising a concern over the contamination through its feeding processes. The annual pollution load in 2000 is estimated as 61,200 t of household origin and 92,200 t of industrial origin. Within the Laguna de Bay basin, there are 1,481 offices/factories registered as industrial point sources; 695 of them are equipped with wastewater treatment facilities, the rest discharge the effluent untreated. Among the influx pollutants into the lake, the annual total nitrogen and phosphorus are calculated as 3,942 t and 942 t, respectively.

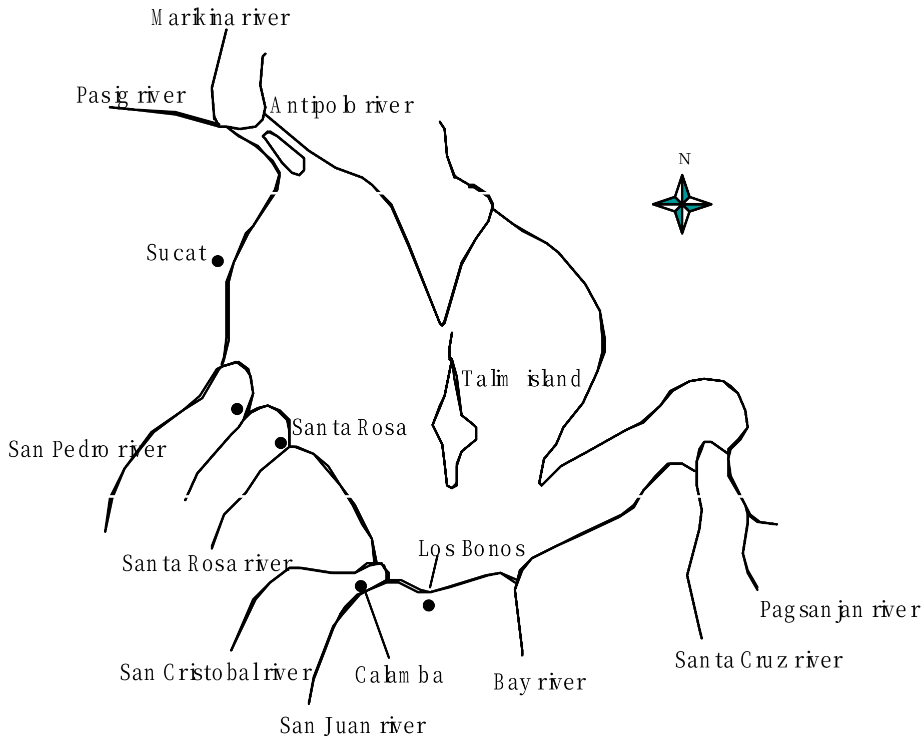


Fig.4-7-2 Drainage of Laguna de Bay

The water quality figures in Laguna de Bay are as follows: CODcr 5.3-32.7 mg/*l*; nitrate nitrogen concentration 0.02-0.4 mg/*l*; dissolved PO_4-P concentration 0.1-1.0 mg/*l*; and transparency 11-23 cm. May to October, a rainy season in the Laguna de Bay basin, sees the monthly precipitation reaching 300-500 mm, which exceeds the decupling of that in the dry season. For this reason, the water quality in the rainy season tends to improve somewhat. Wild weather, including typhoons, severely stirs the lake water, which is observed to discolor the water brown every year by rolling up the sediment deposits. Observation has found that, under such conditions, the COD level rises all the way up to around 50 mg/*l*, thus significantly reducing the transparency down to 6 cm.

4-7-3 State of Control Measures and their Future Direction

The influent pollutants into Laguna de Bay are controlled by various regulations and systems instituted mainly by the Department of Environment and Natural Resources (DENR) and its subsidiary organization the Laguna Lake Development Authority (LLDA). The measures at this lake are characterized by the Environmental User Fee (EUF). Under this system, the polluters are required to pay the tax according to their discharge volume, and the tax rate depends on the biochemical oxygen demand (BOD) of the effluent. The taxation now extends to approximately 1,400 facilities, and 31 cases were reported between 1998 and 2000 where businesses were forced to suspend operations as a penalty for violating the regulations. The taxation is in two tiers: fixed and progressive. As for the fixed rate, 15,000 pesos is imposed on a business with a daily discharge of 150 m^3 and over, 10,000 pesos on a business with a daily discharge of between 31 and less than 150 m^3, and 5,000 pesos on a business with a daily discharge of less than 31 m^3. As for the progressive rate, effluent with a BOD level of less than 50 mg/*l* is charged 5 pesos per kg BOD, whereas effluent with a BOD level of 50 mg/*l* and higher is charged 30 pesos per kg BOD. The annual BOD total is calculated as average BOD concentration (mg/*l*) × average daily discharge (m^3/day) × 300 × 10-3, which provides the basis for this specific tax. The constant 300 in the equation represents the average operating days a year. Under this tax system, any business that discharges more than 50 mg/*l* faces a larger taxation rate, which cannot be reduced simply by diluting the wastewater due to the volume-based element in the system. Such a system of taxation urges businesses to strive for minimizing the BOD rate of the effluent as well as the total discharge volume. The effluent is monitored by the local offices of the DENR, whose analysis capacities at the lab fall short of the number of samples. Under this circumstance, several private institutes have launched a measuring service, although the measured values are not officially certified and remain merely as a non-binding reference. The EUF system, currently in its first phase, targets organic wastewater, which results in a lack of nitrogen and phosphorus control. Discussion now proceeding for a second phase of the system concerns imposing a tax on businesses that discharge toxic substances and other pollutants in their industrial effluent. The EUF system ultimately aims at its application on the particles and NOx in the air. In this climate, the future challenge lies in the early enactment of a regulative law targeting nitrogen and phosphorus, which is essential for facilitating the efforts toward control of eutrophication at Laguna de Bay. At the same time, it is important to upgrade the monitoring system for rigid application of the EUF, such as through opening up the official certificate issuance in regard to the effluent analysis of the private institutions.

The Laguna de Bay catchment area stretches over an area as vast as 3,820km^2, of which 41 % and 52 % are covered by the natural vegetation of forests and farmlands, respectively. For this reason, the lake has more influx of infiltration water, which originates from rainfall on the forests which penetrate into the soil. This is corroborated by data showing that the lead-lag correlation between precipitation and chlorine ion concentration of the lake is about three months. Such rechargeability is crucial in terms of conserving the water resource. As Laguna de Bay is expected to supply the water to Manila in the future, environmental education PR activities for catchment residents and industries will share an important role in disseminating knowledge about the importance of the water resource.

4-8 Lake Ypakarai

4-8-1 Characteristics of the Lake and its Watershed

Lake Ypakarai is located in the Republic of Paraguay in South America; more specifically, it is at S 25º14-22' and W 57º17-22', and approximately 30 km to the east of the center of the capital Asuncion (see Fig. 4-8-1). The geometric features of the lake are as follows: a surface area of 59.6×10^6 m^2; a maximum depth of 3 m; a mean depth of 2 m; a surface altitude of 64.1 m above sea level; a water capacity of 115×10^6 m^3; a shore length of 40 km; and a catchment area of 833 km^2. Of the area surrounding the lake, farmland, including the pastureland, accounts for approximately 65 %, and natural vegetation, such as grassland and wetland, shares approximately 19 %. Its catchment area embraces cities such as San Lorenzo, Luque, Capiata, and San Bernardino, whose household wastewater flows into the lake through 20 influent rivers. As shown in Fig. 4-8-2, the major influent rivers are Yuquery River from the north and Pirayu River from the south. The lake has only one effluent river, the Salado, which flows into Rio de la Plata via the Paraguay River to reach the South Atlantic. The area between the efflux of the Salado and influx of the Yuquery on the north of the lake is extensively covered by wetland: the influent from the Yuquery flows into the lake through numerous streams.

The Ypakarai catchment population is about 207,000 with a rather low density of approximately 250/km^2. Mainly used for the recreational purpose, the lake has beaches, hotels, and villas developed along its watershed, and the population density in San Bernardino on the east and other cities skyrockets during the weekends and holiday seasons. The lake supplies service water and irrigation water for farmlands and pasturelands, and also provides a fishing ground that extensively contributes to the local fishery.

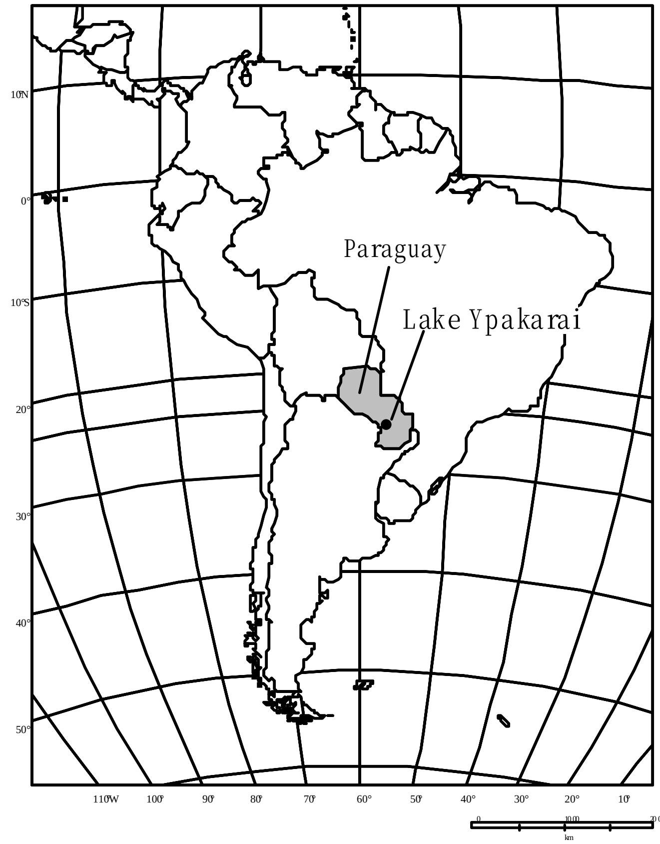


Fig.4-8-1 Situation of Lake Ypakarai

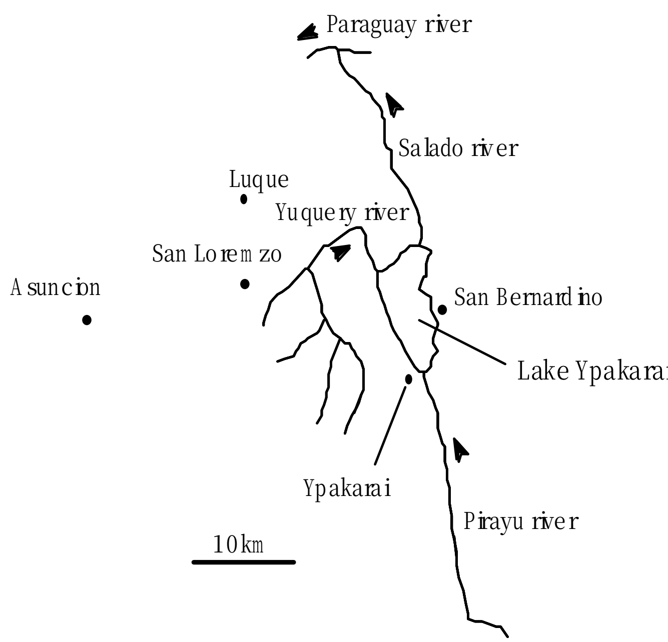


Fig.4-8-2 Drainage of Lake Ypakarai

4-8-2 State of the Lake

Due to its shallowness (a mean depth of 2 m) and little headway in pollutant control in its catchment area, Lake Ypakarai has suffered from ever advancing eutrophication in recent years. The year 1999 saw precipitation decrease immensely, which triggered acute drought by reducing the water level by over 1 m. Consequently, the mean depth decreased to less than 1 m, sending the lake into a crisis with the extraordinary propagation of cyanobacteria. Photo 4-8-1 shows the blue-green algae bloom (*Microcystis aeruginosa aeruginosa*) blown toward the Ypakarai lakeshore. The drifted cyanobacteria, when decomposing, released a foul smell which plagued the lakeshore residents and industries. This obnoxious odor dealt a hard blow to the tourism industry: many lake beaches had practically no business despite being open. Relying on the lake for its water supply, San Bernardino on the east particularly faces considerable social problems when there is drought and the toxigenic cyanobacteria bloom. San Bernardino is a tourist city and summer retreat, which means that its water demand rises in summer when water is in short supply. Moreover, the city, without a sewerage system, drains its domestic wastewater untreated into its service water source Lake Ypakarai, which poses a fundamental problem to the city itself.

Photo 4-8-1 Algae bloom blown toward the Ypakarai

The lake water is colored brown from the influent soil particles due to soil erosion in the catchment area. For this reason, the lake is characterized by significantly low transparency (0.07-0.15 m) and a considerably high SS concentration (70-80 mg/*l*). Since the lake water constantly looks brown due to the suspended soil particles, it is hard to identify the green color of the cyanobacterial colony by the unaided eye. At the same time, however, a large mass of algae can be found accumulated by the sweeping waves, and the plankton sample collected from the lake water by plankton net always contains an extremely high concentration of blue-green algae. The algae concentrations at the lake center were 320,000 cells/m*l* of *Microcystis aeruginosa aeruginos*, and 96,000 cells/m*l* of *Anabaena spiroides* as of January 2000.

The water quality figures in Lake Ypakarai are as follows: CODcr 10.3-15.7 mg/*l*; T-N 0.58-0.89 mg/*l*; T-P 0.15-0.30 mg/*l*; DO 6.0-8.9 mg/*l*; and pH 6.0-8.7. The lake is distinctive for its relatively high phosphorus concentration compared to the nitrogen level, thus there is an excessively low ratio between nitrogen and phosphorus of 1.9-5.9.

Urban and domestic wastewater in the basin accounts for around 48 % of the loading pollutants flown into Lake Ypakarai. The industrial effluent from over 80 business establishments in the catchment area is estimated to share approximately 24 %, most of which are ascribable to meat packaging and leather processing. In Paraguay, deforestation swept most of its land, where virgin forests have fallen into a disastrous condition. The Ypakarai catchment area is no exception, where the forests are replaced by pastureland and wasteland. Consequently, such a land condition cannot prevent soil erosion, increasing the non-point loads of the catchment area to 9,800,000 kg/year of CODcr, 370,000 kg/year of T-N, and 94,000 kg/year of T-P. The influent soil particles raise the SS level to 20,000,000 kg/year. This situation clearly testifies that non-point source control is a critically urgent matter.

4-8-3 State of Control Measures and their Future Direction

In compiling the water quality improvement plan at Lake Ypakarai, there are some technological transfer projects provided by Japan to Paraguay: a development survey concerning the water quality improvement plan at Lake Ypakarai (recipient: Technical Secretariat of Planning, Presidency of the Republic) in 1988-1989; technological cooperation by individual specialists (recipient: National Environment and Health Service (SENASA)) in 1995-1998; and a specialist team sent in 1998-2001. Based on this technological cooperation series, deliberation is now proceeding regarding how to formulate and implement the water quality improvement plan. *Consejo de Municipalidades de la Cuenca del Lago Ypacarai* (CLYMA), composed of 21 municipalities in the Lake Ypacarai catchment area, and *Consejo de Gobernaciones Municipalidades de la Cuenca del Lago Ypacarai* (CLYGMA), composed of three departments (provinces) in addition to the said municipalities, were established in 1999 to concentrate efforts to improve the water quality in the Lake Ypacarai basin. These councils, through various activities, are expected to contribute to better water quality at the lake. The pilot projects for water quality improvement have just begun, and full-fledged project planning and project promotion are still on their way and eagerly awaited.

At present, Caacupe, though outside the Ypacarai basin, has been equipped with a sewerage system, and the same initiative was launched to develop a sewage treatment system in the Ypacarai basin cities such as Itagua, Capiata, and Ypacarai. Realization of this vision should contribute to drastic purification of the lake by reducing pollutants in the untreated effluent into the lake. Radical measures, such as the sewerage plan, are hard to implement, not to mention to complete early, in the Ypacarai catchment area. Furthermore, non-point sources share a large portion of the loading pollution, which clearly require more than the development of a sewer treatment system. Under these circumstances, an eco-engineering approach that makes best use of the vast wetland covering the north of the lake (shown in Photo 4-8-2) is considered to exert a substantial effect. Since the watercourse of the Yuquery River goes through this area, the pollutants from the Yuquery should be significantly abated with the effective use of aquatic plants. Ecological awareness and the ethics of the catchment community members have not yet reached an adequate level. Full-geared implementation of environmental education and edification will be able to greatly stimulate their interest in the lake pollution, thus slashing the pollutant loads such as through illegal waste dumping.

Photo 4-8-2 The vast wetland covering the north of the lake

5. New International Problems Related to Lakes and Marshes

This chapter deals with problems that are newly emerging as common international tasks relating to the water environment at lakes and marshes.

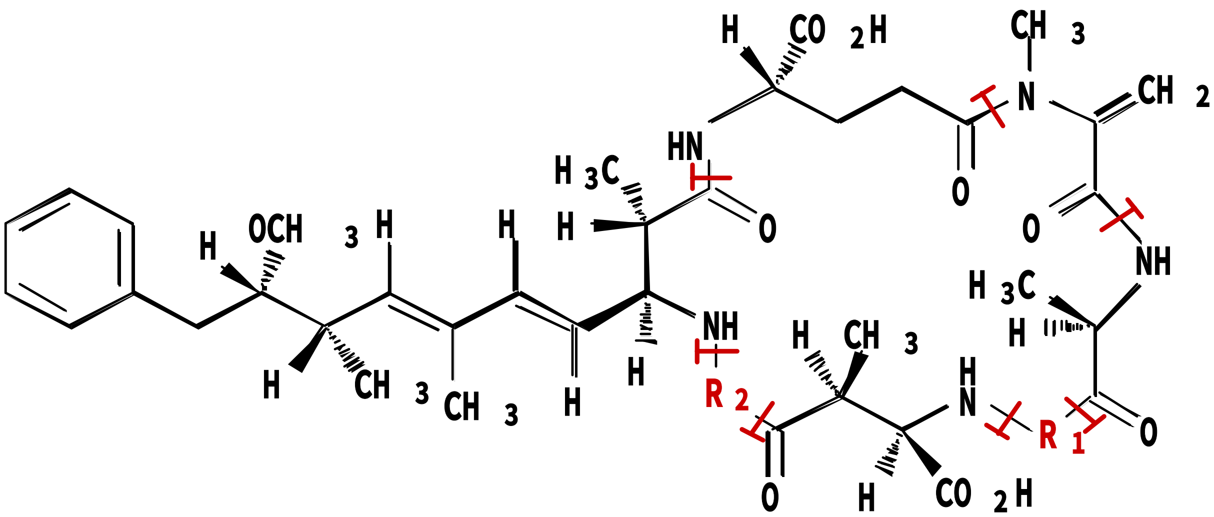
5-1 Animal death due to toxic microcystins produced by water-blooms

Among bloom-forming blue-green algae, some toxic species have been confirmed to exist in eutrophic lakes. Representative toxin-producing blue-green algal species are the *Anabaena* genus, the *Aphanizomenon* genus, the *Cylindrospermopsis* genus, the *Microcystis* genus, the *Nodularia* genus, the *Nostoc* genus and the *Oscillatoria* genus. In particular, microcystins are frequently detected in eutrophic lakes all over the world. Representative types of toxic blue-green algae and toxic substances are shown in Table 5-1-1. In lakes and marshes across the world toxic water-blooms have been unusually proliferate, and cases of the death of livestock and humans arising out of such toxic algae are being revealed. Harm to livestock deriving from toxins produced by blue-green algae has been reported in Australia, the United States, Finland and so forth; animals afflicted are cows, horses, pigs, sheep, poultry, etc. In a Caruaru hospital in the state of Pernambuco, Brazil, microcystins got mixed in the hospital's private tap water system and killed more than 50 people. Against such a background, the WHO (World Health Organization) in its guidelines on drinking water quality provisionally provides that microcystin-LR shall be under 1μg/ *l*. The microcystin is a cyclic peptide consisting of seven amino acids (Fig. 5-1-1). Due to differences of the amino acids positioned at X and Z, microcystins can be divided into microcystin-RR, microcystin-YR, microcystin-LR and others. The microcystin is believed to have nearly 60 homologues. Of all the microcystins, the most toxic is microcystin-LR. Its LD_{50} (lethal concentration 50%) in mice is reported as 50 μg/kg. Some members of the *Microcystis* genus contain microcystins and therefore are toxic, while some others do not contain microcystins and are not toxic.

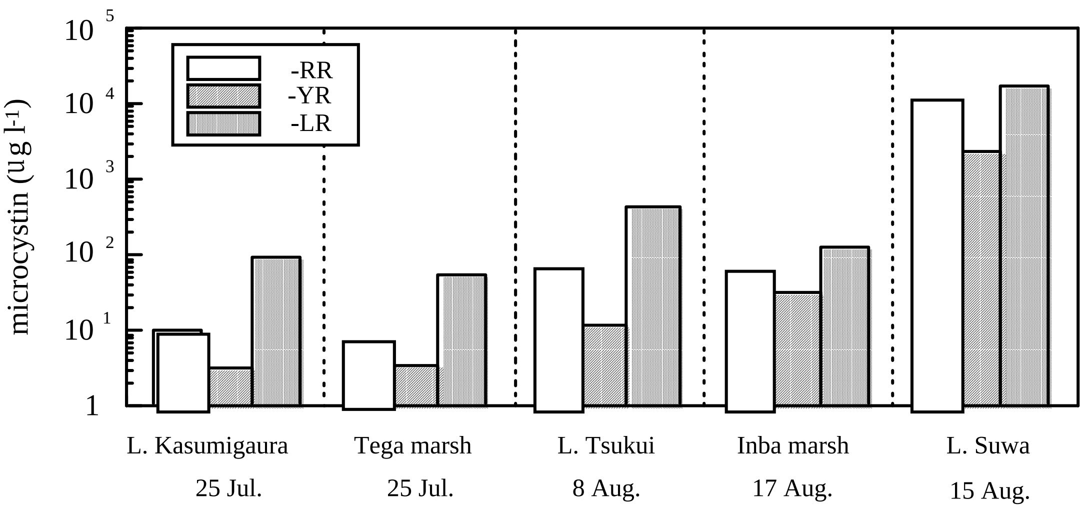
Table 5-1-1 Toxic blue-green algae and their toxins

Anabaena flos-aquae	anatoxin	(neurotoxin)
	microcystin	(hepatotoxin)
Aphanizomenon flos-aquae	aphantoxin	(neurotoxin)
Cylindrospermopsis raciborskii	cylindrospermopsin	(hepatotoxin)
Microcystis aeruginosa	microcystin	(hepatotoxin)
Nodularia spumigena	nodularin	(hepatotoxin)
Oscillatoria agardhii	microcystin	(hepatotoxin)

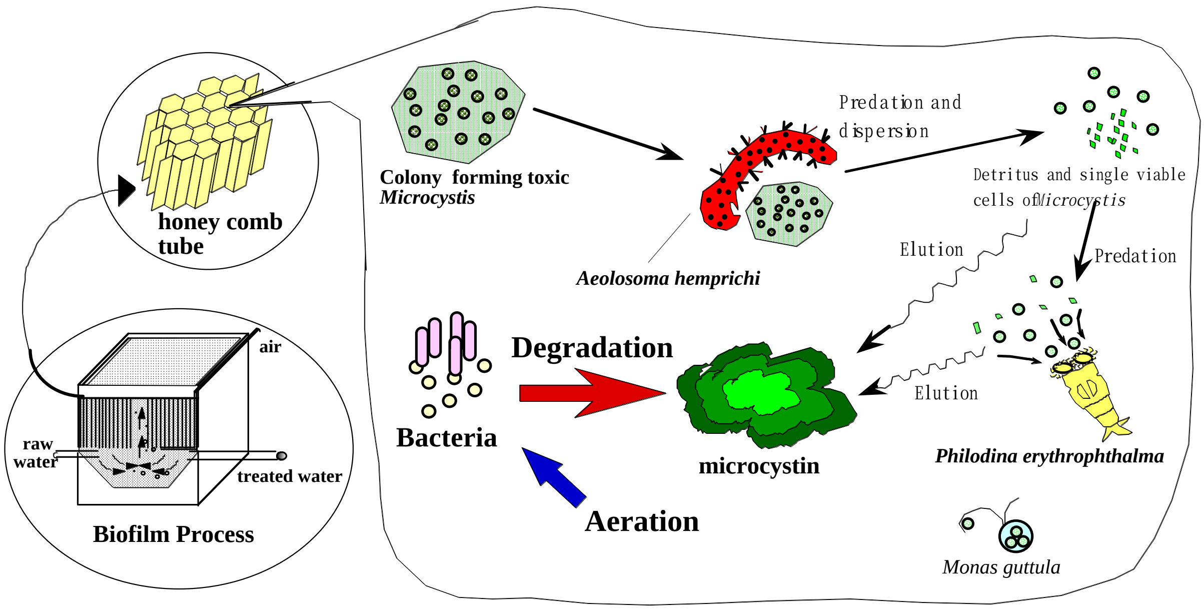
Consequently, the microcystin content varies greatly depending upon which type is dominant, a toxic type or a non-toxic type. The blue-green algae beginning with the *Microcystis* have a strong tendency to float, and are likely to be driven by wind to become accumulated; therefore, the microcystin concentration differs greatly even in the same water area depending upon the place. The *Microcystis* genus prefers high temperatures and therefore, in the temperate regions, microcystins appear mainly in summer and their concentration varies depending upon the time of the outbreak. Various cases of microcystin content have been reported. Such cases report 0.2 to 0.4 mg MCYST/g dry weight on lakes in Japan, 0.7 to 0.8 mg MCYST/g dry weight on impounding reservoirs in Thailand and 0.05 to 0.415 mg MCYST/g dry weight on impounding reservoirs in South Africa. The existing quantities of microcystins at Japanese lakes are as shown in Fig. 5-1-2. In Japan, microcystins appear principally in summertime revealing the dominance of the microcystin-RR and microcystin-LR in many cases.



	R_1	R_2
RR	arginine	arginine
YR	tyrosine	arginine
LR	leusine	arginine



Effective methods to remove microcystins from drinking water are the ozone treatment, the activated carbon treatment and the biological treatment. In the biological treatment, it is reported that protozoans and metazoans eat blue-green algae, and the eluted microcystins are ingested and decomposed by bacteria (Fig. 5-1-3). Microcystins are usually present within cells, and elute into the water when dead. Those who control water purification facilities need to be careful about the microcystin concentration in each process at the time when microcystins die. The blue-green algal proliferation is triggered by increased concentrations of nitrogen and phosphorous that flow into the water area contained in residential wastewater, business wastewater and livestock-related wastewater; therefore, strengthening measures against nitrogen and phosphorous is very effective in preventing blue-green algal outbreaks.



5-2 Fish Death by Aggressive *Dinoflagellida Pfiesteria*

Among *Dinoflagellidas*, there are species that produce toxic substances. These species are known to be harmful to fish and shellfish; they accumulate toxins within fish and shellfish, and humans who eat them suffer poisoning. The toxins produced by *Dinoflagellidas* are ciguatera toxins, saxitoxins, okada acids and so forth. Of all the members of *Dinoflagellidas*, the most problematic of recent years is the *Pfiesteria piscicida*, which is one of the species of *Dinoflagellidas* known as red-tide algae that have as many as 2,000 different types throughout the world. *P. piscicida* is said to be responsible for the massive fish deaths occurring in the estuaries in North Carolina and Maryland. The Unites States provide that any research on this microorganism requires a Level-3 laboratory. The toxin produced by *P. piscicida* destroys the skin of the fish and damages its nervous system and vital organs. Furthermore, this species has the great ability to produce volatile toxins harmful particularly to human health, react severely in fish and in a short time, change from being nonpoisonous to being poisonous. Also reported is the fact that the existence of *P. piscicida* prevents fish eggs from hatching and deprives young shellfish of their ability to close their shells. Photos showing the stage of *P. piscicida* proliferation confirm that microorganisms similar in form exist in nature; however, it appears that in many places, no problem has ever been induced by such microorganisms. That is to say, judgment from mere appearance may lead to incorrect identification, and therefore their culture is necessary. Ocean vessels may bring in ballast water allowing *P. piscicida* to move to other countries; therefore, the utmost care is required at seaports where the loading and unloading of cargo or the transfer of large amounts of ballast water is conducted. Furthermore, imports of raw materials such as sea urchins may allow *P. piscicida* to move to other countries; thus, a check should be made to determine whether *P. piscicida* has ever been present in places where such sea animals existed. The factor that allows *P. piscicida* to massively proliferate is eutrophication due to the inflow of nitrogen and phosphorous. *P. piscidida* is supposed to proliferate on a massive algal outbreak; therefore, to prevent such toxic *Dinoflagellidas* from unusual proliferation, measures against nitrogen and phosphorous occupy a very important position.

5-3 Bird death due to Toxin-Producing Botulinus

Botulinus bacilli (*Clostridium botulinum)* are gram-positive bacteria and obligate anaerobes. Their spores are present in diverse environments such as soil, water environments and animal intestines. Resistive to high temperature, they proliferate in food and cause food poisoning. The botulinus bacilli are the causative fungi of poisoning derived from the putrefaction of food placed in an anaerobic condition such as sausages and canned food. The botulinus bacilli produce a neurotoxin consisting of a protein called botulinus toxin and cause botulism in anyone who ingests it. There are seven types of botulinus toxins, A - G, on which botulinus bacilli are classified. Botulism occurs all over the world. Besides humans, domestic animals such as chickens and cows, and wild animals such as mink and seabirds are also infected. The sources of infection are food for humans, feed for livestock and dead and decomposed fish and animals for wild animals. Birds also become infected when they eat dead animals in which botulinus bacilli have proliferated and produced toxins. Birds' botulism is caused by botulinus bacillus type C and type D. The lethal dose of 50% (LD50) is so small that in an experiment with a mouse, less than 1ng per kg of body weight injected in its body is lethal.

5-4 Obstacles by Unusual Proliferation of Free Floating Plants

5-4-1 Current status of unusual proliferation of free-floating plants

In water areas where nitrogen and phosphorous concentrations are high and water is stagnant, plants such as water hyacinths and water lettuce freely float and absorb nutritive salts such as nitrogen and phosphorous directly from water to proliferate; then, such plants become dominant at the waterside. Free-floating plants have their leaves above water; they are not affected by decreased transparency and little affected by waves as they move with the motion of the waves. Within communities, they interrupt light and contain phytoplankton proliferation. In Kyushu, Shikoku and Chugoku districts in Japan, there has been a huge outbreak of water hyacinths; they have occupied closed water areas including Lake Kojima and adjacent creeks, and are a menace to the existing plants and animals; furthermore, they clog the water intakes. In autumn, they decay and deteriorate the water quality to a great extent. In China, *Alternanthera philoxeroides* (Chinese name "xi han lian zi cau") grow out of the creek waterside, store air between joints through an extraction period, float stalks on the water surface and form intervolved communities; once their old joints have connected to the water bottom or the waterside has become rotten, they shift to a free-floating life and proliferate, filling up the whole waterside. They are not liked by domestic animals, and therefore have little added value; however, when compared with water hyacinths, they cause a large number of biofilms to be attached to their rootstalks and provide habitats for aquatic insects such as larva of midge; therefore, they are supposed to contribute to the proliferation of aquatic animals. In China, there are also a large number of water hyacinths. In Dian Chi that extends south of Kunming, this plant has flourished covering over half of the water surface at Lake Cau Hai (an inner lake) that leads to the city zone. In the Kingdom of Thailand, other floating plants are more dominant; therefore, "Xi han lian zi cau" which is known as "alligator weed," is seen only at the waterside or on land. In the Kingdom of Thailand, principal free-floating plants are water hyacinths, swamp cabbage and *Neptunia oleracea*. Of swamp cabbage and *Neptunia oleracea*, edible kinds are selected and cultivated on water as vegetables. In heavily polluted water areas, water hyacinths are dominant, and in agricultural districts where no aquaculture is in practice, swamp cabbage spreads on the water surfaces in many places.

5-4-2 Measures against Free-Floating Plants

Representative problems that are caused by free-floating plants are the hindrance to boat navigation, the clogging of water intakes, the formation of anaerobic water masses and deterioration in water quality by dead stumps. Water hyacinths are not strongly connected to each other; however, they are highly proliferating. They form large communities and obstruct boat navigation. They drift separately and gather at water intakes, blocking them. Furthermore, they interrupt light obstructing photosynthesis under water below the communities. As they have low added value, they are left to die uncared for and deteriorate water quality, creating yet another hindrance. In China, pig farmers collect water hyacinths to feed pigs; then, the diffusion of a collecting and reusing system of such floating plants appears to be useful. Swamp cabbage serves as food and has a high added value, and actually, they are distributed for sale in the Kingdom of Thailand and other countries. Swamp cabbage forms communities interconnected with stalks; therefore, if fixed by bamboo stakes at two points or bound to bamboo floated between two stakes, the cabbage will not flow out on the current. The swamp cabbage has a larger capacity to supply oxygen under water than water hyacinths and its stalks and leaves are cropped and brought to the market for mass consumption. However, as they are not as resistive to waves as water hyacinths or *Alternanthera philoxeroides,* they can be cultivated only in calm inlets at lakes; therefore, they are cultivated principally at creeks attached to inflowing rivers or lakes. In the Kingdom of Thailand, at some places swamp cabbage and *Neptunia oleracea* are cultivated in a continuous creek under careful control along with some fisheries, while at other places, water hyacinths block the water areas rendering them quite unusable. Right granting for the use of creeks properly partitioned and the introduction of a system to set up responsibility for its control will enable productivity improvement and water purification to coexist, and thus, recycle-based water purification will be established.

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6. Projects for Water Environment Renovation of Lake Kasumigaura as the Core for Eutrophication Control Strategy in Japan

In November 1997, the Science and Technology Agency (reorganized as part of Ministry of Education, Culture, Sports, Science and Technology) designated the Project for Water Environment Renovation of Lake Kasumigaura in Ibaraki Prefecture as a Collaboration of Regional Entities for the Advancement of Technological Excellence (CREATE), which launched this ongoing five-year joint research project commissioned by the Japan Science and Technology Corporation. A wide range of organizations, universities, independent administrative institutions, prefectural research institutes, and R&D-oriented enterprises, jointly participated in the project to address technological development for water environment remediation, under the banner of “research concerning the development of the aquatic environment restoration for polluted lake areas by introducing eco-engineering approaches, and research on the comprehensive evaluation of the improvement efficiency brought by the new system.”

Ibaraki Prefecture is home to Lake Kasumigaura, the second widest freshwater lake in Japan and an essential water resource due to it providing service, industrial, and agricultural waters and nourishing freshwater fishery. At the same time, however, the lake suffers from an aggravated water quality going way over the permissive levels in environmental standards, with toxigenic cyanobacteria proliferation in summer and year-round manifestation of the filamentous blue-green algae. This lake pollution poses various, immense challenges, such as obstructions to water utilization and a deteriorating landscape. The fundamental solution to these problems requires the urgent implementation of radical measures focusing on the elimination of the nitrogen and phosphorus that feed the abnormal cyanobacterial proliferation. The damage caused by toxic blue-green algae, in particular, is emerging in many regions of the world, which the World Health Organization (WHO) addressed recently by setting a guideline value for microcystin, a toxin produced by cyanobacteria, under its Guidelines for Drinking Water Quality. Such a situation, where our water sources fall into conditions hazardous to human life, is grave enough to call for urgent control measures. Tsukuba and Tsuchiura Cities in Ibaraki Prefecture hosted the 6th World Lakes Conference in 1995, which delivered the Kasumigaura Declaration. Based on this declaration, Ibaraki Prefecture with Lake Kasumigaura must adopt strong leadership to serve as an arena for providing new proposals on lake water environment restoration and remediation to the rest of the world.

With an eye on making the efficiency of actions directed towards a healthy lake water environment noticeable to Ibaraki taxpayers, the project is to proceed with objectives of 1) developing various elemental technologies for water environment restoration, such as processing, monitoring, and multimedia utilization, under an organic teamwork of industry, academia, and government, and 2) fostering venture business for generalizing and disseminating these developed technologies in order to apply these technologies to Lake Kasumigaura and its basin in an optimal way, as well as to activate industry within the prefecture. Furthermore, Ibaraki Prefecture is currently pursuing a construction plan for a “Lake Kasumigaura Environmental Center (tentative name)”. This project aims to establish a foundation for the center to function as a world-leading institute on water environment research, and concurrently to develop the area with this institute into a Center of Excellence (COE) on lake environment remedial technologies, with the institute as its mainstay. It envisages its ultimate goal as establishing a foothold to implement the Kasumigaura Declaration. This declaration is hoped to provide a gem not just for Japan but for the world through its collection of know-how to navigate by into the 21st century.

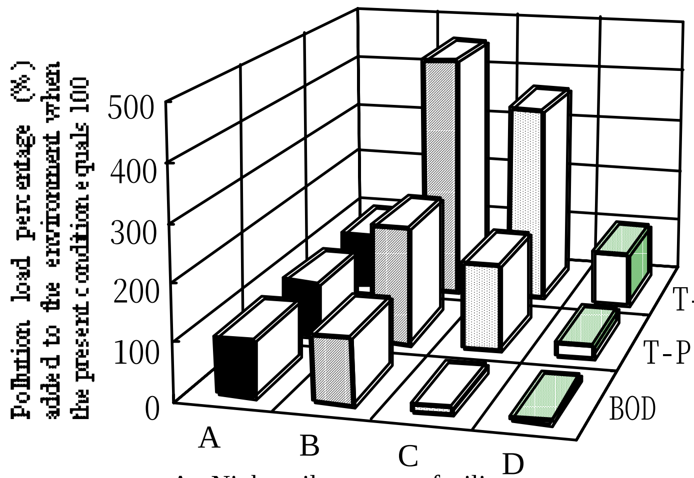
Nitrogen and phosphorus elimination essentially requires measures for source control and direct purification. For successful implementation, both control measures vitally need development of elemental technologies, keeping track of the state of water quality to effectively apply developed technologies to Kasumigaura and its basin, and development of bettering/predicting schemes after launching these technologies. The nucleus of such elemental technologies consists of the bioengineering approach using biological processing, and the eco-engineering approach by inducing engineering elements in natural ecosystem. In addition, development of techniques to achieve the optimal application of the elemental technologies is listed as one of the tasks in the project. These techniques include monitoring, analysis, assessment, and prediction.

These tasks of technological development are common to developing countries suffering from eutrophication of their precious water resources, just as with Lake Kasumigaura. In this sense, the project shares an important initiative role in the research and development of technologies to control such conditions.

Giving consideration to the above circumstances, the Kasumigaura Project has pursued research for developing bio-eco-engineering-based remedies for the water environment which feature energy-saving, cost-cutting, and low-maintenance applicable to eutrophication control in developing nations, as well as establishing area-wide maintenance schemes. The following sections will describe the achievements that were obtained so far through these research activities.

6-1 Pollutant Source Control Utilizing the Bioengineering Approach

Eutrophication of Lake Kasumigaura is chiefly ascribable to the inflow of nitrogen and phosphorus derived from domestic effluent. Yet, sewerage work covers less than 50 % of the catchment area. Since the population is fairly widely scattered in the basin area, a private sewer treatment system (known as JOKASOH), which processes wastewater on the site of the pollutant source, has been endorsed for household wastewater control, as opposed to developing a centralized sewerage plant. Nevertheless, the private sewer treatment system installed in the past focused its pollutant reducing capacity on the biochemical oxygen demand (BOD) only and not on nitrogen or phosphorus. Due to this inadequacy, the system could not contribute to efforts to counter eutrophication in Kasumigaura. The result of such a situation is demonstrated in Fig. 6-1-1, by comparing the differences of the pollutant load volumes between the household with a privy and untreated drainage of miscellaneous wastewater and households with a flush lavatory. The graph sets the environmental loads of BOD, total nitrogen (T-N) and total phosphorus (T-P) by the sewerage work as 100 each. On one hand, the treatment by only the septic tank registers 400 % and 150 % increases in T-N and T-P figures, respectively, substantially exceeding the sewerage rates. On the other hand, the combined type on-site sewer treatment system, capable of batch processing of night soil and other wastewater, can reduce the BOD level, but still increases T-N and T-P by 300 % and 100 %, respectively, failing to achieve any noticeable reduction. In the Kasumigaura catchment area, stringent add-on effluent standards, authorized by the Water pollution Control Law, extend to nitrogen and phosphorus as living environment items, setting the permissible values as T-N ≦ 10 mg/*l* and T-P ≦ 1 mg/*l*. In this context, the key to success in anti-eutrophication lies in the development and widespread use of a high-performance combined on-site sewer treatment system featuring denitrification and dephosphorization of the same level or even higher than the sewerage work. Against this backdrop, this project has been pursuing the development of various elemental technologies with the objectives of establishing and disseminating a bioengineering method that can process wastewater to meet the BOD ≦ 10 mg/*l*, T-N ≦ 10 mg/*l* and T-P ≦ 0.5 mg/*l* requirements to control household pollutant sources.



A : Night soil treatment facility
B : Night soil treatment Johkasou
C : Domestic wastewater treatment Johkasou
D : Advanced treatment Johkasou

Fig. 6-1-1 Comparison of Removal Effects by Type of Johkasou

(1) Advanced On-site Sewer Treatment System

Denitrification can be divided into two varieties of approaches: biological elimination making use of microorganismic activities, and physiochemical elimination such as ammonia stripping and zeolite adsorption. Nitrogen takes the form of organic nitrogen and ammonia nitrogen in household wastewater, whose T-N concentration, including both nitrogens, is approximately 50 mg/*l*. The high-performance combined private sewer treatment system, unlike the public sewerage system, does not receive constant monitoring by an administrator. For this reason, the biological elimination approach is applied to the system to allow easy maintenance, a simple structure, and a low running cost. The biological reaction in nitrogen elimination proceeds in three steps: deamination, nitrification, and denitrification, if setting organic nitrogen as the starting point. To facilitate the smooth development of these series of reactions, the high-performance combined on-site sewer treatment system has an anaerobic tank, an aerobic tank, a settling tank, a circulation line, and other parts all in one unit.

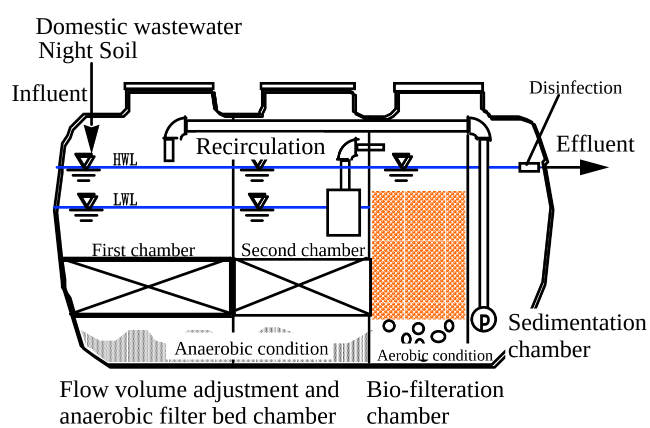


Fig. 6-1-2 Biological Filter Method Type Advanced Combined Johkasou

Fig. 6-1-2 presents the nitrogen removal flow in a high-performance combined sewerage system. The chart shows the example of such a JOHKASO capable of controlling the flow to deal with the two inflow peaks a day. The wastewater first enters the first chamber of the anaerobic tank, and then is pushed into the second chamber. In these chambers, anaerobic bacteria reduce the organic nitrogen into the ammonia nitrogen. The airlift pump transfers the semi-treated water in the second anaerobic chamber by batch into the aerobic tank. Under aerobic conditions, nitrifying bacteria oxidize the ammonia nitrogen into the nitrate nitrogen through two steps. First nitrite bacteria oxidize the ammonia nitrogen into nitrite nitrogen (shown in the equation 1), which is then oxidized into nitrate nitrogen by nitrate bacteria (shown in the equation 2). The semi-treated water containing the nitrate nitrogen is then pushed into the settling tank, from which the water returns to the first anaerobic chamber via a circulation line on a continual basis.

$$2NH_4 + 3O_2 \rightarrow 2NO_2^- + 4H^+ + 2H_2O \quad \cdots\cdots\cdots \quad 1)$$

$$2NO_2^- + O_2 \rightarrow 2NO_3^- \quad \cdots\cdots\cdots \quad 2)$$

$$2NO_3^- + 5(H_2) \rightarrow N_2\uparrow + 2OH- + 4H_2O \quad \cdots\cdots\cdots \quad 3)$$

At the first chamber of the anaerobic tank, the nitrate nitrogen in the returned semi-treated water is reduced by denitrifying bacteria all the way to nitrogen gas (shown in the equation 3). The bacteria involved in denitrification are common, facultative anaerobic bacteria. These bacteria use the dissolved oxygen in the water when available, otherwise, just as in the anaerobic tank, they take in the oxygen united to the nitrogen in the nitrate nitrogen and the ammonia nitrogen. The hydrogen shown in the equation 3 is provided through the organic substance (e.g., carbohydrate) in the effluent flow. Denitrification requires organic matters in the form of the BOD volume approximately 2.5-3 times larger than the nitrogen volume to be processed. The above denitrification process is called circulatory denitrification, which works for effluent with a BOD/N ratio of over 2.3 (household effluent usually registers about 4.0). As explained above, the high-performance on-site combined sewerage tank uses the principle where nitrogen is eliminated as a gas through the activities of nitrifying bacteria and denitrifying bacteria. This project concentrated its efforts into developing a microorganism-bonding carrier to facilitate a stable denitrification process by densely fixing the nitrifying bacteria in the aerobic tank, an arena of nitrification that determines the rate of nitrogen elimination as a whole. The developed carrier is a porous ceramic (see Photo 6-1-1), made from the sludge dredged from the bottom of Lake Kasumigaura to relieve the eutrophication. The manufacturing process of this sludge-made ceramic will be detailed later in section (5). The dredged sludge, previously buried in the designated reclaiming site on the lakeshore, is now successfully utilized under this project to benefit us as a microorganism-bonding carrier for a sophisticated on-site sewerage system, which plays a vital role in controlling eutrophication in Lake Kasumigaura.

Photo 6-1-1 Poruse sludge ceramic medium

(2) Dephosphorization and Resource Recovering System

Microorganismic activities can only eliminate a limited amount of phosphorus, a culprit in eutrophication. On this account, the Kasumigaura Project developed two physiochemical methods of dephosphorization. One is the iron electrolytic dephosphorization process, shown in Fig. 6-1-3: two iron electrodes dipped in the water treated by the on-site sewerage tank are charged with a slight direct current to produce from the anode the trivalent ferrous ions, which unite with the orthophosphate ions in the water to form precipitating iron phosphate. The deposited iron phosphate is dipped up along with the surplus sludge, and then made into compost for reuse in farmland. The verification tests of a high-performance on-site combined sewerage tank equipped with the sludge-ceramic and iron electrolytic dephosphorization have demonstrated that a) it delivers a performance of BOD ≦ 10 mg/*l*, T-N ≦ 10 mg/*l* and T-P ≦ 0.5 mg/*l*, b) the ferrous ions eluded from the iron electrode accelerate the flocculation of sludge to improve the solid-liquid separation capacity, and c) the level of surplus sludge produced by the tank displays no difference from the conventional on-site treatment system.

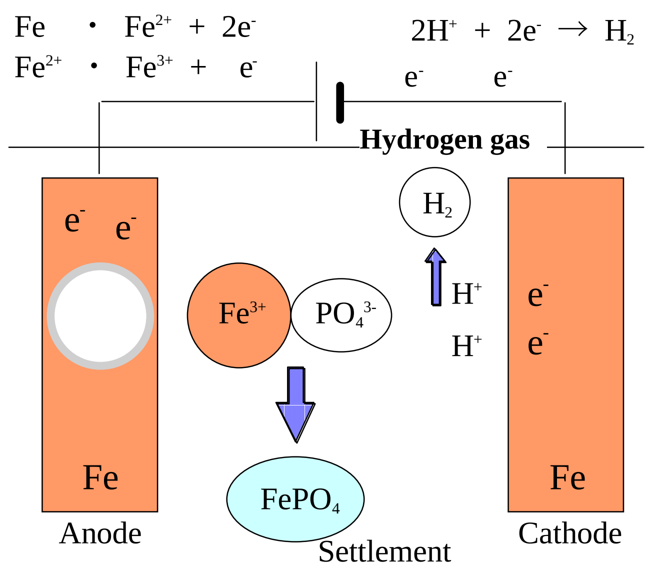


Fig. 6-1-3 Principles of the Iron Electrolysis Method

The other physiochemical method is the use of a phosphorus-adsorbing carrier. Though causing eutrophication, phosphorus is an essential resource for agricultural and industrial production, and Japan imports more than 1.4 million ton of phosphate ore every year. Since phosphorus is a finite resource just as is oil, the U.S. has instituted a no-export policy of phosphate ore to prevent phosphorus depletion. With no domestic mining resource, Japan completely depends on imports from overseas for its phosphorus, of which the U.S. accounts for approximately 30 %. Other phosphorus exporters may also ban the export or raise the price significantly. Under these circumstances, Japan will need to establish a social system to recover and recycle the phosphorus already existing at home. In this context, development of a dephosphorization method using a phosphorus-adsorbing carrier targets formation of a phosphorus recovery/recycle system as shown in Fig. 6-1-4. Spherical zirconium ferrites of ϕ 0.7 mm are used as the phosphorus-adsorbing carrier. The process in the field test is as follows. A column filled with these carriers is placed after the high-performance combined private sewerage system to adsorb the phosphate in the treated water. Once in every three months, the adsorbing carriers are taken into a phosphorus recovery station, where the carriers are

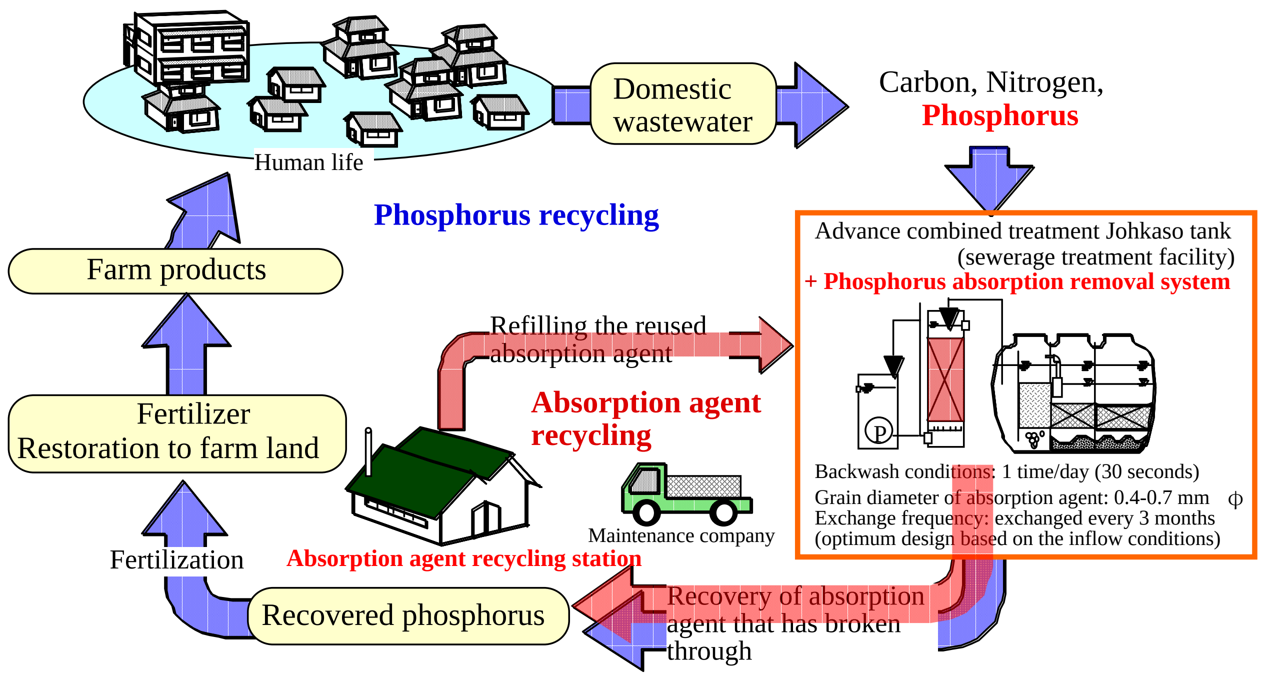


Fig. 6-1-4 Conceptual Chart of a Phosphorus Resource Recovery Type Ecosystem

dipped into a 7% sodium hydroxide solution to desorb the phosphorus, which then is crystallized by boosted sodium hydroxide solution to recover as over-90% sodium phosphate. The desorbed absorbing carriers are activated by the sulfate acidity to adjust the pH level around neutral, and then refilled into the column after the sewerage tank. This method demonstrated a remarkable treatment performance to achieve BOD ≦ 10 mg/*l*, T-N ≦ 10 mg/*l* and T-P ≦ 0.5 mg/*l*, as well as achieving significant progress in developing a new recovery-type phosphorus resource recycling system technology that paves the road to high-purity recovery of finite phosphorus.

(3) Beneficial Microorganism Concentration Boosting System

Beneficial microorganisms play a key role in the sophisticated treatment of domestic wastewater. In particular, animalcules, which contribute to the transparency of the treated water, and nitrifying bacteria and denitrifying bacteria which respectively contribute to the ammonium nitrification and denitrification, essentially need to be fixed in the reaction chamber in high density. For this reason, the project undertook development research on a technique to boost the density of the *Philodina* genus (see Fig. 6-1-5) of rotifers in the private sewerage tank, and achieved it through biological filtration using a sponge carrier that proved to keep the transparency of the treated water extremely high. We also found that crop residues contain the reproduction-inducing ingredient for the *Philodina* genus, which successfully led to the mass culture of these rotifers. Furthermore, these results demonstrated that addition of the crop residues into the tank could selectively boost the density of the *Philodina* rotifers in a diverse-microorganism ecosystem undergoing biological filtration. Success in providing these beneficial microorganisms to a high-performance private sewerage system lies in easiness of use. The *Philodina* rotifers, coupled with its reproduction-inducing agent, have an emerging potential of being made into a formulation for market availability. These results are considered to develop into the creation of a new eco-industry where water-treatment-bettering microorganisms are formulated for market distribution

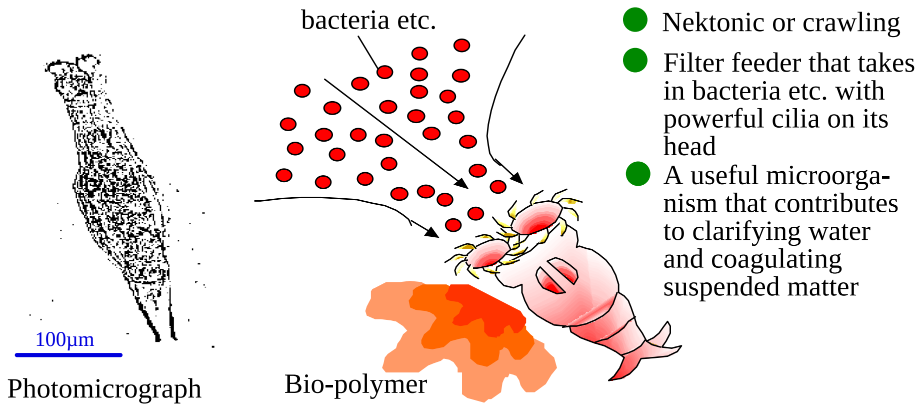


Fig. 6-1-5 Characteristics of a specimen of the rotifera *Philodina erythrophthalma*

(4) River/Canal Hybrid Purification System

In the Kasumigaura Catchment, miscellaneous household effluent (domestic wastewater except for night soil) is a major contributor to lake pollution, yet this often drains into the canals and streams without being properly treated. Those tributaries containing the polluting wastewater merge into the main river to enter Lake Kasumigaura. Many canals and small streams, in this respect, serve as the pathway of the pollutants into the lake. Consequently, it is necessary to develop technology to purify the tributaries to reduce the pollutants before their inflow into the main stream and the lake. The canals and small streams vary in their flow rate, the degree of pollution, and their size, depending on the districts and areas, which means that the decontamination technology must be developed to fit the conditions of the place. The project particularly focused its

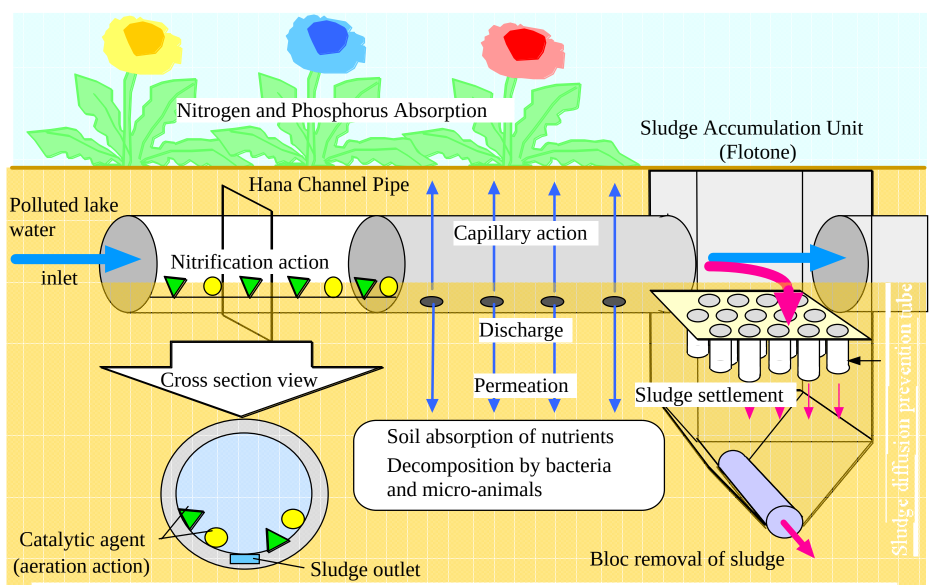


Fig. 6-1-6 Purification Mechanisms of the Hana Channel

technological development efforts on maintenance-free performance and cost reduction. For severely polluted tributaries with a relatively high flow rate, we developed the phosphorus-recovery-type purification system using the anaerobe/aerobe-cycle ceramic filling process in combination with the phosphorus elimination/adsorption process. The year-round verification tests demonstrated that this system has a high possibility for its application. For those with a relatively low flow rate, the purification system through eliminating pollutants, planting, and soil (hana channel) is being developed (see Fig. 6-1-6). Both systems proved to deliver a high performance of BOD ≦ 10 mg/*l*, T-N ≦ 10 mg/*l* and T-P ≦ 0.5 mg/*l*, and will undergo further field tests for simplifying the structure, and reducing the cost, of the systems.

(5) Non-Circulating Purification System Using the Soil Trench

Effective control of household wastewater essentially relies on the choice of purification method to be applied based on land availability. To be more specific, a bioengineering-oriented purification system, such as the high-performance private combined sewerage system, is most effective for the pollutant source with strictly limited land availability. For a pollutant source where a vast amount of land is available, a purification system with an eco-engineering approach is considered effective. This project pursued research on developing new technology utilizing the natural purification capacity of the soil, with minimal energy requiring no power input, e.g., a technique to link sets of anaerobic filter beds and the soil trenches to each other in sequence, according to the target water quality (Photo 6-1-2 and Fig. 6-1-7). Verification tests have found that the three connected-sets of anaerobic filter bed and soil trench, i.e., a system with an order of the first anaerobic filter bed, the first soil trench, the second anaerobic filter bed, the second soil trench, the third anaerobic filter bed, and the third soil trench, delivers a

Photo 6-1-2 Soil treatment system experiment equipment installed at Kokinu Experiment Site

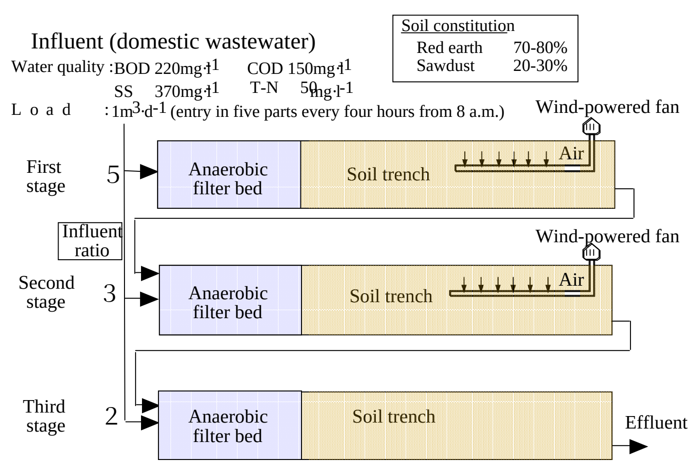


Fig. 6-1-7 Treatment flow for non-circulatory anaerobic/aerobic soil treatment system

purification performance of BOD ≦ 10 mg/*l*, T-N ≦ 10 mg/*l* and T-P ≦ 0.5 mg/*l* without circulation or power input, when the effluent inflow is divided so that 50 %, 30 %, and 20 % flow into the first anaerobic filter bed, the second anaerobic filter bed, and the third anaerobic filter bed, respectively. This system is recognized suitable for rural areas and developing countries where plenty of land is available. In the future, its study under the Kasumigaura project will focus on the life style of rural areas in Ibaraki Prefecture to clarify the relation between the inflow pollutant load fluctuation and the system's performance.

(6) Electrochemical Purification System

While most of the wastewater treatment methods employ biological processing approaches, this is a system where electrochemical approaches are applied. In many cases, the physiochemical treatment of wastewater requires the input of agents, such as flocculants, to facilitate separation of the suspended organic matters. Unlike conventional methods, this electrochemical purification system needs no chemical feeding. There are generally three methods of electrochemical purification: flotation of suspended organic matters, flocculation, and oxidization. Both the suspended and the dissolved organic matters in wastewater are eliminated through these reactions. Among them, the most important process for removing the dissolved organic matters is oxidization, which can be divided into direct oxidization and indirect oxidization. In the direct oxidization process, the organic matters are oxidized directly on the oxidized metal of an electrode by catalysis of the oxidized metals, such as TiO_2 and SnO_2. In the indirect oxidization process, the organic matters are oxidized by a hydroxyl radical (·OH) produced from the water through anodic discharge. This R&D project pursued elucidation of the detailed mechanism of these principles for their effective utilization in wastewater treatment, and the creation of practical reactor for wastewater disposal that takes account of the treatment cost, the site area, and the energy input. As a result, we have succeeded in developing a pilot-scale high-rate electrochemical wastewater treatment unit (processing capacity of 7.2 t/day). Its system flow is shown in Fig. 6-1-8.

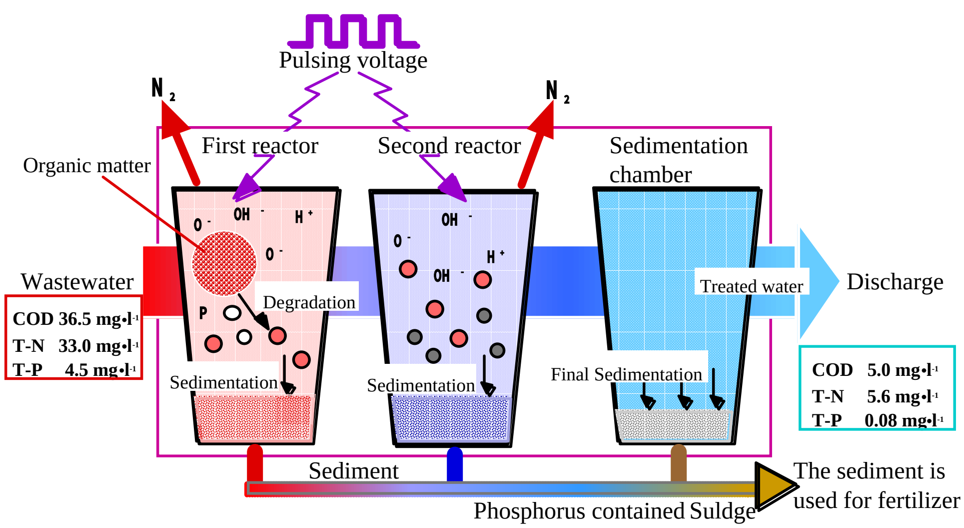


Fig. 6-1-8 Electrochemical Purification System

After large solids are eliminated from the wastewater through the screen, the wastewater undergoes the flocculation process for approximately 15 minutes in the oxidization tank, and then is sent to the first settling tank for solid/liquid separation. The supernatant liquid is processed in the reduction tank, and again sent to the second settling tank for solid/liquid separation. The final supernatant liquid is then discharged. The oxidization tank is charged with a low voltage to generate mainly the active oxygen radical (·O). The reduction tank is charged with a high-voltage pulse to generate mainly the hydroxyl radical (·OH). Both the oxidization and the reduction tanks are equipped with oxidized-metal (mainly TiO_2) electrodes. The verification tests of the unit on both household wastewater and lake water containing algae found that its elimination rates for T-N, T-P, NH_4-N, and COD in the domestic effluent achieved 83 %, 97 %, 89 %, and 86 %, respectively, and that its elimination rates of T-N, T-P, and COD in the algae-containing lake water reached 84 %, 94 %, and 92 %, respectively, with SS and chlorophyll α removal rates of over 99 %. Though no flocculant was added in the purification process, the treated water became clear. As seen above, the electrochemical system proved that it accelerates the reaction of organic matters, facilitates denitrification, and has excellent flocculation capacity for the reaction residues. In addition, the unit is showing its potential of reducing costs down to a third of the conventional electrochemical methods.

6-2 Intra-Lake Control Utilizing the Eco-Engineering Approach

Lake eutrophication is ascribable to not only the external loads flown in from rivers and other waterways, but also to the internal loads derived from sludge. These internal loads, i.e., the nitrogen and phosphorus elution from the sludge, increase when the bottom layer become anaerobic due to the oxygen consumption near the sludge by microorganisms decomposing excessively accumulated organic matters on the lake bottom. In this sense, intra-lake direct purification targets technological development for to curb the organic sediments in the sludge and anti-elution of nitrogen and phosphorus from the sludge, in addition to the decomposition/elimination of toxigenic Cyanophyceae and the direct removal of nitrogen and phosphorus.

(1) Purification System with Hydroponics and Biopark

Though having been studied before, the purification method using aquatic plants such as reeds and cattails has drawbacks in resource recovery and recycling. Taking this aspect into account, this project focused its technical development efforts on forming a purification system using edible plant hydroponics. The biopark-style purification system with hydroponic edible plants, e.g., watercress and swamp cabbage, has been created for researching its water purification capacity. The results of the study revealed that its purification reached nearly 10 times that of the reed/cattail approach, and that proper selective harvest of the plants maintained a high purification capacity. In terms of the selective harvest, this system proved that it allowed the recovery of a resource with market values as a "product". In addition, a substantial propagation of freshwater clams was identified in the rooting zones of the plants. The monitoring of their growth led us to believe that they significantly contribute to the water purification. A freshwater clam is a benthos ingesting through filtration: it eats suspended matters in the water to dramatically improve the water transparency, and is also a highly valuable fishery resource as a food product. Removing these products out of the ecosystem is expected to exert a spillover effect for water purification. Under the project, we opened the biopark to the public where they were encouraged to harvest the plants and the freshwater clams to take them back home free of charge. This public-participation selective harvesting demonstrated itself to be effective for improving the purification capacity, and on top of that, it served as an arena for environmental education to raise the eco-awareness of the citizens. As seen above, the hydroponics/biopark purification system (shown in Fig. 6-2-1) was found capable of producing edible plants and fishery products and water purification all at the same time, while contributing to environmental education and edification. In the future, the project will pursue research and development to apply the system to practical use in optimal conditions: the study typically targets a) the planting method to contribute to easy maintenance, cost reduction, and boosted purification capacity, and b) analysis of its purification capacity in highly-closed, hypertrophic water areas.

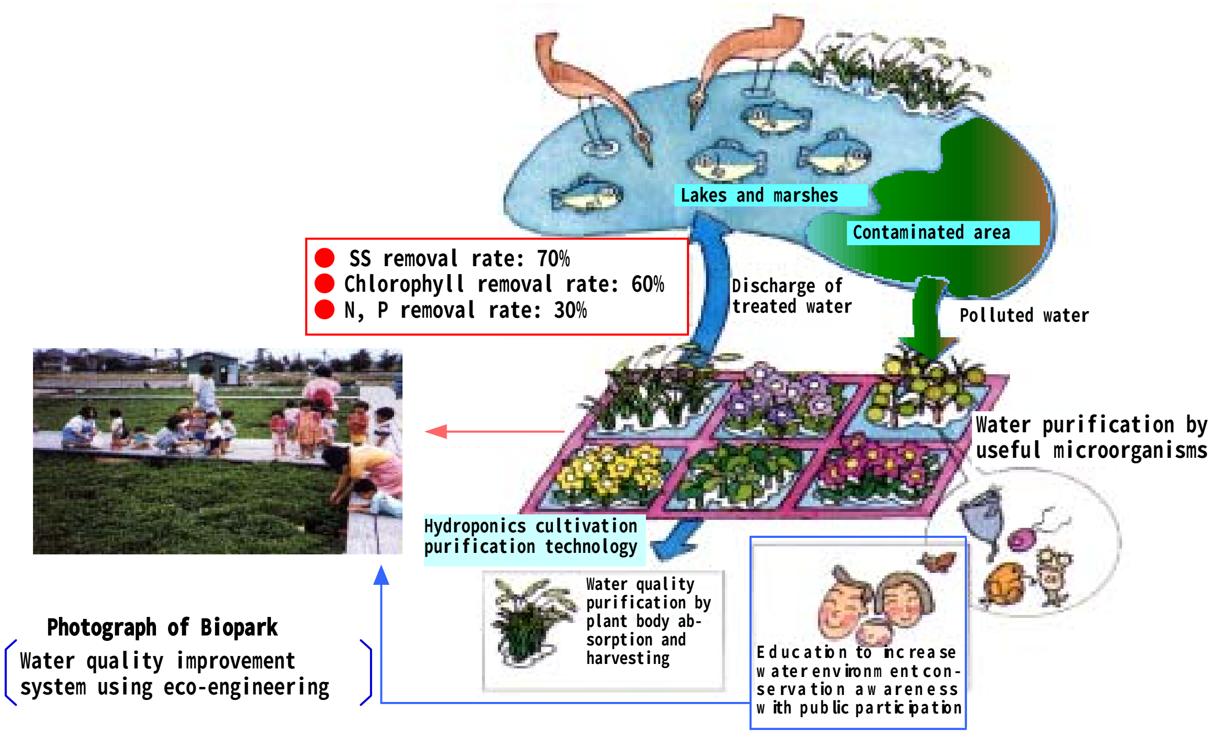


Fig. 6.2.1 Hydroponics cultivation purification system based on eco-engineering with public participation (Biopark)

(2) Ultrasonic Algae Removal System

The *Microcystis* algae of a blooming nature form a colony with numerous cells, which contain air bags, called gas vesicles. By expanding and contracting the vesicles, the alga can float and submerge at will. This system combines the physiochemical approach and the biological approach, where ultrasonic irradiation kills the *Microcystis* algae floating near the surface, which then undergoes sedimentation to a part of the lake bottom by generating a single-direction water current in order to decompose them using super-decomposing bacteria. Fig. 6-2-2 presents the flow of the prototype unit. This system proved itself to be highly applicable as an algae eliminator for small to medium lakes with some algae bloom and the water areas extensively infested by the cyanobacteria. In addition to this method, the project has been undertaking a commercialization study of the lake density current dispersion method, which blocks the nutrient supply to the *Microcystis* algae from the sludge by making the bottom layer aerobic, and facilitates the aerobic decomposition of the suspended matters in the water. This method also incorporates an ultrasonic generator. The system aims at disabling the *Microcystis* algae, being equipped with a unit to suppress the algae reproduction by destroying their gas vesicles

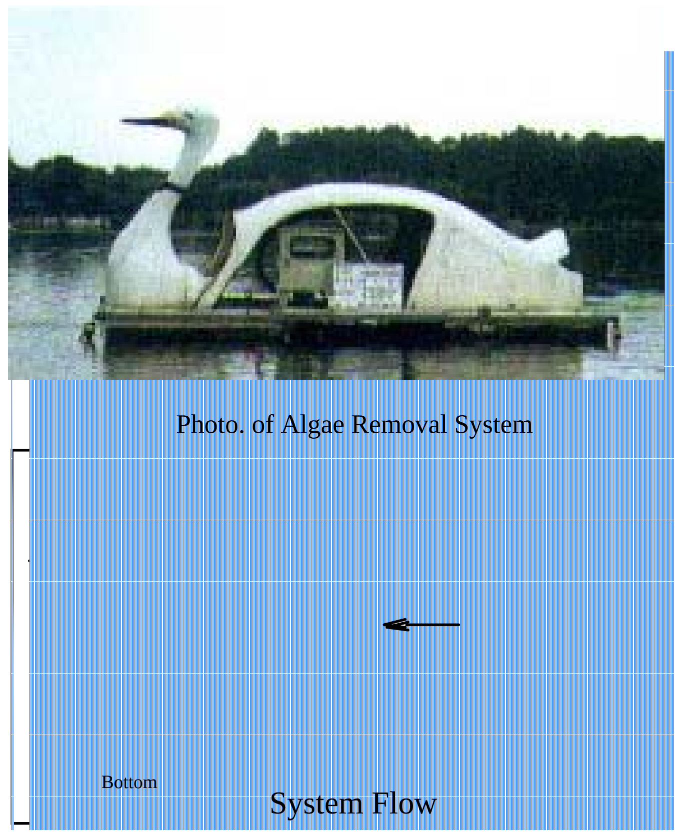


Fig. 6-2-2 Algae Removal System using Ultrasonic Waves

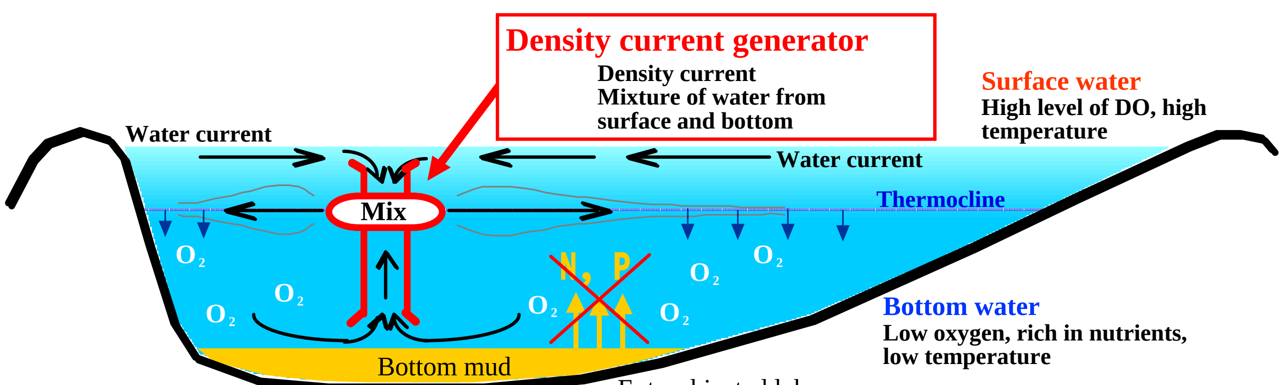


Fig. 6-2-3 Lake water density current dispersion technology

with slight ultrasonic irradiation and forcing them to settle on the lake bottom in a low photosynthetic environment. Verification tests of its performances are also under way (shown in Fig. 6-2-3).

(3) High-Rate Superconductive Flocculating Filtration System

This system eliminates magnetic particles in the fluid by separating them by the magnetic force. It has traditionally been used to remove iron oxides from the effluent from steelworks and from the circulating water from thermoelectric power stations. Application of this method to solid-liquid separation at algae-infested lakes requires magnetization of the non-magnetic suspended particles (algae). The solid-liquid separation mechanism of this system is that first magnetic powder and flocculant are added to the lake water to form a magnetic flock made of the magnetic powder and the algae. Then, this flock passes through water in a magnetic separation section to be caught by the magnetic filter in a magnetic field generated by twin electromagnets. Based on this mechanism, we produced a prototype (the bore diameter of the superconductive electromagnet at the room temperature: 310 mm, the magnetic field between the twin electromagnets: approximately 1 sr) to effectively recover and eliminate the algae, and conducted verification tests on its performance. The system treated 400 m^3/day, and the treated water showed high removal rates of 86 % of COD, 71 % of T-N, 93 % of T-P, and 95 % of algae. Being open to miniaturization, this system has reached the commercial stage as a decontamination unit installed on a small boat. It can also be applied to the high-rate removal of algae at dams and reservoirs.

(4) Filamentous Blue-Green Algae Elimination System Using Beneficial Animalcules

For the past few years, the filamentous blue-green algae as *Oscillatoria* and *Phormidium* genera came to manifestly dominate Lake Kasumigaura from autumn through to spring when the water temperature drops. With the increasing biomass of these algae, the COD level rose and transparency decreased in the lake even during the low water temperature seasons. The *Oscillatoria* algae, in particular, produce a substance to significantly abate flocculation, which causes disablement of the solid-liquid separation of the water treatment process. Against this background, the project pursues the development of a lake water purification system using the beneficial

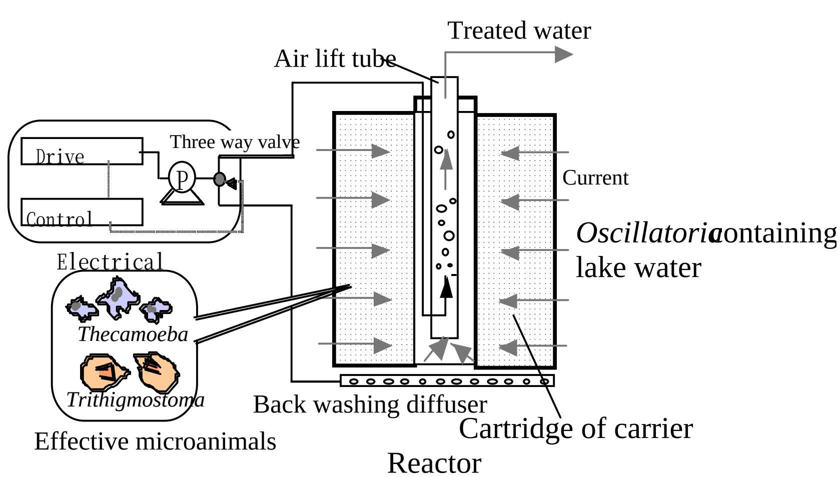


Fig. 6-2-4 Constitution of the Predatory Microanimals Inhabiting in Bio-film

animalcules that eat and decompose the filamentous blue-green algae. *Trisigmostoma* and *Thecamoeba* genera were explored so far, where they were isolated for cultivation tests to elucidate their reproduction and feeding properties and the density boosting method. Furthermore, we strive toward prototyping a biological filter fixable with these beneficial animalcules, and conducting field demonstration tests, using a prototype, on its direct purification capacity in Lake Kasumigaura. The flow of purification under this system is described in Fig. 6-2-4. The current study is under way according to plan to 1) comprehensively analyze its performances on aspects of the elimination rates of the filamentous cyanobacteria and COD, the treatment volume, the population behavior of the animalcules, and the dynamic energy consumption rate of the unit, and 2) formulating proper design and maintenance guidelines for its commercialization by determining any problems and their remedies. In order to apply this direct purification system to the actual water area, we designed a mobile unit, whereby floats support a charcoal-filled cartridge densely fixed with the beneficial animalcules (presented in Fig. 6-2-5). The unit can easily be transferred to the target water area by a small boat, and the power necessary for operation is supplied by a combination of solar batteries and a capacitor circuit. Due to its low-cost, low-energy features, the system is expected to be highly suitable for developing countries, and in fact, there is a plan for its introduction into China through the Sino-Japanese research collaboration "Water Environment Remediation Project at Lake Taihu".

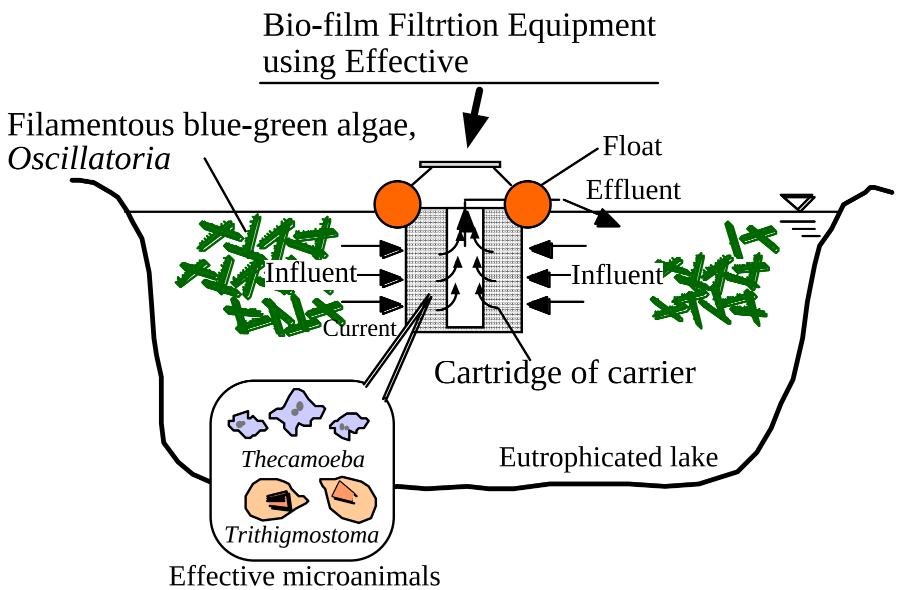


Fig. 6-2-5 Direct Purification of Eutrophicated Lake by Predatory Microanimals Inhabiting in Bio-film Filtrtion System

(5) Resource Exploitation System from Dredged Sludge

The Kasumigaura Project devised a use of the otherwise-wasted sludge eliminated from the lake bottom (*dredged*) as materials for purifying contaminated lakes and rivers, and started an applied study on manufacturing ceramics made from the dredged sludge. Specifically, we pursued development of a manufacturing technology for porous ceramics highly capable of bonding organisms in order to use the sludge from polluted lakes as microorganism carriers for direct lake purification and for effluent treatment. As a result, this technical development study successfully established the manufacturing processes of the sludge-made ceramics, as shown in Fig. 6-2-6. The sludge dredged from Lake Kasumigaura is first dried by a fan dryer (at 120 ºC for 24 hours), and then roughly ground by a jaw crusher. A Fret mill pulverizes the ground substance into 1.0 mm size, which is then burned by a rotary kiln (at 1,150 ºC for 15-20 minutes). This process allows us to manufacture a low-specific-gravity (1.2-1.4), porous sludge-made ceramics appropriate as the filling carrier in the bio-filtration process. As mentioned in Section 6.1 Part 1), this porous sludge-made ceramics underwent field tests of its decontamination performance in a high-performance, combined-type, on-site sewerage system, which demonstrated sufficient capacities. Based on the results from these basic studies, we will study its manufacturing cost reduction methods to establish a mass-production process, as well as to undertake field tests to determine the direct purification capacity in polluted lakes and its applicability to other water purification technologies.

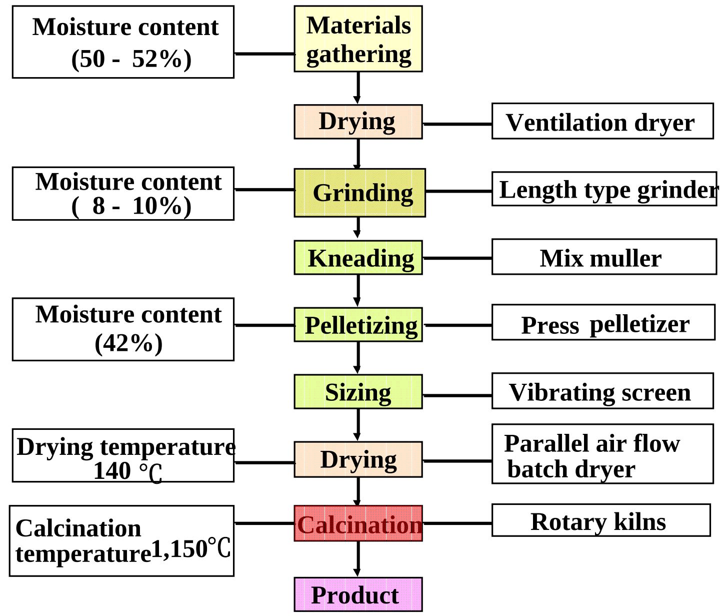


Fig. 6-2-6 Sludge Ceramic Processing Flow

6-3 Comprehensive Analysis and Assessment of the Water Quality Renovation Effect

Unerring management of the Kasumigaura catchment area needs constant monitoring of the water quality fluctuation of the lake and its catchment area. For this, the elemental technologies developed under this project must find their most suitable application where they can exert their maximum effect to control the pollutant sources and the lake itself with minimum cost. Determining such applications will essentially require a remedy prediction method after the system's introduction, and a comprehensive analysis and assessment, based on the follow-up method, of the on-site water decontamination effect. For the analysis and assessment of the water quality renovation effect, the Project has pursued the development of a catchment management monitoring system, and of an evaluation method for the catchment management on the cost/investment and energy input to improve the water quality.

(1) Development of the Water Quality Analysis Method for Catchment Management

As for proper catchment management and the elucidation of the relation between the lake-water quality change and the algae occurrence, the prediction of algae bloom from the water quality change, if these became possible, would allow the prompt implementation of catchment control measures. On this account, we have employed neural network analysis (shown in Fig.6-2-7) for comprehensive analysis of the water quality data of Lake Kasumigaura for the past 24 years. The result of this analysis has so far revealed that phosphorus has greater correlation with both the particular algae bloom as an environmental factor and the eutrophication as an effect than nitrogen does, and that the algae diversity index drops when *Microcystis* algae dominate the lake. Through further analysis of these water quality properties, the project aims to develop an analytic method to realize algae bloom prediction.

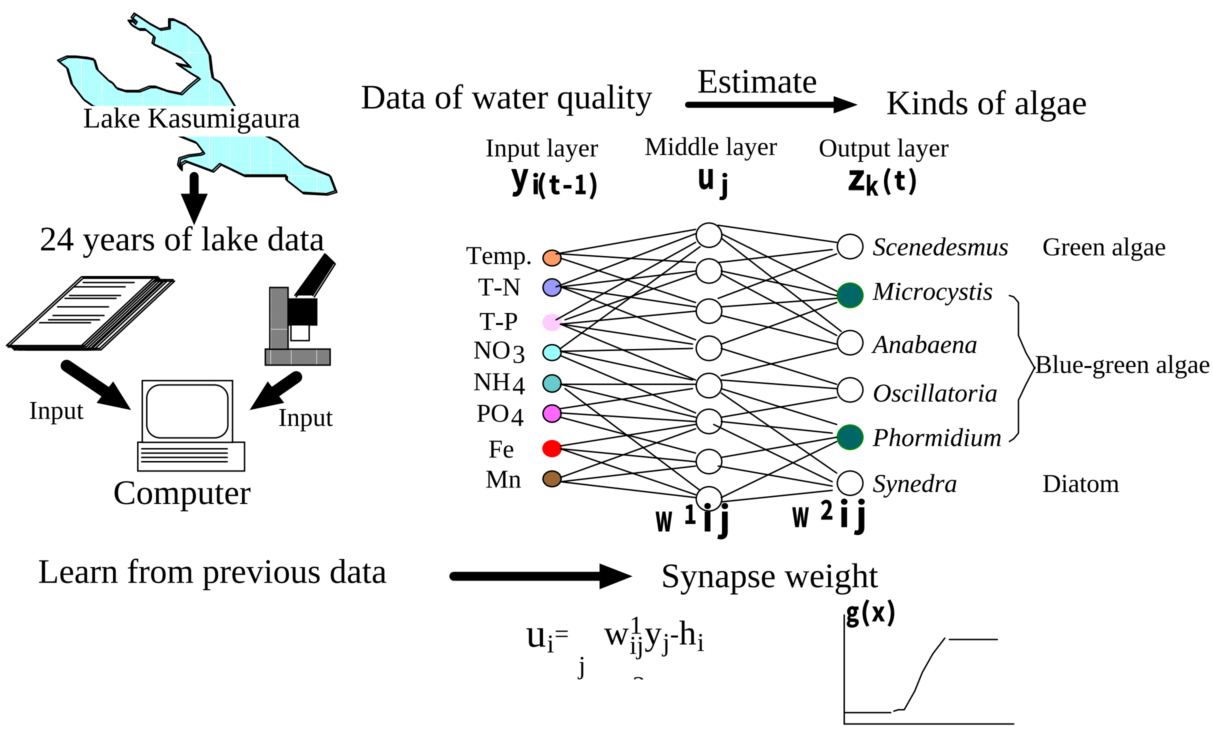


Fig. 6-2-7 Neural Network Water Quality Evaluation

(2) Development of the Catchment Management Monitoring System

Water quality analysis needs speedy obtainment of a large number of data. Conventional water quality analysis required a specific analytic method for each parameter, which imposed a phenomenal amount of time and labor of data obtainment. Under this circumstance, the Kasumigaura Project has pursued the development of an analytic method for lake water quality using near infrared light extinction (NIR method), shown in Fig. 6-2-8. In this method, the samples are irradiated with the near infrared to obtain the absorption data of the target parameters, which undergo such statistical analysis methods as multiple regression analysis and principal component analysis to extract the necessary information. Every substance has its own absorption wavelength in this region. For this reason, analysis of the absorption peaks and the waveforms with various methods is very likely to offer the biomass of a particular matter even in a solution containing a mixture of various substances. This method was found to allow the swift analysis of water with numerous parameters, including nitrogen, phosphorus, and COD. In addition, it is becoming clear that this method allows the analysis of the humic acid suspected to influence algae reproduction and the glycolic acid produced by algae, which may pave the way to count the biomass of the *Microcystis* algae. Based on the results of these foundational studies, the Project is to undertake field tests of an on-site monitoring device equipped with this method.

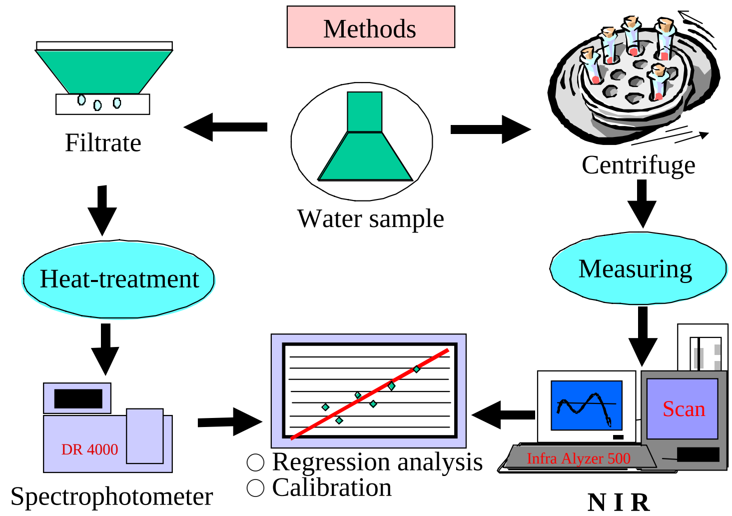


Fig. 6-2-8 Flow of NIR (Near infrared) analysis

(3) Development of a Cost Effectiveness Assessment Method for Catchment Management

This project aims at establishing a scheme to effectively implement and disseminate the pollutant source control technologies and intra-lake purification techniques developed by the project, and suggesting and instituting a lake/catchment management system through simulating catchment management techniques for the most effective purification with the minimum cost and energy requirements. For these objectives, the project pursues the development of adjusting techniques and the establishment of comprehensive analysis and assessment techniques. The abovementioned concept of this project has been introduced in Fig. 6-2-9.

6-4 Future Challenges and Perspectives

In conformity with the objectives set under the Collaboration of Regional Entities for the Advancement of Technological Excellence (CREATE) program, the Project for Water Environment Renovation of Lake Kasumigaura pursues the feasible development of the elemental technologies and effective area-wide application methods of these feasible technologies to maximize their effect on water quality renovation in Lake Kasumigaura, with a view to decontaminating the lake and fostering the formation of venture industries. As for the elemental technologies with a potential for generalization, Phase I of the project saw efforts to establish commercialization of the system with special attention to low-cost, maintenance-free, and recycling features. In order to present the achievements of the

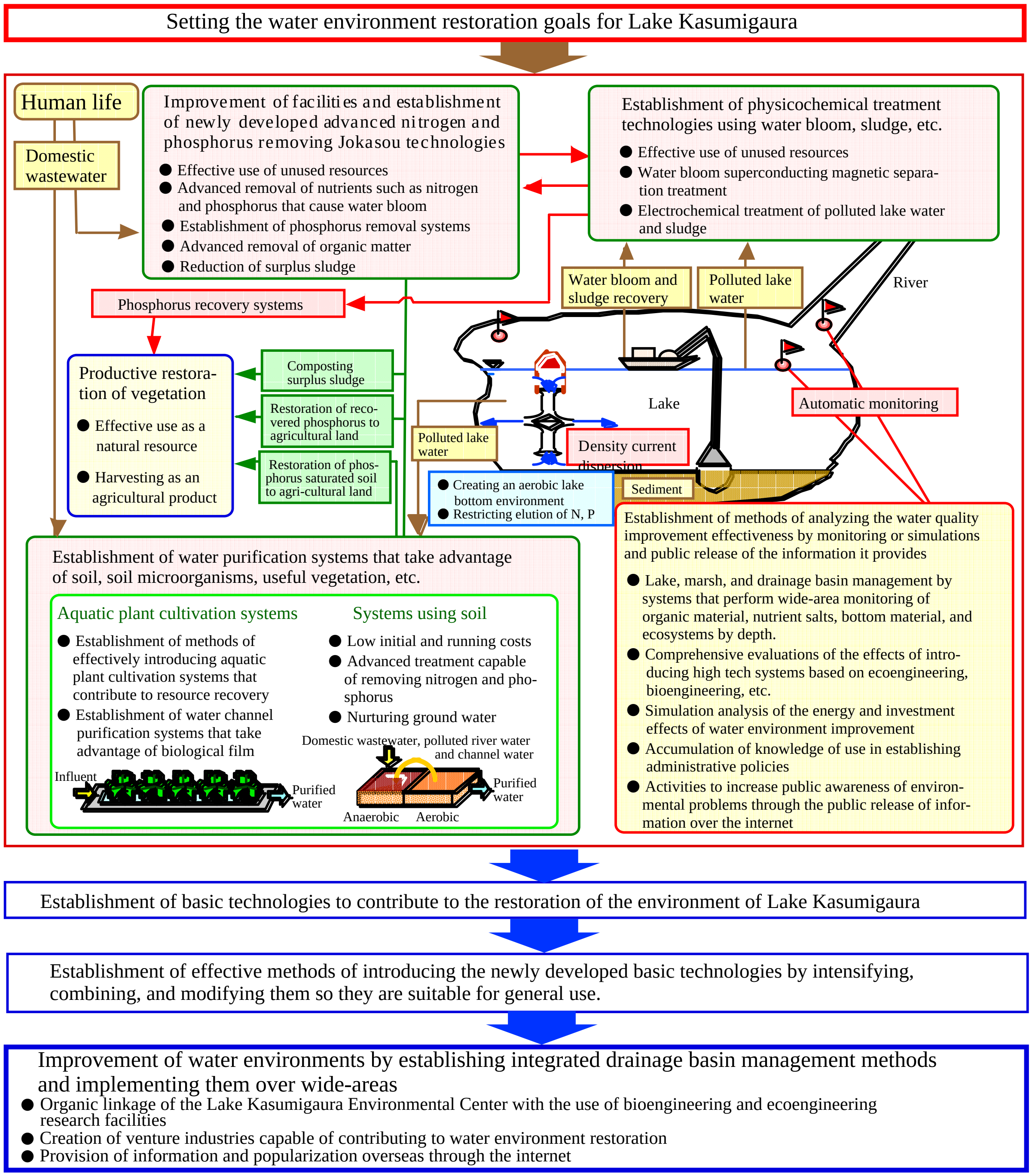


Fig. 6-2-9 Lake Kasumigaura Water Purification Technology Developments : Effective Approaches and Future Prospects

project in a more visible way, we must concentrate our efforts in Phase II on reinforcing the development of techniques for the appropriate combination of the elemental techniques to permit technical improvement and sophistication during the field tests. In addition, Ibaraki Prefecture will need to institute an evaluation and certification system for these developed technologies to contribute to fostering venture industries. It is also necessary for the project to prepare for Phase III by instituting a system and organizational mechanism for the Lake Kasumigaura Environmental Center, which is scheduled for construction in Ibaraki Prefecture, and the Bio-Eco-engineering Research Center scheduled for development at the National Institute for Environmental Studies to contribute to the establishment, actual dissemination and sophistication of the systems technology at these facilities. Through these activities and efforts, it is greatly hoped that the achievements of the project visible to the community members will ripple through domestically and internationally to exert their effects on water environment renovation.

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7. Transfer of Japanese Technology and Assessment of its Applicability

Japanese state-of-the-art eutrophication technologies, such as those for control and monitoring, have been transferred to developing countries, with emphasis on the efficiency of technological transfer by focusing on energy conservation, cost saving, and low maintenance. This chapter will discuss some case studies of technology transfer, as well as the applicability of these technologies, including water purifiers and monitoring equipment, in the recipient countries.

7-1 Lake Hongfeng Hu and Lake Bai Huau Restoration Project in China (Ministry of Environment)

7-1-1 Objective of the Project

In many developing countries, water pollution in lakes is progressing faster as social and industrial activities are being stepped up. China, in particular, suffers from manifest proliferation of toxic algae in many hypertrophic lakes, which threatens the security of water resources to the extent that toxigenic cyanobacteria control is urgently required. Although an efficient control technology focusing on nitrogen and phosphorus needs to be introduced to abate eutrophication, very little has been done concerning the fact-finding survey of noxious algae bloom and development of its control technique. Under these circumstances, the Ministry of Environment of Japan allocated one of its FY2000 projects to the feasibility study concerning the applicability of national engineering for decentralized control of water pollution in Lake Hongfeng Hu and Lake Bai Huau in Xizhou Province of Western China, as model lakes, in order to determine the applicability of the water pollution control devices of Japanese technology considered suitable for Western China by actually putting them to use on site. Although initially a single-year project, the study proved itself important enough to be followed up in FY2001, which still continues at present. This research project pays attention to the newly emerged, urgent challenge to the global water environment, the cyanobacteria producing microcystin, which is more poisonous than potassium cyanide and is now regulated in the WHO Guidelines for Drinking Water Quality. The microcystin biomass in the eutrophic lakes in the Province was surveyed, and concurrently, the research project strived to upgrade the treatment of the toxin by making use of bioengineering-based water-treatment engineering and the eco-engineering.

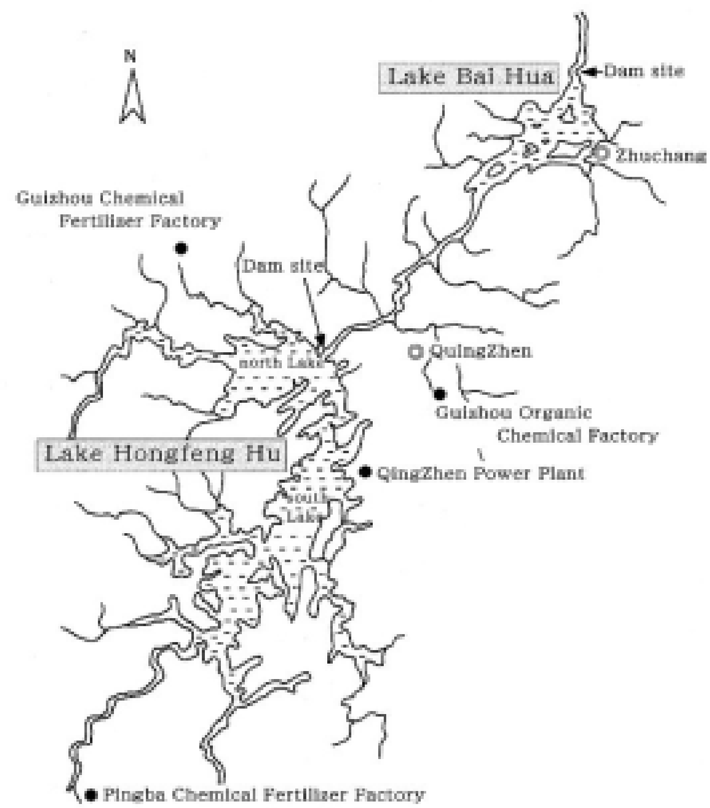

Fig.7-1-1 Topography of Lake Hongfeng Hu and Lake Bai Hua

7-1-2 Outline of the Project

This research project is an international collaboration participated in by the Ministry of Environment and the National Institute for Environmental Studies from Japan, and the Chinese Research Academy of Environmental Sciences, Guizhou Research and Designing Institute of Environmental Science, and Shanghai JiaoTong University from China. The water purification devices of Japanese technology introduced through this project were two medium-sized private sewerage systems, two small-sized private sewerage systems, one soil trench system, and one aeration pumping tube, all regarded to be suitable to the locality of Western China. Described in China as "no three days of fine weather in the sky, no three miles of plain on the earth, or no three grams of silver for the people", Guizhou Province has many rainy and cloudy days, and a rough terrain. The following section will outline the characteristics and the catchment effluent control measures of Lake Hongfeng Hu and Lake Bai Huau (Fig. 7-1-1), located at N 26º and E 106º and 1,000 m above sea level.

Photo 7-1-1 Lake Hongfeng

(1) Lake Hongfeng Hu

Lake Hongfeng Hu (see Fig. 7-1-1) is a dam completed in 1960, with a catchment area of 1,610 km^2, a lake surface area of 57.2 km^2, a gross capacity of 601×10^6 m^3, a mean capacity of 300×10^6 m^3, a maximum depth of approximately 45 m, and a mean depth 10.5 m. The lake is divided into two, the North Lake and South Lake. It embraces various industries such as tourism, boat transportation, and fish cultivation, although the latter will be phased out for anti-eutrophication purpose. The lake serves as an important water source for the provincial capital Guiyang (population of 2.6 million), supplying 40,000 m^3/day to the city. The sewerage development in the catchment area is significantly underdeveloped: a roughing tank is installed at each house for digestion and sedimentation, and the supernatant is discharged into the nearby streams via open channels and sewer culverts. Excreta from public and domestic toilets are used as a fertilizer in farmland. Although the wastewater from tourist facilities is partially treated by the roughing tanks, they can merely remove 20 % of BOD, 15 % of COD, and 50 % of SS. Moreover, due to poor maintenance, the tank's performance is reduced so much to probably be capable of SS elimination only. As for the pollutant sources in the catchment, industrial effluent, domestic wastewater, and cultivation in the lake are among the point sources, whereas paddy fields, farmlands, and forests are among the non-point sources. The past studies revealed that electric, chemical, and other factories around Lake Hongfeng Hu are the major polluters of the lake through their effluent, which tends to be high in nitrogen. A typical factory around the lake forms almost like a town as it is, with its population reaching 10,000 including the family members of the employees. The domestic wastewater drained from there, however, is hardly treated, and effluent control is still at the discussion stage initiated by the administration. In regard to any upcoming plans of enhancing tourist facilities, sightseeing, vacation and health establishments which are scheduled for building, these must equip themselves with their own effluent treatment facilities. All in all, with the current state of eutrophication control in the Lake Hongfeng Hu catchment area, the administration has finally set out to address domestic effluent.

(2) Lake Bai Huau

Completed in 1966, Lake Bai Huau is a dam downstream from Lake Hongfeng Hu, with a catchment area of 319 km^2, a lake surface area of 14.5 km^2, a gross capacity of 182×10^6 m^3, a mean capacity of 110×10^6 m^3, a maximum depth of approximately 45 m, and a mean depth 10.8 m. It embraces various industries such as tourism, boat transportation, and fish cultivation, and also serves as an important water source for Guiyang City, supplying 25,000 m^3/day to the city. Past studies revealed that various industrial effluents and domestic wastewater from around the lake are the chief polluters, which tend to be high in COD load. Wastewater in the catchment is hardly treated, and such domestic wastewater is discharged into the lake via streams and drainage canals (see Photo 7-1-2). The pollution load per capita as of 2000 is 100-150 *l*/day, whereas the 2005 figure is expected to increase to 200 *l*/day, which is the basis for designing the standards. Fish culture in the lake has been basically banned since 1998 as part of the eutrophication control measures. There are, however, more than a few fishers who still make a living from the fishery, and for them fish breading in some areas is still allowed under certain conditions within the set compensatory period. In this sense, the fish-breeding ban has not covered the entire lake yet. The government legislated for phasing out phosphate-containing detergents to abate the phosphorus load to the lake, although phosphate-free detergents are presently too expensive to be in common use. Such a situation holds true for not only the Lake Bai Huau basin, but also the entire Guizhou Province.

Photo 7-1-2 Lake Bai Hua where domestic wastewater directly

As described above, the typical administrative measures in the Lake Hongfeng Hu and Lake Bai Huau basin are domestic drain control, industrial effluent regulation, development of a sewage disposal facility, and a total ban on the fish cultivation. In introducing Japanese engineering in these circumstances, the focus needed to be on the domestic wastewater control, which confronted the Province as a critical issue. For this reason, it was decided to apply water purification devices that work to abate the toxigenic-algae-boosting nitrogen and phosphorus, namely, an advanced private sewage treatment tank, at the level of bioengineering, and a soil trench, at the level of eco-engineering. At the same time, an aeration pump was to be introduced to arrest the proliferation of the already-existing algae in the lake. Device selection criteria entailed cost saving, energy conservation, and easy maintenance, but the priority was on suitableness for the conditions in Guizhou. This research project pursued the applicability of these selected devices to

Western China, and in addition, it extended to the checkup of continuous and constant treatment performance in its follow-up survey.

7-1-3 Achievement of the Project

(1) Toxigenic Algae Biomass

In Lake Hongfeng Hu, Lake Bai Huau, and XiaoGuan Reservoir, all of which supply service water to Guiyang City, algae biomass and the toxic microcystin biomass were monitored in October 2000. The observation method was as follows: first, the algae were collected and concentrated using a quantitative plankton net NXX25 for the purpose of sampling the toxigenic cyanobacteria; second, the noxious algae were identified by optical microscope; and finally the microcystin biomass was determined by high performance liquid chromatography (HPLC). XiaoGuan Reservoir registered the largest algae propagation (19,350 individuals/*l*), followed by Chafan downstream from Lake Bai Huau (4,280 individuals/*l*), Jiangjundong in the center of South Lake of Lake Hongfeng Hu (3,940 individuals/*l*), and the dam site of Lake Hongfeng Hu (320 individuals/*l*), in descending order. Breakdown of the algae according to species indicated that the *Microcystis* genus of the Cyanophyceae group dominated the XiaoGuan Reservoir, whereas the *Fragilaria* genus of the Bacillariophtceae group, and the *Pediastrum* genus of Chlorophyceae group and the *Microcystis* genus of the Cyanophyceae group were the dominant species in Lake Bai Huau and Lake Hongfeng Hu, respectively. Subsequent identification of the algae found that the toxic types blooming in the Lake Bai Huau and Lake Hongfeng Hu catchment were *Microcystis aeruginosa* and *Microcystis viridis*. It was also revealed that the XiaoGuan Reservoir registered 18,100 *Microcystis* colonies per liter, a larger standing crop than in any other water area surveyed in the study.

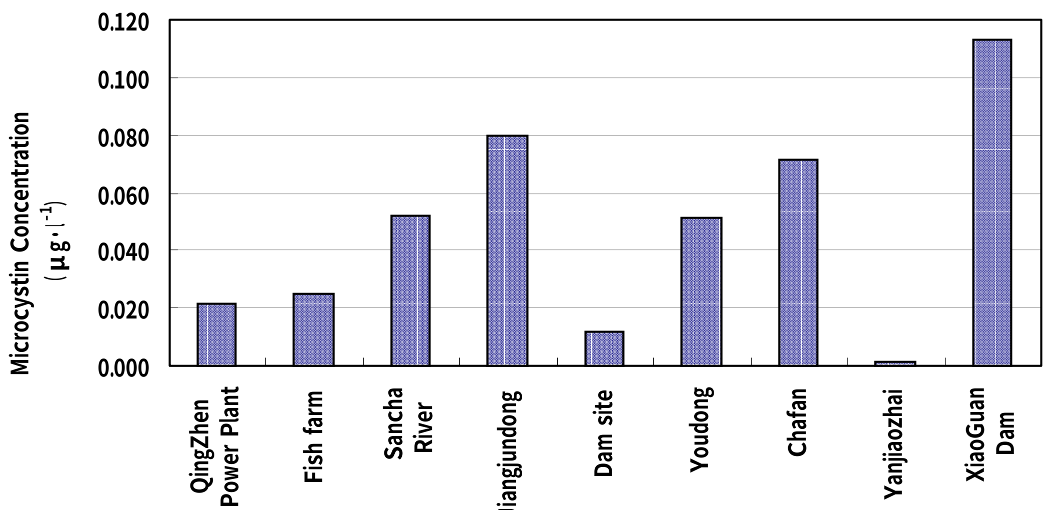

Fig.7-1-2 Concentration of Microcystin in Lake Hongfeng Hu, Lake Bai Hua, and at the XiaoGuan Dam

Fig. 7-1-2 shows the analysis of the toxic substance microcystin, which indicates that the largest microcystin biomass of 0.11338 μg/*l* was found in XiaoGuan Reservoir, followed by 0.07988 μg/*l* of Jiangjundong in Lake Hongfeng Hu and 0.07148 μg/*l* of Chafan near the intake gate of Lake Bai Huau. From a study of the correlation of the Microcystis biomass and the microcystin concentration based on these results, we concluded the correlation coefficient as 0.767 and the linear expression as y = 0.000043x + 0.021973. From these results, the microcystin content per Microcystis colony (500-1,000 cells per colony) was derived as 0.000043 μg, which led to the estimate that as many as 23,000 colonies of Microcystis would be required to exceed the guideline value of 1 μg for microcystin set under the WHO Guidelines for Drinking Water Quality. The number of samples in this survey session, however, was too small to ensure reliability, which means that the data needs further accumulating to strengthen its credibility in the future. Besides, since the session this time was carried out during the low season of toxic algae bloom, another observation will have to be conducted in the high biomass season. At any rate, the fruits of this survey session have extreme value as the first detection of microcystin of toxigenic algae origin in Guizhou Province, offering significant information concerning the future direction of the water resource conservation of the lake. In parallel with the microcystin survey, other harmful algae than Microcystis were also investigated, since Lake Hongfeng Hu, Lake Bai Huau, and XiaoGuan Reservoir all supply the city water. The study found the emergence of musty-odor-producing *Phormidium tenue* in the fish-breeding areas in Lake Hongfeng Hu and XiaoGuan Reservoir, which indicates possible odor and taste impairment of the drinking water. The above findings revealed the propagation of such harmful algae as Microcystis genus and *Phormidium tenue* in Lake Hongfeng Hu, Lake Bai Huau, and XiaoGuan Reservoir, which pointed to the urgent need for eutrophication control in order to conserve the environmental health of the waters.

(2) Advanced Private Sewage Treatment Tank

Advanced private sewerage tanks using bioengineering technology were installed at the Guizhou Chemical Fertilizer Factory and Guizhou Research and Designing Institute of Environmental Science to study the applicability of the devices which employ Japanese technology. Both were equipped with two medium-sized private sewerage systems and two compact private sewerage systems, respectively, for pursuing comparative study of the removability of organic matters, nitrogen, and phosphorus.

1) Guizhou Chemical Fertilizer Factory

Located in the northern catchment area of Lake Hongfeng Hu, the Guizhou Chemical Fertilizer Factory (shown in Photo 7-1-3) is a large factory with 3,000 employees (7,000 including their family members) that produces 120,000 tons of principally urea fertilizers per year. The factory drains 55×10^3 t daily, where its effluent fails to meet the nitrogen (NH_3-N) and SS values of the first-degree national standard due to the existing effluent treatment facility lacking in capacity/performance and operation/maintenance. Recently, a clean production facility construction project at the

Photo 7-1-3 Medium-sized private sewrage system

Guizhou Chemical Fertilizer Factory was launched by the State government to examine the anti-pollution provisions at the factory. Meanwhile, the domestic wastewater drained from the employee accommodation facilities are released via a roughing tank within the factory, although it is mostly untreated and without any particular control measures under discussion. Against this background, the household effluent from the chemical fertilizer factory was chosen as the subject of an applicability test for Japanese engineered technology. As for the medium-sized private sewerage systems for the factory, a batch-type denitrification/dephosphorization system (batch-type activated sludge method) and an intermittent-aeration-type denitrification/dephosphorization system (continuous activated sludge method) were employed, whose treatment flowcharts are shown in Fig. 7-1-3. The operation flowchart of each approach is detailed below, and the operation commenced in March 2001.

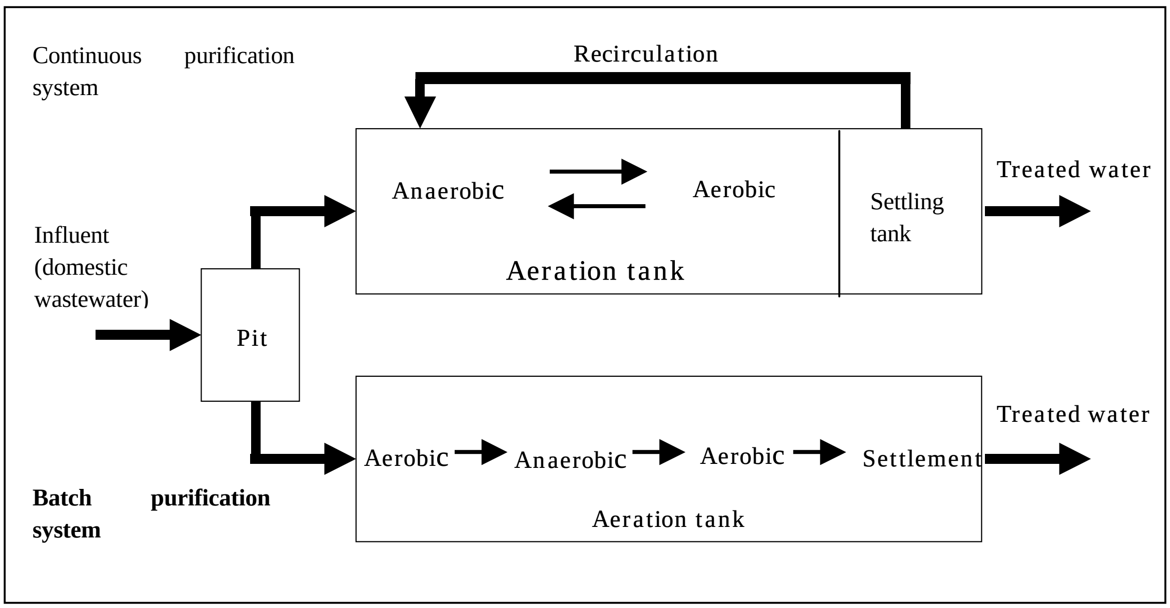

Figure 7-1-3 Medium Size Domestic Wastewater Treatment Systems at the Guizhou Chemical Fertilizer Plant

Operation Flowchart of the Batch-Type Denitrification/Dephosphorization System (6 hrs. per running cycle)

Inflow Process→	Aerobic Process→	Anaerobic Process→	Aerobic Process→	Sedimentation Process→	Drain Process
60 min.	90 min.	60 min.	30 min.	60min.	60 min.

Operation Flowchart of the intermittent-aeration-type Denitrification/Dephosphorization System (3 hrs. per running cycle)

Inflow Process→	Aerobic Process→	Anaerobic Process→	Sedimentation Process→	Drain Process
Constant	120 min.	60 min.	Constant	Constant

The volume of daily treatment of each system is 20 m^3. Both systems receive voltage stabilization provision through a control completely independent of the distribution panel, the control panel, and other components. While the flocculant-dosing tank and the pH controlling tank are fully automated, the electric system employs a relay combination. Ferric chloride was used as the flocculant, with its concentration set at 30 ppm on the assumption of an influent T-P level of 4 ppm. The pH sensor was adjusted so that it would feed sodium hydroxide under 6.5 to neutralize the water up to 7.0. In order to prevent excessive aeration, the aeration operation was programmed to stop at the DO level above 4. In the intermittent aeration approach, the sludge (circulation) rate was set as 200 %.

The water quality figures for the influent raw sewage between March and September 2001 were T-N 15-40 mg/*l*, T-P 2-4 mg/*l*, BOD 30-70 mg/*l*, and COD_{Cr} 90-140 mg/*l*. During this period, the batch-type system treated the water to reach T-N 9-25 mg/*l*, T-P 0.7-2.1 mg/*l*, BOD 1-10 mg/*l*, and COD_{Cr} 18-60 mg/*l*. At the same time, the intermittent aeration type attained the treatment levels of T-N 6-17 mg/*l*, T-P 0.5-1.7 mg/*l*, BOD 0.4-6 mg/*l*, and COD_{Cr} 18-60 mg/*l*. Based on these monitoring data, the treatment performances (average removal rates) for T-N, T-P, and other substances of each system are summarized in Fig. 7-1-4. It revealed that both systems delivered satisfactory performances in BOD and COD elimination, whereas T-N was only removed at the rate of 59 % by the intermittent aeration type and 45 % by the batch type. T-P removability was unsatisfactory with both the intermittent aeration type and the batch type, registering a mere 47 % and 17 %, respectively. The low removability of nitrogen and phosphorus largely results from poor operation and maintenance: specifically, inadequate DO control is presumably responsible for the nitrogen problem, and the phosphorus problem is possibly ascribable to flocculant feeding failure due to a clogged dosing pump or some other blockage. As seen above, the medium-sized private sewerage systems installed at the Guizhou Chemical Fertilizer Factory could exert an adequate effect in eliminating organic matters, although further simplification of operation and maintenance must be pursued for a better result with nitrogen and phosphorus treatment.

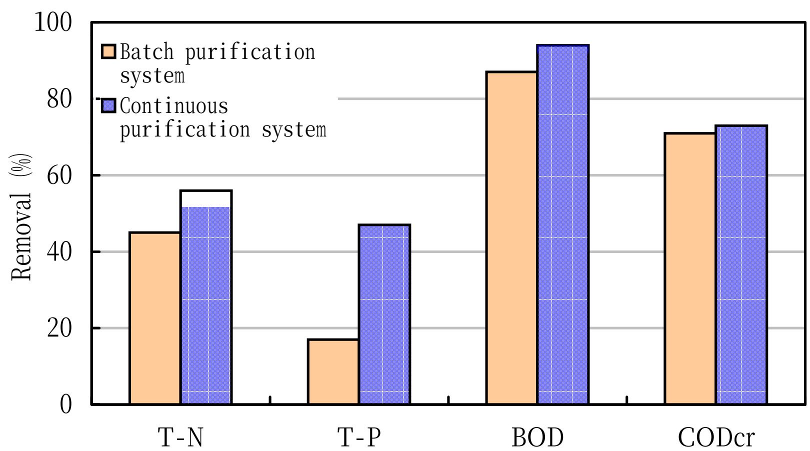

Fig.7-1-4 Comparison of treatment capacity on Medium Size Domestic Wastewater Treatment Systems

2) Guizhou Research and Designing Institute of Environmental Science

Compact private sewerage systems (see Photo 7-1-4), employing the cycle method of aerobe/anaerobe treatment(see Fig.7-1-5), were installed at the Guizhou Research and Designing Institute of Environmental Science to purify the wastewater discharged from its apartment housings. The volume of daily treatment was 2 m^3, and the return (circulation) rate was set at 200 %. The system was originally meant to be operated under the control of a timer according to the daily life cycle, yet, as of September 2001, a responsible employee manually actuated the system with an on-off switch. The sewerage systems were programmed to run for a total eight hours a day, four hours between

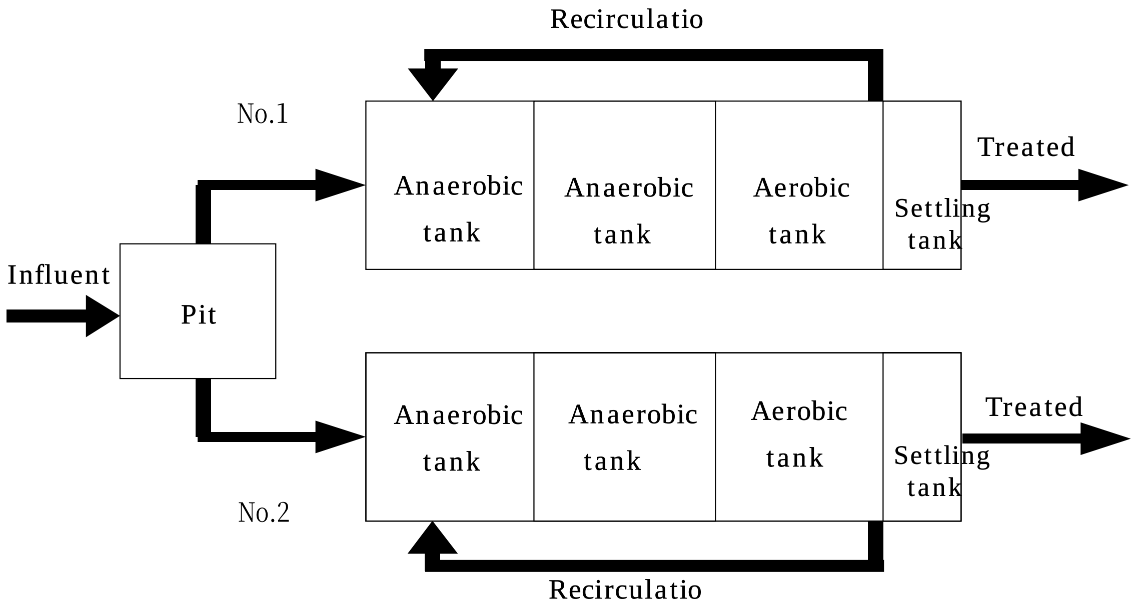

Fig.7-1-5 Minimum Size Domestic Wastewater Treatment Systems at the Guizhou Research and Designing Institute of Environmental Science

Photo 7-1-4 Landscape of researching compact private

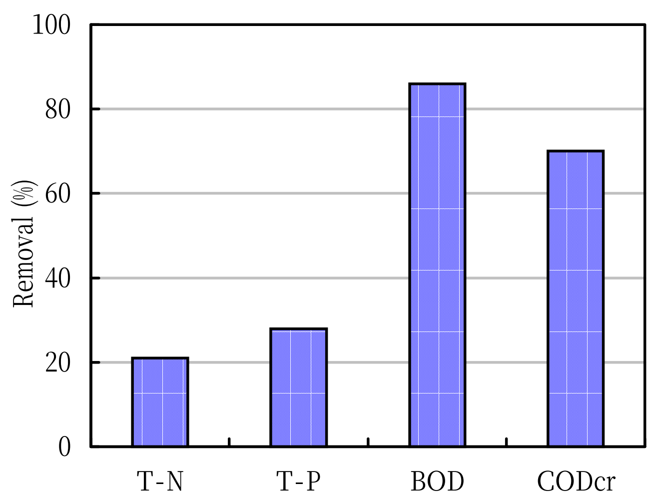

Fig.7-1-6 Treatment capacity on Minimum Size Domestic Wastewater Treatment Systems

8:00 and 12:00 and another four hours between 14:00 and 18:00. At present, two systems are in action under the same conditions. In the future, a comparative study is to be pursued by changing the conditions, including the load volume, to determine the optimal operating condition.

The water quality figures of the influent raw sewage between March and September 2001 were T-N 80-100 mg/*l*, T-P 8-11 mg/*l*, BOD 50-120 mg/*l*, and COD_{Cr} 100-250 mg/*l*. During this period, the sewage system (No. 1) attained the treatment level of T-N 42-100 mg/*l*, T-P 5-11 mg/*l*, BOD 3-15 mg/*l*, and COD_{Cr} 45-100 mg/*l*. The treatment figures at the system No. 2 reached roughly the same level. The treatment performances (average removal rates) of the system for T-N, T-P, and other substances are summarized in Fig. 7-1-6. It revealed that the sewerage system delivered satisfactory performance in BOD elimination, whereas T-N and T-P removability was rather poor. The low T-N elimination rate, in particular, was ascribable to a high concentration of ammonia nitrogen in the influent raw sewage (70-90 mg/*l*). This may have occurred from the imbalanced BOD/N ratio due to a decomposition/elimination of organic substances through pre-treating the apartment housings' wastewater at the septic tank before the raw sewage pit, when a proper BOD/N ratio was crucial to denitrification.

(3) Soil Trench

The Water Sports Training Center, situated on the shore of North Lake of Lake Hongfeng Hu, is a facility to train the Olympian-candidates for water sports, with about 80 people living on the site. A new building is currently under construction, and upon completion, the center will be able to accommodate approximately 300 people. As for effluent control, the wastewater is drained as it is, although development of a treatment facility is currently under review. Among the Japanese effluent control technologies, an eco-engineering-based soil trench (Photo 7-1-5), which is a purification method using soil with an anaerobic filter bed (Fig. 7-1-7), was selected for introduction at the center. This system employs a gravity flow method being free from an aeration device and a chemical feeder, which guarantees extremely easy maintenance. Crumbled topsoil, from corn fields, was brought in and laid out to boost the microbial activity. The volume of daily treatment was 3 m^3.

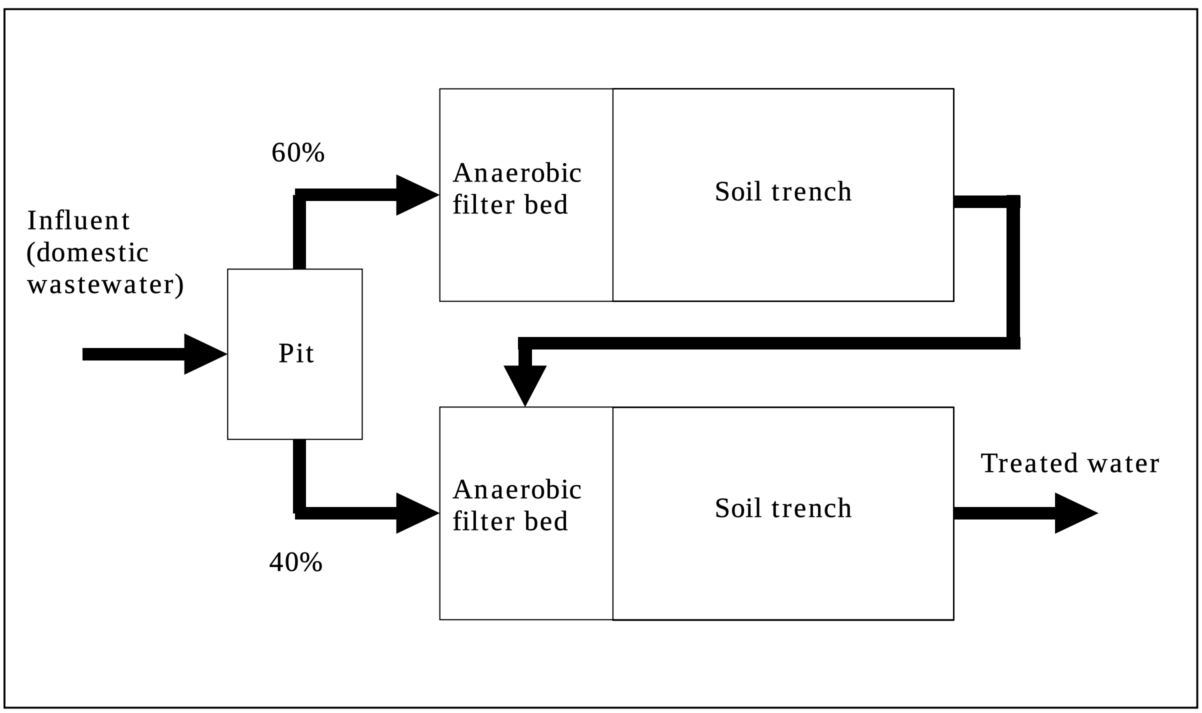

Figure 7-1-7 Soil Trench Treatment Process at the Water Sports Training Camp on Lake Hongfeng Hu

The water quality figures of the influent raw sewage between March and September 2001 were T-N 7-33 mg/*l*, T-P 0.7-2.2 mg/*l*, BOD 30-70 mg/*l*, and COD_{Cr} 55-90 mg/*l*. During this period, the soil trench attained a treatment level of T-N 1.8-7 mg/*l*, T-P 0.08-0.2 mg/*l*, BOD 1.5-10 mg/*l*, and COD_{Cr} 18-33 mg/*l*. The treatment performances (average removal rates) of the system for T-N, T-P, and other substances are summarized in Fig. 7-1-8. It reveled that the treatment system delivered exceptionally satisfactory performances with the elimination rates in all four parameters exceeding 70 %. In fact, this system turned out to record the highest performance in T-N and T-P removal. T-P elimination particularly showed excellent results, sometimes below 0.1 mg/*l* in the treated effluent. This soil trench system with an anaerobic filter bed has the advantages of easy maintenance, minimal construction cost, and low running costs, which proved the system to be an effective denitrification/dephosphorization instrument and a possibly successful measure for pollutant source control.

Photo 7-1-5 Soil trench

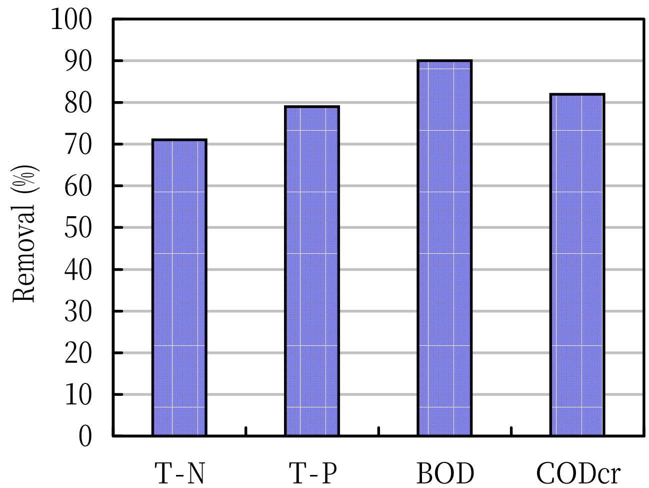

Fig.7-1-8 Treatment capacity of soil trench

(4) Aeration Pump

For the purpose of suppressing the propagation of harmful algae such as toxigenic cyanobacteria, an aeration pump tube was introduced among the Japanese anti-eutrophication technologies. The aeration pump was designed so that it generates a circulating current throughout all of the water area by causing water convection between the surface and bottom layers to transfer the photosynthetic algae from the reproduction-inducible photic zone to the nonreproducible aephobic zone. At the same time, the instrument is also capable of reducing elution of iron, manganese, phosphate and other materials by supplying oxygen to the deep layer, thus exerting its effect in controlling the manganese-origin black water and the phosphorus-derived eutrophication. With due consideration in choosing the installation location of this algae-bloom suppressor, it was found that the XiaoGuan Reservoir is the most suitable place for the aeration pump to deliver its maximum capacity. To be more specific, the reservoir was chosen because, 1) it is a source for the service water supply in Guiyang, 2) the black water which emerged in the city water can be controlled by abating manganese, and 3) the algae biomass survey in this research project found that the reservoir contains the largest standing crop of the algae and of the hazardous microcystin. XiaoGuan Reservoir is an artificial reservoir completed in 1959, with a catchment area of 16.3 km^2, a gross capacity of 2.26×10^6 m^3, and a maximum depth of approximately 14 m. It daily supplies 2,500 m^3 as service water. Fig. 7-1-9 shows the survey results of the stratification in the deepest area in March 2001 before installing the aeration pump. The observations showed that the thermocline was formed between the 1.5- and 2.0-meter area, revealing a lack of convection between the surface and bottom layers. The survey also found the alga biomasses of 2,200 individuals/m*l* at the surface layer, 600 individuals/m*l* at the middle layer (2.5-m deep), and 250 individuals/m*l* at the deepest layer (5.5 m), which revealed that the highest propagation of algae was at the surface. For information, the maximum depth in March registered 5.5 m, with the pondage at the lowest level. The aeration pumping was started in June 2001 when the water capacity at the dam reached a level sufficient for the operation. Fig. 7-1-10 presents the observations in September 2001, which revealed that the aeration pumping destroyed the thermocline and supplied oxygen to the deepest layer by generating water circulation. The 4-hour intermittent operation of aeration pumping managed to disrupt the thermocline yet failed to deliver oxygen to the deep layer. Extension of the running period to 12 hours successfully provided oxygen to the deep layer. The October 2000 observation found the biomass of toxigenic algae as 17,000 individuals/*l*, which significantly dropped down to 2,200 individuals/*l* by September 2001, the blooming period of cyanobacteria. The dam administrator also confirmed that the algae bloom was extremely low that year. Based on the above data, aeration pumping with Japanese technology is estimated to exert effect in destroying the thermocline, supplying oxygen to the deep layer, and reducing the algae reproduction.

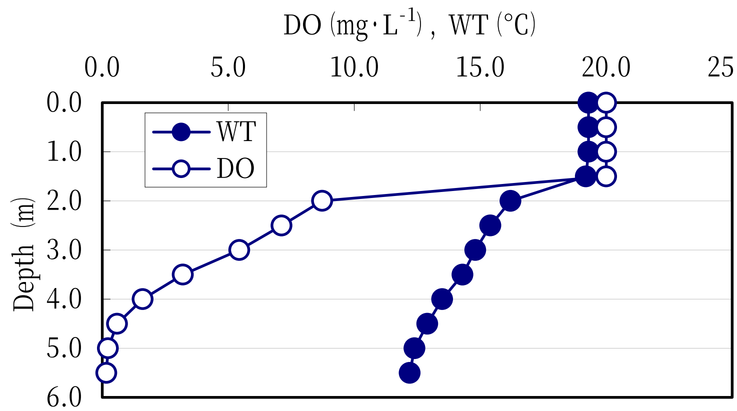

Fig.7-1-9 Thermocline of XiaoGuan Reservoir

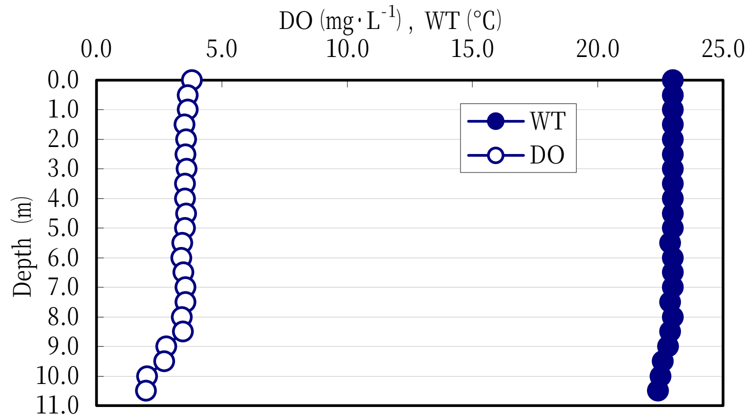

Fig.7-1-10 Distribution of Water Temperature after Air Lift Bubbling in XiaoGuan Reservoir

(5) Evaluation of the Japanese Engineering

As has been described above, Japanese engineering considered suitable to western China was introduced as eutrophication control in Lake Hongfeng Hu and Lake Bai Huau, and its applicability was investigated at the same time. Such engineering is the advanced private sewerage system, the soil trench, and the aeration pump, whose assessment is summarized below.

As for the high-performance private sewerage system using a bioengineering-based water treatment technique, the medium- and small-sized treatment systems proved themselves applicable for eliminating organic substances such as

BOD and COD reduction, whereas nitrogen and phosphorus removal performance varied from time to time, calling for an upgraded operation/maintenance capability. The future technical challenge lies in simplifying the device and adding maintenance-free feature to it. Yet, this project is scheduled to send the local engineer in charge of the system operation to Japan for technical training, which is expected to contribute to better water quality as skill acquisition progresses.

As for the soil trench using the natural purification capacity of soil based on eco-engineering, excellent removability was achieved for nitrogen and phosphorus as well as the organic substances such as BOD and COD. In addition, the soil trench sported easy operation/maintenance and low construction cost, which rendered it effectively applicable as a water treatment method to areas with a vast site and low wastewater volume. Attracted by the treatment efficacy and the low building cost, Chinese government initiated construction of a full-scale soil trench with a daily treatment capacity of 30 m^3 at the Water Sports Training Center where the pilot introduction took place through this project (see Photo 7-1-6).

Photo 7-1-6 The soil trench facility constructed by Chinese

The aeration pump installed at the dam for the purpose of suppressing toxic algae bloom showed its effect in circulating lake water, reducing algae, and turning the deep layer aerobic, which suggested that the device be applicable. This device can be used in eutrophic waters, such as lakes, dams, inland seas, and inner bays, for water quality conservation and restoration, while due consideration must be paid regarding its efficacy for water quality improvement in shallow lakes, cost effectiveness in large lakes, and its impact on the algae colony structure caused by lowered water temperature at the surface layer.

Recapitulation of the above results finds that, among the Japanese engineering, the soil trench and aeration pumping can exert their effects in wastewater treatment right away without modification in Guizhou Province in Western China. Under the operation and maintenance pursuant to the specifications, the high-performance private sewerage system should be able to attain a satisfactory improvement in water quality. At this moment, however, the sophisticated technological nature of the device itself hinders proper operation and maintenance, leaving us the challenge to address that problem. Through the study, it was understood that the water environment restoration on a global-scale would require further advancement of international cooperation to foster technological development as well as the training of local personnel.

7-1-4 Possible Ripple Effects

This research project is part of the strategic policies of science and technology responding to national and social needs; specifically, the Japanese government is to lead the construction and promotion of comprehensive remedial technology for aqueous ecology to control toxigenic algae and lake eutrophication, targeting Lake Hongfeng Hu and Lake Bai Huau in Guizhou Province in China, yet also common to various countries around the globe. Reinforcing and furthering this research project is believed to establish a locally-contained bioengineering- and eco-engineering-based purification system within the lake and the riverhead areas in developing nations, as well as to construct the circulatory and symbiotic ecosystem on an eco-friendly and sustainable development basis by developing the technology suited for each locality.

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7-2 Development Project for the Water Quality Remedial System in Korea (Japan International Cooperation Agency)

7-2-1 Objective of the Project

The Korean economy has achieved a high-level growth centered, first, around industrialization through an initial process of light-industry-concentrated economic development in the early 60's and, second, a transitional period of heavy industry development in the 70's, along with various midcourse corrections. This series of economic growth, however, brought about serious social issues, such as urban population concentration, along with industrialization-led environmental problems, such as air pollution, water contamination, and waste disposal.

These social and economic developments contributed to upsurges in the pollution sources and the sewage volume. Sewerage system development in urban areas could not catch up with the growth of the sewage volume, which not only deteriorated river water but also triggered many grave problems caused by acute progress of eutrophication in closed waters, such as dams, that were supposed to supply service water to the cities.

Under a national plan, the central government annually undertook improvement works on wastewater treatment facilities and sewer conduits. Yet, the construction costs of the sewerage system were so phenomenal that sewerage system development alone could not rectify the water quality promptly.

Discussion and study on introducing a decentralized system for effluent treatment, targeting the suburban areas with service water sources, remained at an immature stage; control measures for nitrogen and phosphorus against eutrophication posed especially tough challenges. In this sense, it was assessed through analyzing, evaluating, and predicting the state of pollution in the ever-polluting rivers that a proper water quality management system needed to be established. Based on such an assessment, the urgently necessary measures and engineering were determined as 1) technological development for pollutant reduction that matched the locality, such as for the distribution, size, and variety of pollutant sources, and 2) a purification technology that can be directly applied to the rivers using their self-decontamination capacity. It was also pointed out that both types of technologies must be maintenance-free and cost-effective.

Located in the downstream part of Kyonang River basin, Paldang Dam supplies the service water to Metropolitan Seoul and its 15 million population, which means that it is extremely important to develop a water purification system with direct influence on Seoul's water quality. For this reason, the Ministry of Environment of the Republic of Korea has already conducted various environmental conservation projects to induce water purification in Kyonang River by designating the Yongin area in the upstream basin as the pilot area for environmental conservation. In this context, both Japan and Korea came to recognize the priority of facilitating improved efficiency in the above projects by conducting a bilateral joint research projects.Based on an Agreement Between the Government of Japan and the Government of the Republic of Korea on Cooperation in the Field of Science and Technology in 1985, the Korea Environment Institute (KEI) concluded a research cooperation agreement for developing environmental conservation technologies with the National Institute for Environmental Studies of Japan (NIES) in March 1988. Furthermore, KEI and the Japan International Cooperation Agency (JICA) agreed regarding environmental management of the Han River basin in November 1989, which launched a three-year research cooperation project. The results of this research disclosed the urgent need to develop a river/lake water quality management system according to the river system, and a decontamination system tailored to the region's characteristics. The Korean side urged cooperation in the area of a decontamination system particularly, as the most widespread private sewerage system in Korea was the so-called septic tank, which is capable of eliminating only 50 % of the BOD and none whatsoever of the nitrogen or phosphorus, when water pollutants and pollution sources were skyrocketing.

Based on the results of this three-year JICA mini project, the Korean Government requested a project-type technical cooperation from JICA in November 1992, to which JICA responded by sending a preliminary assessment team and a group of long-term researchers to investigate the request details and the adequacy of the cooperation.

Their results found that the transfer of two technologies, the decentralized effluent treatment technology and the purification technology directly applicable to rivers, could greatly contribute to water quality conservation in Korea. To be more specific, the former technology consists of a high-level combined type private sewage treatment system, developed and widely spread in Japan, which can eliminate the BOD as well as nitrogen and phosphorus, and the latter technology is represented by a canal purification scheme by filling the contact materials.

After the preparatory assessment group delivered the results, a study group for project implementation was dispatched to Korea to sign the Record of Discussion (R/D) on August 27, 1993, which launched a five-year cooperation project on September 1. On the occasion of sending the final assessment group in March 1998, the Korean side urged extension of the project, which was met by extending the project for one year until August 31, 1999. This project-type technical cooperation is the only project actually launched out of the 13 propositions based on environmental cooperation agreed by the then Japanese Prime Minister Kiichi Miyazawa and the then Korean President Roh Tae Woo.

The purpose of the technical cooperation is, first, to transfer Japanese technologies to KEI in the fields of aquatic environment remediation and a river/lake water quality management system, next to stimulate research to modify and tailor these technologies to the needs of the Korean situation, and finally, to develop water quality remedial technologies suitable for the locality to contribute to the overall improvement of the aquatic environment in Korea.

7-2-2 Outline of the Project

The technical cooperation under this project targeted the fields listed below.

(1) Water Quality Remedial Technology

a) Advanced and decentralized treatment techniques for domestic wastewater.

b) Advanced treatment technique for livestock effluent.

c) Advanced treatment techniques for polluted canals.

(2) River/Lake Water Quality Management System

a) Environmental capacity determination method.

b) Development of methods countering lake eutrophication.

Since the project focused on the water quality improvement of service-water sources, such as Seoul's water supplier Paldang Dam, around which the population is relatively dispersed, the technical cooperation project chose a decentralized wastewater treatment system, where effluent is treated promptly right at its origin, rather than a centralized wastewater treatment system, such as a sewerage system, where the wastewater is collectively brought through pipes to wastewater disposal plants. The reasons for this decision are listed in Table 7-2-1.

In view of the issues presented in Table 7-2-1, pilot effluent treatment devices, covering the aforementioned cooperation targets, were installed on site for data collection and analysis, optimization of the operation conditions, and cost evaluation, and their data and results were used to tailor the technologies to the locality by providing reasonable guidelines for the structure and operation/maintenance of the device.

At the same time, the river/lake water quality management technology development targets Seoul's water supplier Paldang Dam for study on techniques to determine the environmental capacity and development of technologies to predict and control the algae bloom caused by lake eutrophication.

Table 7-2-1 Issues Considered for the Decentralized Effluent Treatment System Tailored to Korean Situations

1) It is economically advantageous in a sparsely populated area. (A sewerage system is economically disadvantageous due to the length of the pipes.)
2) Prompt wastewater treatment at the pollution source returns the cleansed water quickly into the public water body to be used for maintaining the aquatic environment. (A sewerage system carries the water downstream via conduits, raising a problem of reducing the flow rate in the midcourse rivers.)
3) It is easier to institute a system to recycle water for miscellaneous and landscape uses.

For making use of these advantages

↓

It is necessary to develop wastewater treatment technologies applicable to a decentralized wastewater treatment system to meet various needs such as 1) high-quality treated water, 2) a compact structure, 3) easy maintenance, 4) cost efficiency, and 5) energy conservation.

7-2-3 Achievement of the Project

(1) Technological Transfer Concerning Water Quality Betterment

At the outset of the project, the common system for decentralized wastewater processing at detached houses and apartment buildings in Korea was a septic tank only capable of anaerobic treatment, which also had a serious problem in its maintenance, such as the failure to vacuum out the sludge. In addition, livestock wastewater was treated mainly by septic tanks and lagoons, the processing performance of which was extremely low. This project began under the above circumstances, and also when water pollution scandals repeatedly occurred one after another concerning major rivers, raising national concerns about the aquatic environment as well as great interest and hopes, including in the media, for an advanced wastewater treatment equipment to replace the septic tanks. At the same time, however, the situation in Japan concerning the private sewerage system, in particular the high-performance combined private sewerage, was hardly known and was not anticipated as a means to meet such expectations. Once the project started, and especially after the installation and operation of real-size effluent disposal equipment, their performance drew considerable attention and raised expectations, which accelerated the study, by mainly KEI researchers, on customizing the structure of the provided devices to fit Korean circumstances, and the acquisition of maintenance techniques under the guidance of the Japanese expert team.

Table 7-2-2 lists the equipment provided under this project. As for the small-size combined private sewerage system for detached houses, we chose two systems capable of removing BOD and nitrogen for comparative study: a circulatory system using anaerobic/aerobic filter beds, and a circulatory system using an anaerobic filter bed and biological membrane filtration. Both systems attained favorable results in water quality to their specifications, registering less than 20 mg/*l* for BOD and below 15 mg/*l* for T-N. As for the medium-size combined private sewerage system for apartment housings, we also chose two systems capable of removing BOD, nitrogen, and phosphorus, for comparative study: a sequencing batch reactor processing system, and a circulating intermittent aeration system. Both systems attained satisfactory results in water quality to reach the set targets, registering less than 20 mg/*l* for BOD, below 15 mg/*l* for T-N, and less than 1 mg/*l* for T-P. The livestock wastewater treatment facility, targeting on pig farming,

Table 7-2-2 Equipment Provided under this Project

	Process Method	Matters Removed			No. of Units	Treatment Volume M^3/day
		BOD	N	P		
Household effluent	1.Small-Scale Combined Private Sewerage System for Detached Houses					
	(1) Circulatory System between Anaerobic/Aerobic Filter Beds	○	○		4	1-2
	(2) Circulatory System between the Anaerobic Filter Bed and the Biological Membrane Filtration	○	○		4	1-2
	2. Medium-Size Combined Private Sewerage System for the Apartment Housings					
	(1) Sequencing Batch Reactor Processing System	○	○	○	1	40
	(2) Circulating Intermittent Aeration System	○	○	○	1	40
Livestock Effluent	(1) Sequencing Batch Reactor Processing System for Livestock	○	○	○	1	10
	(2) High-Speed Composter for Livestock Solid Waste Disposal	---	---	---	1	2

achieved great results for BOD and T-N less than 120 mg/*l* and T-P below 70 mg/*l* out of the raw sewage with BOD around 4,000 mg/*l*, T-N around 2,000 mg/*l*, and T-P around 70 mg/*l*. A composter made it possible to combine the composting of solid content from the corral and the surplus sludge through the effluent treatment process, raising the financial expectation of organic fertilizer (compost), which has a high market value in Korea. As described above, the provided equipment fully delivered its intended performances, which means that it achieved the goal of not only technical transfer to the counterpart, but also educating and raising the awareness of the general citizens.

Based on technical transfer through equipment provision, the next step was technological transfer to develop decentralized domestic effluent treatment facilities capable of eliminating nitrogen and phosphorus for eutrophication abatement, livestock wastewater treatment facilities, and comprehensive wastewater treatment facilities to jointly process restaurant effluent and night soil, in cooperation with the Japanese specialist team. Long-term experts led this technical transfer, with extra dispatch of short-term experts without the year limitation of initial plan. This flexible approach brought about fruitful results. In particular, a comprehensive wastewater treatment facility to jointly process restaurant effluent and night soil is now under discussion in Japan, which, to some extent, is a "reverse import" of Japanese technology from Korea. In Korea, effluent from small restaurants in the service-water source areas, such as in the vicinity of dams, had become an important policy issue. The project addressed this problem by developing technology that could significantly reduce the pollutants from such severe levels as the oil content of 500 mg/*l*, BOD of 1,000 mg/*l*, and T-N of 100 mg/*l*, down to less than 20 mg/*l* for both BOD and T-N. Other facilities also delivered similarly excellent performances, coupled with easy maintenance. For these reasons, KEI decided to facilitate the widespread use of these facilities through the pilot projects, indicating the success of the technological development.
In Korea, the private sewerage systems were regulated not by the structural standard but by the performance standard, for which the project successfully suggested technical standards.

(2) Software-wise Technical Transfer Regarding the Legal System

In Korea, regulation previously imposed only the installation of septic tanks for small-scale buildings, such as apartments, for their on-site sewerage systems. Due to the rising social awareness of the water environment issue and the confirmation of technical feasibility through this project, the Act Relating to the Treatment of Sewage, Night Soil and Livestock Wastewater was amended in March 1997 to require the installation of combined type private sewer treatment systems at small buildings. The revised law also explicitly set various standards such as for their installation, and maintenance and for the quality of the discharged treated water. As seen above, the project for technical cooperation attained excellent results in the field of administrative assistance for water purification.

(3) National Award

In recognition of the earnest work of the Japanese project group, the Korean government granted the following national awards.

Republic of Korea Prime Ministerial Award for Contribution to Environmental Conservation: 1 recipient

Republic of Korea Environment Ministerial Award for Services for Environmental Conservation: 3 recipients

The breakdown of personnel dispatched from Japan through this JICA project is outlined as follows.

1) Long-term Specialists (including the project leader): 5 people

2) Short-term Specialists: Over 70 people

3) Study Group Dispatch: 8 times

7-2-4 Possible Ripple Effects

Through a surprisingly organic interaction and match between the Korean situation and the assistance provided, this project in Korea achieved numerous fruitful results both in technical hardware transfer, such as hi-performance private sewage treatment systems capable of removing nitrogen and phosphorus, and technical software transfer, such as revision of related laws. In each area of industry, academia, and administration, active and enthusiastic transfer of technologies took place through highly effective cooperation with the integration of equipment provision and research instructions as one under the project. This unified project was reflected in the determination and establishment of the proper operating conditions and maintenance techniques of the wastewater treatment facilities, using real-sized facilities, and the research and related analytic techniques for determining the design specifications of the wastewater treatment devices by using the provided bench-scale equipment. Consequently, this project turned out to embody what a JICA project-type technical cooperation should be in every possible way, which raises our hopes for its future application and development in many different regions. In addition, it needs to be noted that an Eco-Frontier (EF) Fellow funded by the Global Environment Research Program developed less-global-warming water and solid waste treatment techniques, which significantly contributed to the progress of the project. The EF Fellowship sponsored by Japanese Government aims to foster international exchange in the field of environmental conservation by inviting foreign researchers to Japan for joint research, etc.

These numerous achievements were appreciated in the form of winning the Republic of Korea Prime Ministerial Award for Contribution to Environmental Conservation and the Republic of Korea Environment Ministerial Award for Services for Environmental Conservation. These honors were previously awarded domestically only, which made this event a milestone as the first overseas winner of the awards. Standing on the basis of this project completed in August 1999, JICA and the Korea International Cooperation Agency (KOICA) launched their joint training program for other Asian nations to improve their water environment, in conjunction with the ex-counterpart KEI. The program just completed its first two-year phase in FY 2001, and will move into a second phase with an even closer partnership between Japan and Korea.

The above ripple effects as well as the results of the project themselves can be proudly summarized as consisting of the foundation of a new Korea/Japan partnership in the 21st century in the most critical field of the century, the environment.

7-3 Pilot Project for the Water Environment Remediation at Lake Taihu in China (JICA)

7-3-1 Objective of the Project

The target of this pilot project, Lake Taihu, preciously supplies city water of as much as approximately 1.05×10^{9} m^{3} annually to some million residents in the surrounding big cities, such as Shanghai, Wuxi, Suzhou, and Huzhou (Fig. 7-3-1). At the same time, however, the lake as a whole suffers from eutrophication, and some parts of the lake suffer serious organic pollution and algae bloom. The Chinese Government has so far designated three lakes and three rivers as the most important areas for environmental control by the state, among which Lake Taihu is top on the agenda. Currently, ongoing pollution control measures focus on industrial and urban wastewater, complying with the ninth five-year plan and the long-tern plan until 2010 to counter water pollution in Lake Taihu. Due to the various measures implemented between 1997 and 2000, the major point sources in its basin are now basically under control. Meanwhile, decentralized (rural) household effluent and non-point-source pollutants are still awaiting to be addressed, owing to technical and financial difficulties. Environmental load cutback requires not only measures to treat the industrial and urban wastewater, but also for the control of decentralized household wastewater sources and organic pollutant sources at the lakeshore. In particular, it is vital to reduce nitrogen and phosphorus, when both are chief culprits of eutrophication.

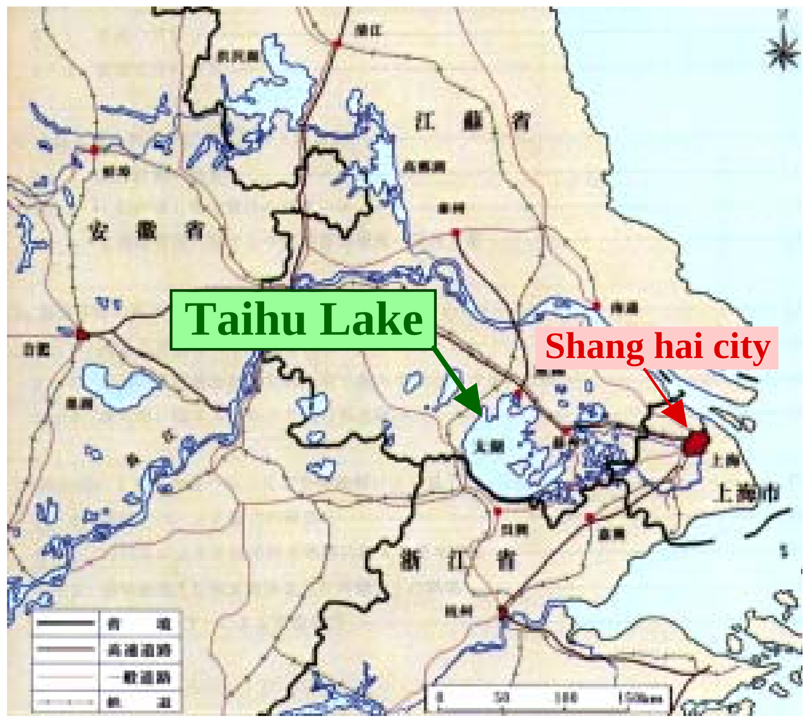

Fig. 7.3.1 Map of the Region Around Taihu Lake 200 Kilometers South-east of Nanjing in Jiangsu Province

Based on the above circumstances, this project aimed a) to research and develop control/processing technologies for household effluent from decentralized sources in the Lake Taihu catchment area applicable to and widely usable in the target area by fitting its social and economic conditions, and b) to render these technologies recognized by the target society. The project put its primary emphasis, in its objectives, on the reduction of the nitrogen and phosphorus influx into Lake Taihu by applying lake water environment remedial technologies developed under this project. Achievements of these goals are expected to deliver the following effects.

1) Developing commercialized technology for an advanced private sewer treatment system targeting rural household effluent.

2) Developing effective eco-engineering-based purification technology targeting rural household effluent.

3) Satisfying the conditions for the developed technologies to be recognized by the targeted society.

In addition, there is great expectation that the technologies scheduled for development under this pilot project will be applicable as aquatic environment remedies to other developing countries than China.

7-3-2 Outline of the Project

This pilot project is a five-year research collaboration launched in FY 2001 under the framework of JICA's project-type technical cooperation jointly participated in by the Ministry of Environment, the National Institute for Environmental Studies, the Ministry of Land, Infrastructure and Transport, and the Public Works Research Institute from Japan, and the China State Environmental Protection Administration, the Chinese Research Academy of Environmental Sciences, the Jiangsu Environmental Protection Department, the Wuxi Environmental Protection Bureau, and Shanghai JiaoTong University of China. The R&D pilot project targets Wuxi, an industrial and tourist city on the north of Lake Taihu with a population of 4.26 million. The most eutrophic area in the lake is the northern water near the city: canals and the lakeshore are particularly infested by toxigenic algae bloom, which raises a big social issue (see Photos 7-3-1 and 7-3-2). Such areas register concentrations of over 1,000 μg/*l* microcystin of cyanobacterial origin, which raises grave environmental and hygiene concerns.

Photo 7-3-1 Abnormal increase of toxigenic algae bloom

Photo 7-3-2 Toxigenic algae at lakeshore in Wuxi

Against that background, this pilot R&D project focuses on Lake Taihu designated as the lake of highest priority by the Chinese Government which places algae bloom control as one of the prime national environmental policies, and aims to reduce the influent loads into the lake. To be more specific, the project gears toward the creation of eco-friendly community systems through development of technology/devices to control household effluent by using a combination of bioengineering and eco-engineering (bio-eco-engineering) and the establishment of standards concerning the structure, maintenance, and performance of the developed technology/devices. The technologies used and developed under this project are, 1) bioengineering as a water treatment technology with the introduction of a private treatment system for household sewer from hotel and apartments, and 2) eco-engineering that facilitates the maximum use of the self-purification capacity of the plants and soils in the water areas polluted by household wastewater. Furthermore, two types of technologies will be systematically combined into a bio-eco-engineering, where each technology is properly applied and allocated in the Taihu catchment to deliver a visible effect in water quality improvement.

7-3-3 Pilot Bio-Eco-Engineering Facilities Installed in Wuxi City

This pilot project comprises Japanese technical transfer, basic research by the Chinese Research Academy of Environmental Sciences, setting standards for the structure and performance of the purification system by analyzing the data acquired through verification study by the Wuxi Environmental Protection Bureau, the Jiangsu Environmental

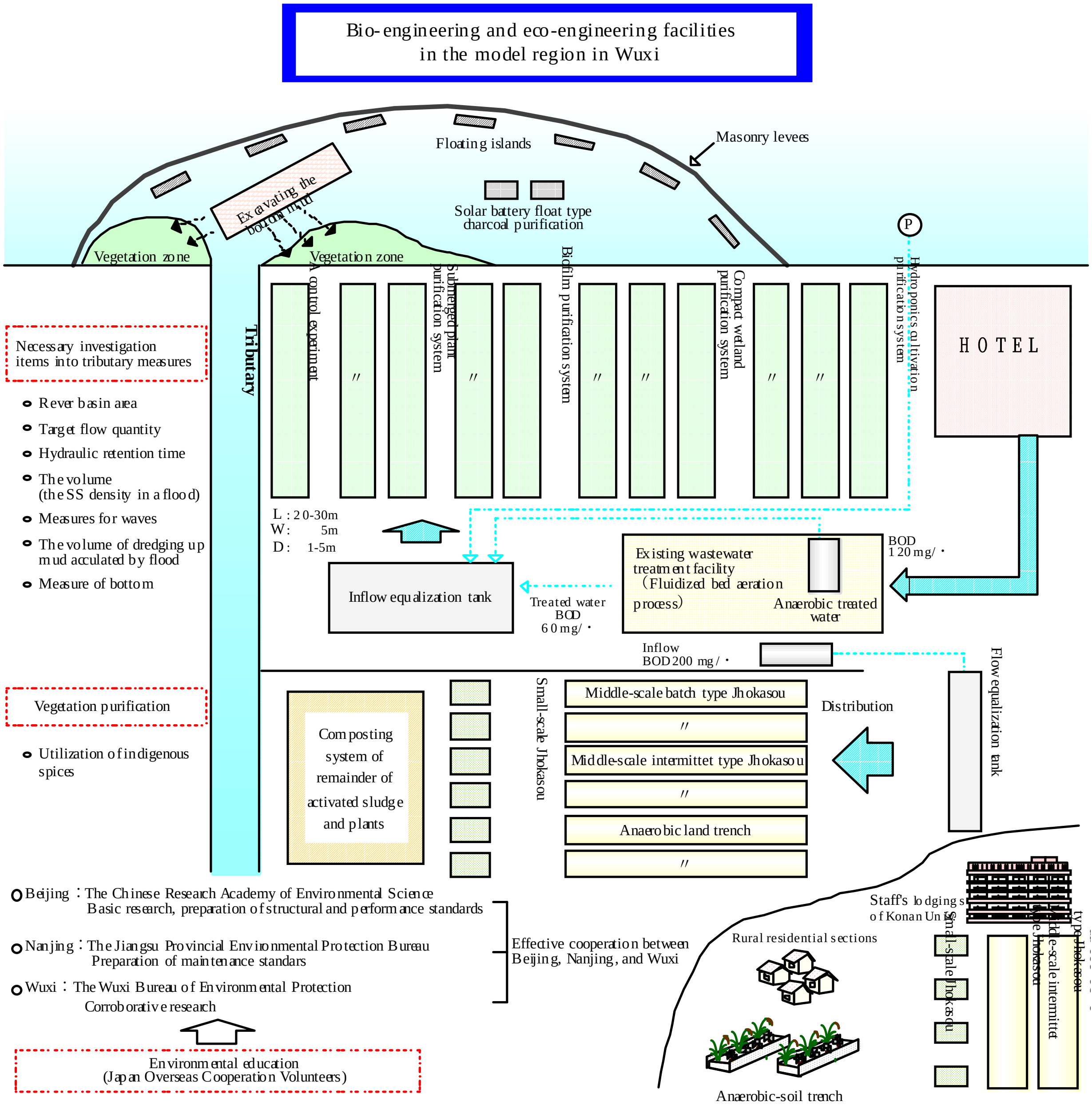

Fig. 7-3-2 Bio-engineering and eco-engineering facilities at the pilot area in Wuxi

Protection Department in Nanjing setting standards for maintenance based on the municipal bureau's verification study, and most importantly, a verification study of the bio-eco-engineering by the Wuxi Environmental Protection Bureau. The conceptual rendering of the pilot area in Wuxi is shown in Fig. 7-3-2, where the private sewerage system is introduced using the bioengineering approach.

As for the eco-engineering approaches, purification through hydroponic plants (biopark), purification by using the soil, and compact wetland purification by using the biological film created by the water plants and the microorganisms proliferated on bonding carriers were all employed. In addition to these conventional approaches, a new eco-engineering attempt is being made through building a new rubble-work bank on the lakeshore near the influx of small rivers carrying household effluent to create lakeshore vegetation zones by digging up its inner sludge, and concurrently introducing a purification method through an artificial vegetated floating island to address the issue of tributary control. The technologies to be developed in this pilot area offer great hope for their international application.

7-3-4 Ripple Effects of the Project

The results of this project, to be obtained through both the basic and applied studies on software and hardware conducted in Beijing, Nanjing, and Wuxi, are expected to earn a high reputation both at home and abroad. Firstly, the project aims to develop the technology for an on-site sewer treatment system capable of eliminating nitrogen and phosphorus to effectively abate lake eutrophication, and simultaneously to construct a standard system set to regulate its maintenance, structure, and performance. When achieved, these promising results will be generalized for use in the regulations to successfully reduce the pollutant loads from household effluent originating from the sources scattered throughout the nation. Secondly, the project can suggest some new lake purification techniques based on energy-saving, low-cost, low-emission, and resource-recycling eco-engineering approaches, such as those using water plants, hydroponic plants, and soils, which have great potentials for having further ripple effects as a nationwide model of lake decontamination in China. The originality of this project lies in the new concept of creating a hybrid system of bioengineering and eco-engineering to maximize the advantages of both approaches, rather than the conventional, individual application of each. In this sense, its achievements are promising for future application on a global basis. As described above, this project should serve as the core for establishing the water environment conservation strategy in the 21st century. Hopes run high that the project will expand its organic partnership beyond Japan and China to the other developing countries to pave the route to water purification tailored to local needs and conditions.

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7-4 Water Quality Remedial Program at Lake Ypakarai in Paraguay

7-4-1 Objective of the Project

The Republic of Paraguay, located inland on the South American Continent, faces a grave social problem of eutrophication at Lake Ypakarai near its capital Asuncion. On this account, the Servicio Nacional de Saneamiento Ambiental (National Environment and Health Service, SENASA) decided to formulate a water pollution control plan, including water quality monitoring and analysis at the lake, and effluent regulations. Against this background, this project aimed to help the SENASA formulate a water pollution control plan, including the water quality monitoring and analysis at Lake Ypakarai, and effluent regulations, and to also upgrade the enforceability of the plan.

7-4-2 Outline of the Project

(1) Targeted Location of the Project

This project targets the Lake Ypakarai catchment area in the vicinity of Asuncion, the capital of the Republic of Paraguay. As shown in Fig. 7-4-1, Paraguay lies in inland Latin American, and is surrounded by Brazil, Argentine, and Bolivia. Lake Ypakarai is located at S 25.2º and W 57.2º, and approximately 30 km to the east of the center of the capital Asuncion (see Fig. 7-4-2). The geometric features of the lake are as follows: a surface area of 59.6×10^6 m^2; a maximum depth of 3 m; a mean depth of 2 m; a surface altitude of 64 m above sea level; a water capacity of 115×10^6 m^3; a shore length of 40 km. Of the area surrounding the lake, farmland, including pastureland, accounts for approximately 65 %, and natural vegetation, such as grassland and wetland, shares approximately 19 %. Its catchment area embraces cities such as San Lorenzo, Luque, Capiata, and San Bernardino, whose household wastewater flows into the lake through 20 influent rivers. The lake has only one effluent river, the Salado, which flows into Rio de la Plata via the Paraguay River to reach the South Atlantic.

Fig.7-4-1 Situation of Lake Ypakarai

The urban and domestic wastewater in the basin accounts for around 48 % of the loading pollutants that flow into Lake Ypakarai. The industrial effluent from over 80 business establishments in the catchment area is estimated to share approximately 24 %, most of which are ascribable to meat packaging and leather processing. Photo 7-4-1 presents the landscape of Lake Ypakarai. The lake water is colored brown from the influent soil particles due to soil erosion in the catchment area. For this reason, the lake is characterized by significantly low transparency (0.07-0.15 m) and a considerably high SS concentration (70-80 mg/*l*). The water quality figures in Lake Ypakarai are as follows: CODcr 10.3-15.7 mg/*l*; T-N 0.58-0.89 mg/*l*; T-P 0.15-0.30 mg/*l*; DO 6.0-8.9 mg/*l*; and pH 6.0-8.7. The lake is distinctive for its relatively high phosphorus concentration compared to the nitrogen level, thus there is an excessively low ratio between nitrogen and phosphorus of 1.9-5.9. The organization responsible for the technical transfer (counterpart) under this project is SENASA. At the time of inauguration of the project, SENASA mainly consisted of three departments.

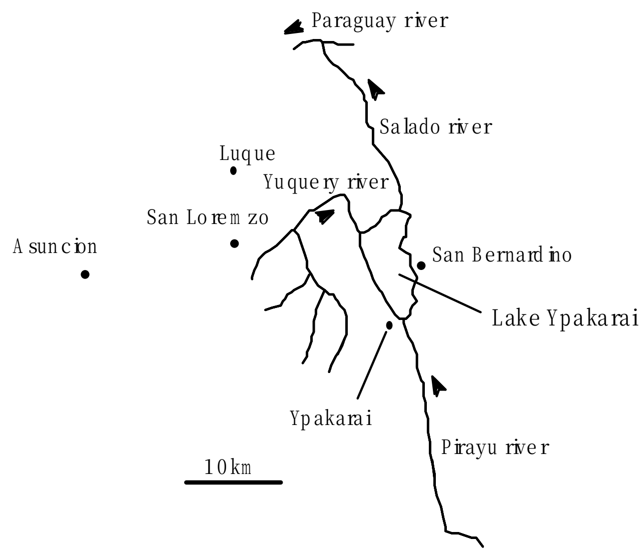

Fig.7-4-2 Drainage of Lake Ypakarai

- Direccion de Proteccion Ambiental (Directorate of Environmental Protection)
- Direccion de Agua y Saneamiento (Directorate of Water and Health)
- Direccion de Administracion y Finanzas (Directorate of Administration and Finances)

The specialists dispatched under the project were affiliated to the Directorate of Environmental Protection, which has jurisdiction over factory effluent regulation, solid waste control, and environmental monitoring and water quality testing.

(2) Background of the Project

Paraguay is an inland country with no sea facing it, which means that Lake Ypakarai serves as a precious water resource not just for water utilization but also for water recreation. Contrary to such a role, the Ypakarai catchment environment was constantly and progressively exacerbated by land development, a population explosion, and industrial development due to either urban sprawl or the capital Asuncion. For this reason, the lake is rapidly losing its value as a

Photo 7-4-1 Landscape of Lake Ypakarai (Paraguay)

water resource and a tourist and holiday resort. In 1988 and 1989, JICA conducted a feasibility survey concerning a water pollution control plan in Lake Ypakarai to address the rapidly ailing water environment. Between 1995 and 1998, individually dispatched experts for water pollution control (mainly for analytical and monitoring guidance) were sent to Paraguay to provide further technical support.

Based on the above background, this three-year technical cooperation project was launched with its objectives to help SENASA analyze the problems of the Ypakarai basin by itself through the process of technical transfer including analysis of newly registered pollutants, administrative guidance, effluent treatment improvement, data analysis, and environmental edification and education, as well as to undertake the review and revision of the current water quality standards and the formulation of a draft for a feasible plan to improve water quality. The ultimate goal of the project is to contribute to the actual water quality improvement of the lake through the results of the project. In July 2000, the final year of the project, Secretaria del Ambiente (Secretariat of Environment, SEAM) was established, which shifted the legal jurisdiction concerning the environment from SENASA to SEAM. In this sense, the counterpart of this project, SENASA, had much reduced administrative authority.

(3) Project Period

The period for technical cooperation under this project is three years, between June 1, 1998 and May 31, 2001.

(4) Range of Activities under the Project

The project initially focused its technical cooperation efforts on monitoring techniques. Once data were acquired through monitoring, the water quality remedial plan, including proposals to related organizations, was formulated on the basis of these data, in order to facilitate further development of measures into activities such as a study on the drafted water quality standards, guidance to the pollutant sources on the effluent treatment renovation, and environmental education. Specifically, the project activities consisted of the six categories listed below.

- Monitoring of, keeping track of, and recording the state of water pollution.
- Formulating a monitoring plan, maintaining the monitoring equipment, introducing new monitoring techniques (including those for agrochemicals, heavy metals, and microorganisms), and compiling a monitoring manual.
- Formulating an enforceable water quality remedial plan.
- Offering instructions on what the water quality standards should be to control the water contamination, and studying their actual water quality standards.
- Training the SENASA personnel so that they themselves can give guidance to the pollutant sources on effluent treatment renovation.
- Conducting edification and PR activities for the general public and those in related fields and industry regarding the actual state of water pollution and the urgency for its control.

7-4-3 Achievement of the Project

(1) Monitoring on the Degree of Pollution

Under the project, the pollutant sources in the Ypakarai catchment area were monitored according to their origins, such as household, industry, and nature. Through the monitoring sessions, several techniques, including those for understanding the degree of pollution, and for elucidating the pollutants, were successfully transferred to the counterpart. Through the project, a whole set of monitoring techniques was passed on, ranging from drafting the plan, conducting the survey based on the plan, sorting the acquired data, and analyzing the data, all the way to compiling the report.

(2) Elucidation of Pollutants and Guidance for Reform

The pollutant investigation covered various sources in the Ypakarai catchment, including illegal waste dumping sites and over 80 business establishments of all size, to elucidate the problems of these sources. Through the technical transfer of administrative guidance and on-the-job training on effluent treatment techniques, the project counterpart became able to provide proper administrative guidance (for reform) to the pollutant sources such as factories.

(3) Maintenance of Survey/Analysis Equipment and Reagents

A register of survey/analysis instruments, reagents, and other equipment and chemicals was created, whereby the management system of these instruments was established through allowing anyone at anytime to access the register. The major equipment and their uses provided under this project (partially the provision of peripherals only) are listed below. These instruments, mainly analyzers, enhanced the transfer of monitoring techniques.

- Gas Chromatograph Mass Spectrometer (GC-MS) (including a solid phase microextracter and a capillary column)

  The GC-MS was used for agrochemical detection. The solid phase microextracter allowed the qualitative analysis and screening for certain agrochemicals, which paved the road for detailed investigation on agrochemical pollution. Through experience in microextraction, an engineer should be able to master the qualitative analysis skills.

- Atomic Absorption Spectrophotometer (including the autosampler)

  The device was used for heavy metals detection within the sediment. The autosampler enhanced efficiency by allowing the automatic and repeatable samplings useful for a large number of samples.

- Oil Concentration Analyzer

  The analyzer was used when the fear of oil pollution arises. It allowed the mechanical analysis of oil, previously conducted manually, which increased the time efficiency at the laboratory.

- High Performance Liquid Chromatograph

  The instrument was used for detection of the organic compounds such as within agrochemicals. Being a complement to the GC-MS, this allowed water ion analysis.

- Biological Microscope System (including photomicrographic equipment, a plankton net for collecting biological samples, and a server net)

  The system was used for the detection and identification of aquatic organisms. The biological observation allowed by this system diversified the evaluations of the state of the water environment, which was hitherto only chemically analyzed.

- Algae Growth Tester

  The instrument allowed test/research on the growth and reproduction of plankton. The algal growth potential (AGP) and other tests are expected to start in the future. Performing these tests vitally requires the acquisition of test/study skills by the engineers in charge through trainings.

- Dissolved oxygen (DO) Meter

  This DO meter was used for the back up and crosschecking of the existing DO meter. The simultaneous DO measurement with the pH level enhanced the time efficiency.

- Ultrasonic Cleaner

  It was used for cleaning glass tools and preparing slightly soluble reagents at the laboratory.

- Ekman-Birge Grab

  The grab was used for sampling the sediment of the lakes and rivers. It allowed sediment sampling under uniform conditions in an efficient way, thus reducing individual differences in the sampling process.

- Multi-Parameter Water Quality Checker

  The analyzer was used for measuring the physical parameters of sampling on the spot. Simultaneous measurements of multiple parameters saved time at the sampling site.

- Liquid-Waste Treatment Device

  It was used for periodic treatment of the effluent containing potassium dichromate. A test/research institute on the environment must not drain the untreated liquid-waste. With this device, it is now possible to publicly announce the clean discharge of effluent.

- Clean Bench

  It was used for the aseptic manipulation such as E. coli culture tests. This instrument enhanced the operation efficiency with bacterial tests, by allowing full-scale aseptic manipulation at the laboratory impossible just by flame sterilization.

- Survey-Use Motorboat

  It was used for the transportation to a fixed point in the regular monitoring session every month.

- Four-Wheel Drive Vehicle

  The automobile was used for sampling activities in the regular monitoring of Lake Ypakarai, factory investigation for the effluent monitoring, and other activities requiring transportation.

- AV Multi-Projector

  The projector was used for environmental edification activities. It allowed the use of ordinary paper, rather than transparency, which eased the preparation work for materials and handouts.

- Photocopier

  It was used for daily business such as paperwork and document preparation.

(4) Development of a Manual

The project produced a manual covering a wide spectrum ranging from samplings, such as of microorganisms, to their analysis using the equipment at the laboratory. This manual will provide a precious guideline to any newly appointed engineers in charge who has no previous experience.

(5) Production of Reports

The project established the system to publish an annual report compiling the data on the Ypakarai catchment area obtained through the monitoring. Those precious data, otherwise likely to be forgotten, are now systematically put together as a report so that they can be effectively used in various ways, including comparative study with past data.

(6) Environmental Edification Activity

Based on knowledge acquired through the study regarding the state of water pollution and the investigation on the pollutant sources, the project sponsored seminars for various groups of people, such as business managers, catchment administrators, catchment area residents, schoolteachers, and the general public, and successfully obtained their understanding on the state of the basin pollution and cooperation for its control measures. It also published a PR kit for citizens and business managers to show the guidelines regarding water pollution control.

(7) Formulation of the Water Quality Remedial Plan and Review on the Water Quality Standard Revision

The water quality remedial plan was formulated on the basis of both the knowledge and technologies transferred under this project, and the ideas and experiences obtained during the project.

7-4-4 Possible Ripple Effects

(1) Local Government

Consejo de Municipalidades de la Cuenca del Lago Ypacarai (CLYMA), composed of 21 municipalities in the Lake Ypakarai catchment area, and *Consejjo de Gobernaciones Municipalidades de la Cuenca del Lago Ypacarai* (CLYGMA), composed of three departments (provinces) in addition to the said municipalities, were established in 1999. These councils, through various activities, are expected to contribute to progress in improvement of the water quality at the lake.

(2) Local Health Council

Every municipality has its own health council (Juntas de Saneamiento) in Paraguay. Authorized as a legal entity, this organization is in charge of development and maintenance of the waterworks and the sewage works. The sewerage department of SENASA, the project’s counterpart, designs and executes the project activities under the control of the local health council. At the request of the health council, Caacupe, though outside the Ypakarai basin, has now been equipped with a sewerage system, and the same initiative was launched to develop sewage treatment systems in other Ypakarai basin cities such as Itagua, Capiata, and Ypakarai. Realization of this vision should contribute to drastic purification of the lake by reducing pollutants in the untreated effluent flowing into the lake.

(3) Catchment Residents

Full-geared implementation of environmental education and edification should be able to raise the awareness of the catchment area community members of the lake pollution, thus slashing the pollutant loads such as through illegal waste dumping. At this moment, however, their ecological ethics have not yet reached an adequate level.

(4) Industrial Guild of Paraguay

In 2000, the Industrial Guild of Paraguay, the Ministry of Industry and Commerce, and the Catholic University jointly started consultation activities for small businesses to improve their productivity and eco-friendliness. These efforts are expected to enable the small businesses in the Ypakarai catchment area to address water pollution control.

<Reference>

1) International Lake Environment Committee, *Survey of the State of World Lake* (2001).

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8. Water Treatment Technology Applicable to Developing Countries

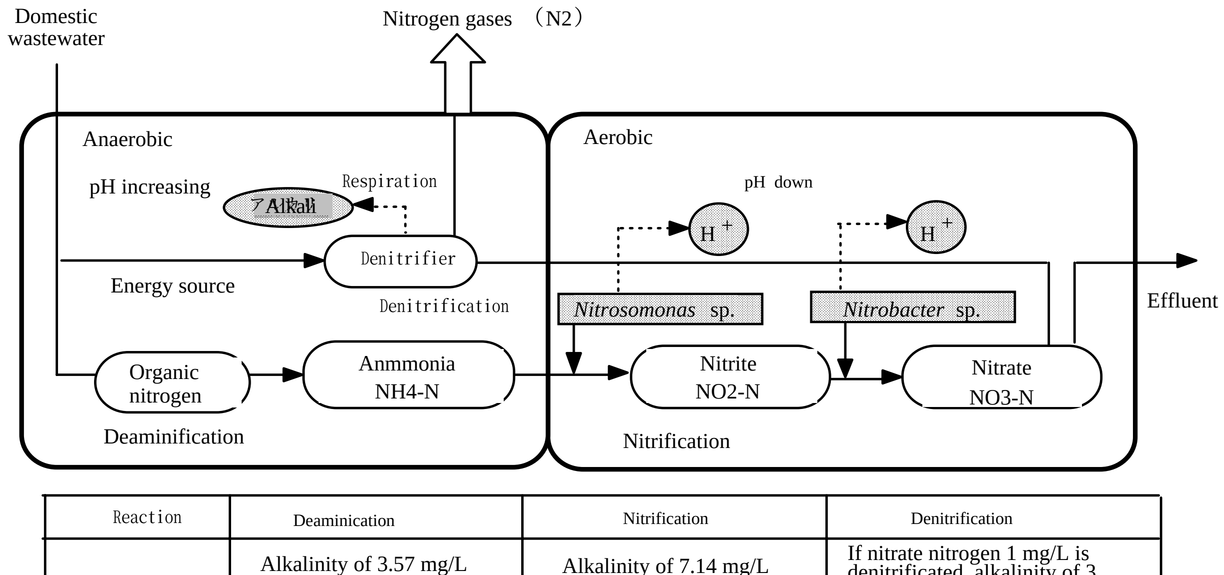
In the prevention of eutrophication of lakes and marshes, the direct transfer of technology from developed countries is not effective. The important thing is energy- and cost-saving, and low-maintenance cost technology based upon the conditions of each country. This chapter describes such technology applicable to developing countries.

8.1 Advanced Treatment Septic Tank

8-1-1 Principle and features of the system

(1) Principle of the system

The treatment of residential wastewater is roughly divided into sewerage systems utilized in densely populated areas and septic tanks utilized in dispersively populated areas. Of the two, the septic tank can return the treated wastewater to the water area onsite by improving its quality. Therefore, the diffusion of the advanced treatment septic tank is very effective in securing the amount of water required to maintain river water and underground water; that is, water recharge. This advanced treatment septic tank is a system for treating residential wastewater allowing nitrogen and phosphorous to be removed, and is available in a variety of sizes from small to large for use at individual households or housing complexes. The treatment methods are principally divided into the activated sludge process, where microorganisms are present suspended in the biological treatment reaction chamber, and the biofilm process where microorganisms are present attached to the carriers. In each process, the advanced removal of nitrogen and phosphorous in the septic tank is being put into effect for the conservation of lakes, marshes, inland seas and inland bay basins as a measure against eutrophication. In this case, certain devices are implemented to maintain alternately



Reaction	Deaminication	Nitrification	Denitrification
Consumption of alkalinity	Alkalinity of 3.57 mg/L is generated when organic nitrogen 1 mg/L is deaminated.	Alkalinity of 7.14 mg/L is generated when ammonium nitrogen 1 mg/L is nitrified.	If nitrate nitrogen 1 mg/L is denitrificated, alkalinity of 3.57 mg/L is generated. C/N ratio is required in the range of 3 to 5 for denitrification reaction.
State of treatment functions	Nitrogen in wastewater is almost ammonium or organic nitrogen. And the ratio of ammonium and organic nitrogen is 4:6	pH value can drop if inflow alkalinity is low. 。 ⇩ Treatment capacity drops and sludge is removed	pH value can increase to generate alkalinity. pH value can be protected from lowering by combining nitrification with denitrification and processing functions are stabilized.

Fig. 8-1-1 Nitrogen removal mechanism in biological nitrification and denitrification reaction.

anaerobic and aerobic conditions, and remove human waste contained in residential wastewater and nitrogen and phosphorous deriving from gray water.

To remove nitrogen, it is first essential to transform amino acids and protein contained in residential wastewater as organic nitrogen into ammonia nitrogen through deamination reaction in the anaerobic reaction chamber, and then transform ammonia nitrogen into nitrate nitrogen in the aerobic reaction chamber by the nitrifying bacteria. This aerobic-treated water, transformed into nitrate nitrogen, is circulated back to the anaerobic reaction chamber; and by the work of denitrifying bacteria that can effectively utilize the oxygen bonded to nitrate nitrogen(NO_3 —N), and by utilizing the BOD that is an organic substance contained in the inflowing residential wastewater as the energy source and the bonded oxygen within NO_3 as the respiratory source, the nitrate nitrogen synthesizes bacteria and transforms itself into an N_2 gas. Thus, nitrogen is removed (Fig.8-1-1).

This kind of circulation of aerobic chamber-treated water back to the anaerobic reaction chamber is used in small-scale biofilm processes for 5 to 50 people as well as large-scale anaerobic-aerobic activated sludge processes. In medium- or large-scale types for more than 51 people, intermittent aeration-activated sludge processes and batch-activated sludge processes are also used to form anaerobic-aerobic conditions.

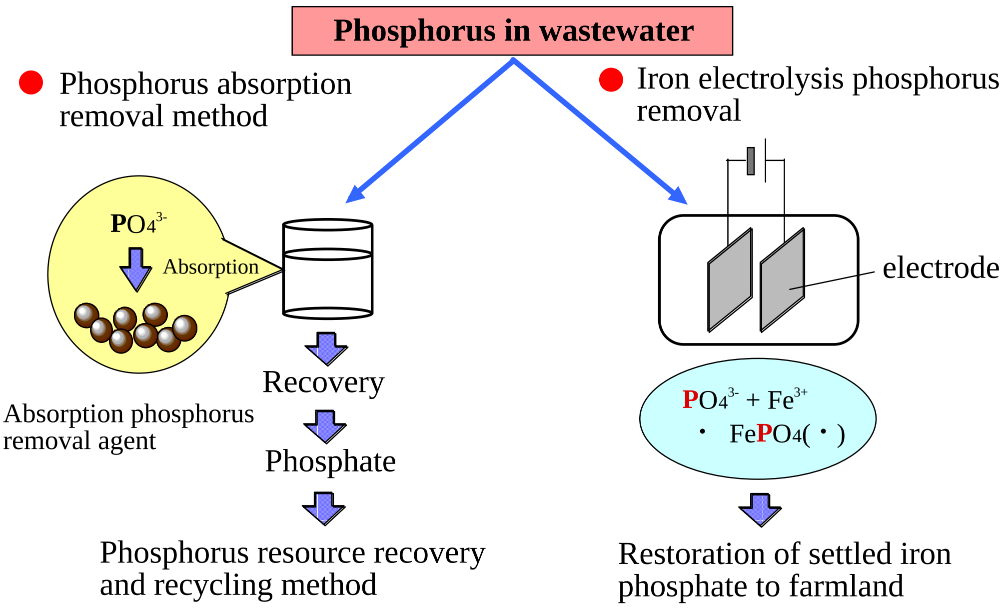


Fig. 8-1-2 Physicochemical phosphorus removal systems

Also, biological processes and physicochemical processes are used to remove phosphorous. One representative of these biological processes is the process where inanaerobic-aerobic conditions utilize the phosphorous-trapping speed in an aerobic condition. This gets to be ten times the phosphorous- releasing speed in an anaerobic condition, causing phosphorous to excessively accumulate in sludge in excess of 5% against the normal 1.5 to 2%. In this process, sludge needs to be extracted at an adequate frequency. Physicochemical processes include the coagulating sedimentation method, the adsorption-dephosphorylation method and the iron electrolysis-dephosphorylation method (Fig. 8-1-2). Of these, the adsorption-dephosphorylation method is one of the more important processes. In this method phosphorous is adsorbed in a tower packed with zirconium carriers; then alkali is added, and the phosphorous is desorbed and recovered for use as a resource. The iron electrolysis-dephosphorylation method is a process where a weak electric current is made to flow across the anodic and cathodic iron plates, and the eluted iron ions are reacted with phosphorous ions contained in the inflowing residential wastewater to become coagulated and removed. This kind of phosphorous removal method is applied to small-scale and large-scale treatments in a varying manner depending upon the characteristics of the treatment.

(2) Flow of the system

1) Flow of small-scale treatment

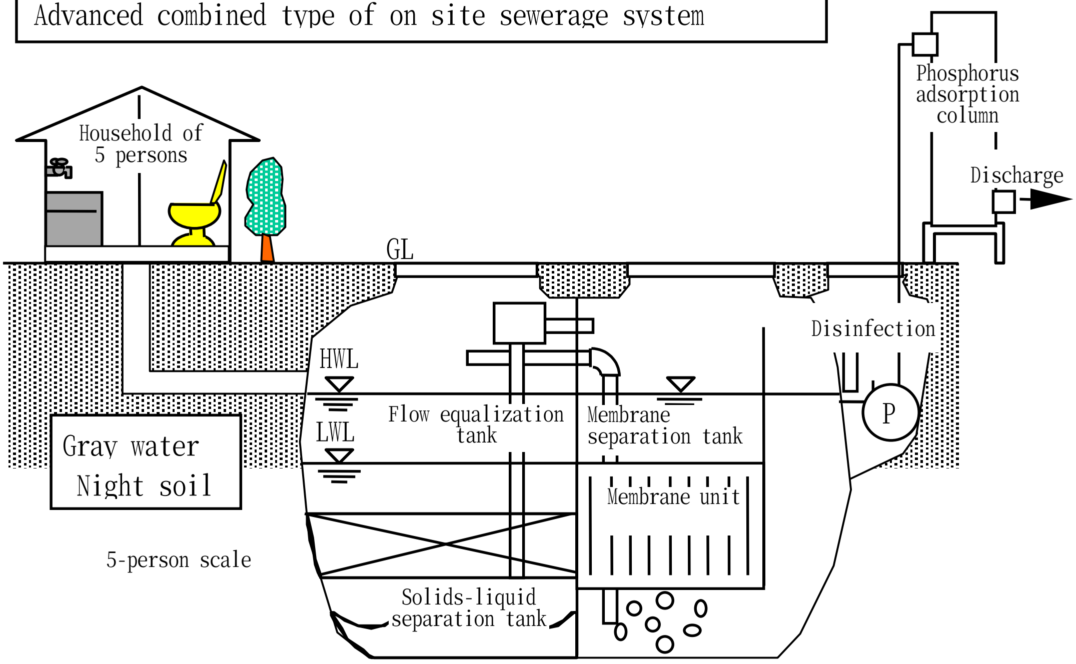
A small-scale advanced treatment septic tank is a system for removing nitrogen by controlling the flow and circulating the water treated in the aerobic reaction chamber in order of the anaerobic-aerobic chamber. For the aerobic chamber, the biological filtration method, the membrane separation- activated sludge method and the contact-aeration method are used. In addition to these nitrogen-removing methods, the adsorption-dephosphorylation method and the iron electrolysis method are employed to remove phosphorous (Fig.8-1-3). The treatment flow of a representative system is shown in Fig.8-1-4~6.

2) Medium and large-scale system

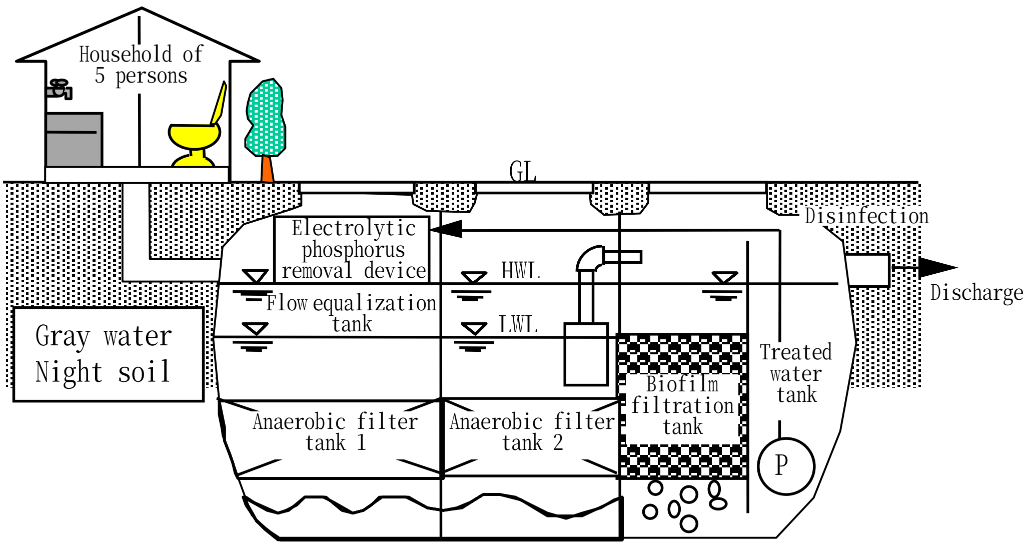
A medium- or large-scale advanced treatment septic tank is basically of the type that controls the flow causing the anaerobic and aerobic conditions to alternate. Processes employed principally to remove nitrogen are: the intermittent anaerobic-aerobic aeration-activated sludge process that has an on-off control of the air supply; the anaerobic-aerobic batch-activated sludge process that repeats inflow-aeration (aerobic)-non-aeration (anaerobic) –sedimentation -discharge; the anaerobic-aerobic circulation-activated sludge process that consists of a non-aeration (anaerobic) chamber, an aeration chamber (aerobic) and a sedimentation chamber, which returns or circulates the sedimented sludge and the activated sludge of the aeration chamber by 50% to 100% and 200% to 300%, respectively. In these anaerobic-aerobic activated sludge processes, phosphorous is also removed biologically. In case there is any stability problem due to fluctuating inflow loads or seasonal fluctuations of water temperatures, the stability in phosphorous removal will be obtained by adding in the activated sludge reaction chamber coagulants such as polyaluminum chloride(PAC), aluminum sulfate, ferrous chloride or ferric chloride to reach a molar ratio of two to phosphorous contained in the directly inflowing water in respect of Al or Fe($^{Fe}/_{p}$, $^{A\ell}/_{p}$) .

Also, in combination with the biological treatment process, the iron electrolysis-dephosphorylation process, the adsorption-dephosphorylation process and the coagulating sedimentation process are employed. The treatment flow of the representative systems is shown in Fig. 8-1-7~9.

Advanced combined type of on site sewerage system



Membrane separation activated sludge type of advanced combined type of on site sewerage system



Biofilm filtration type advanced combined type of on site sewerage system

Fig. 8-1-3 An outline of Advanced combined Johkasou

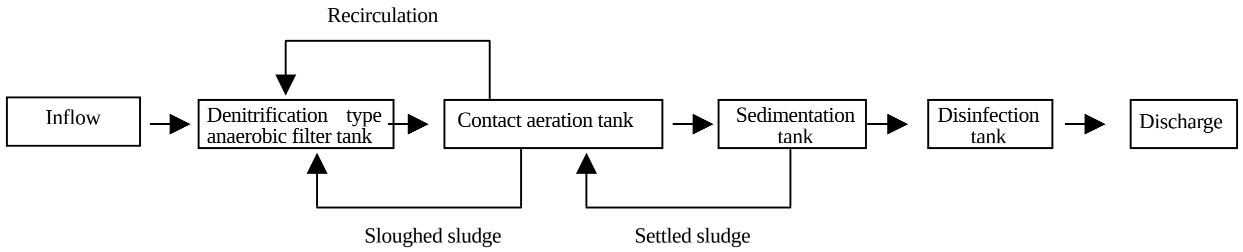


Fig. 8-1-4　Denitrification type anaerobic filter contact aeration process

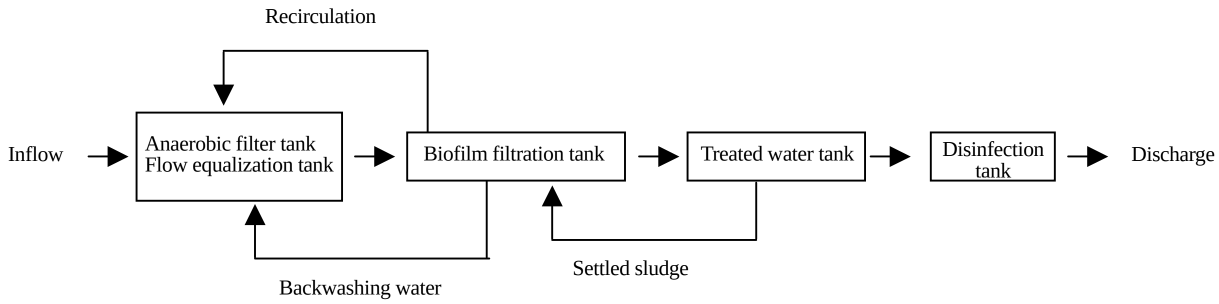


Fig. 8-1-5　Biofilm filtration process

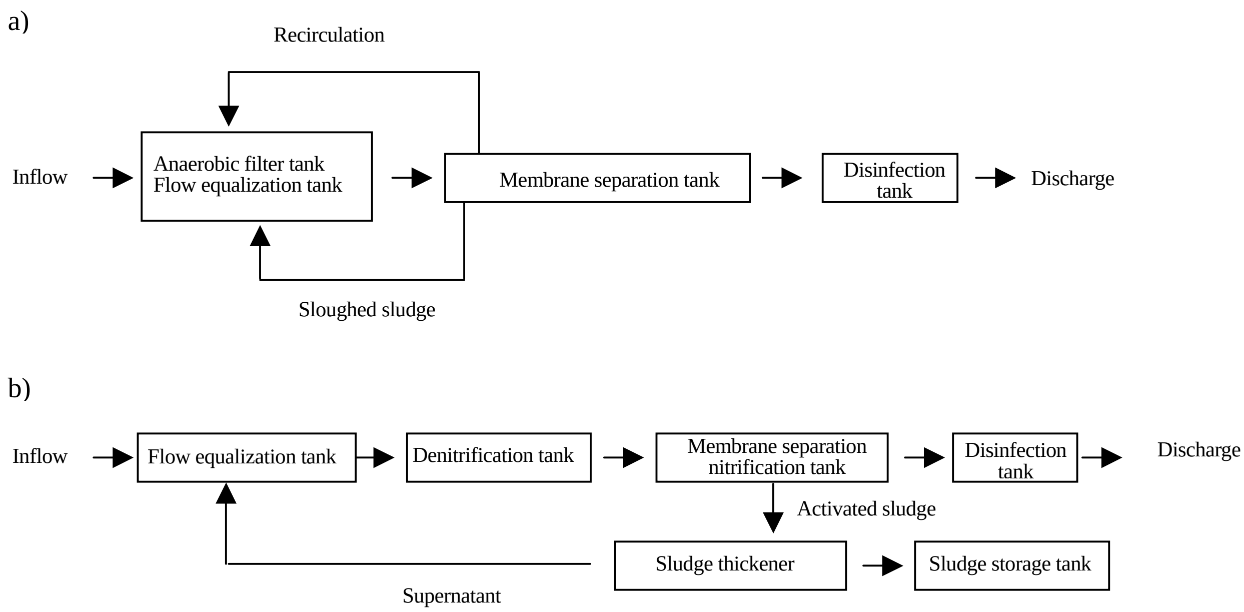


Fig. 8-1-6　Activated sludge process with membrane filtration

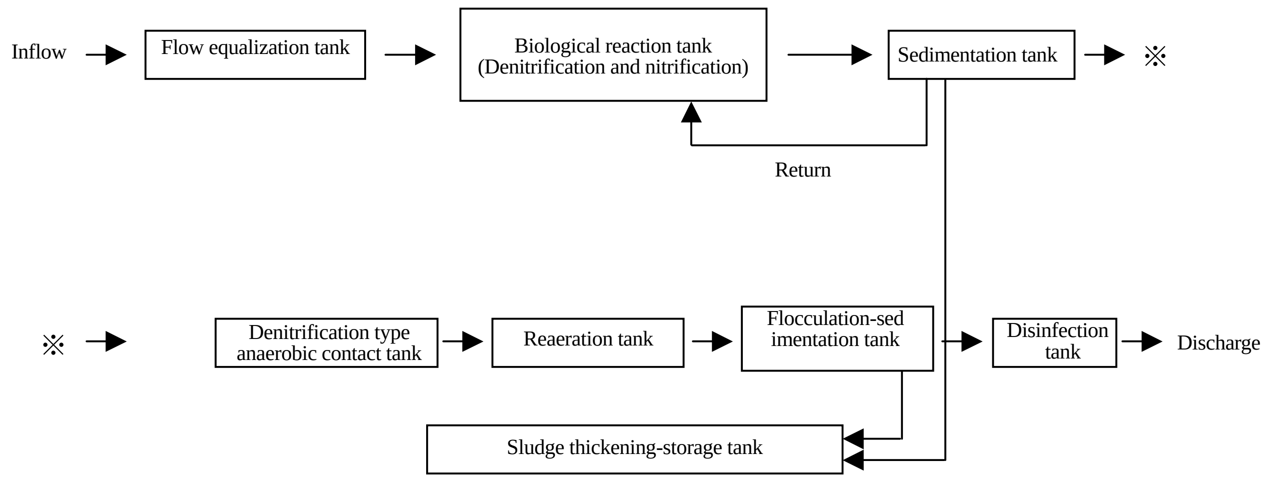


Fig. 8-1-7 Nitrified water recirculation type activated sludge process and tertiary treatment

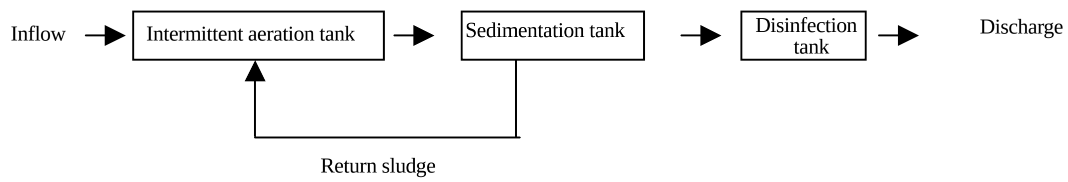


Fig. 8-1-8 Intermittent aeration type anaerobic-aerobic activated sludge process

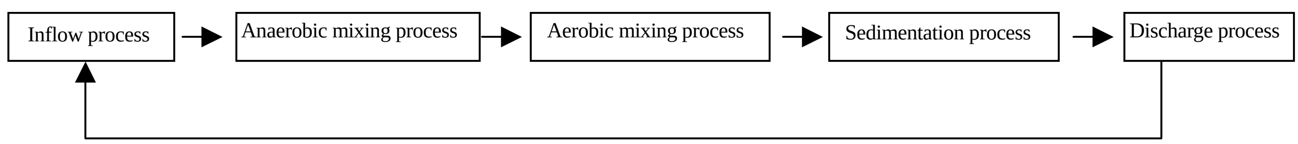


Fig. 8-1-9 Batch system anaerobic-aerobic activated sludge process

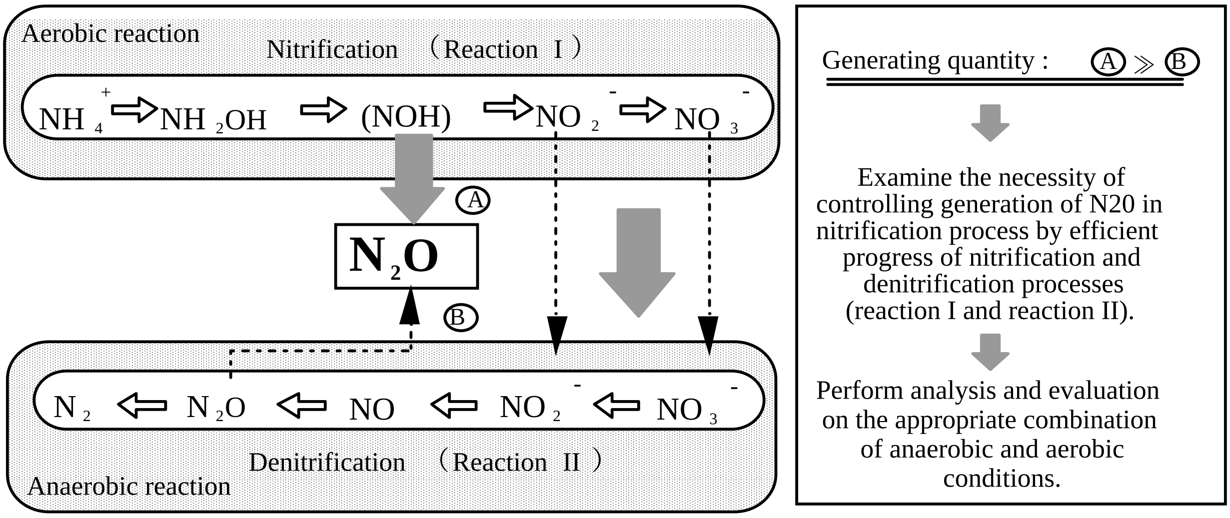
(3) Features of the system

The greatest feature of the advanced combined treatment septic tank system lies, whether it employs either the biofilm process as a biological treatment or the activated sludge process, in the alternate repetition of the anaerobic and aerobic conditions so as to ensure the efficient removal of nitrogen through the nitrification-denitrification reaction. Another important feature of the system is that it allows biological or physicochemical removal of P.

Table 8-1-1 Concept of basic specifications for septic tanks

Effects of performance that is improved with the principle of basic specifications incorporated.

- Eutrophication, that is, nitrogen as major causes of water bloom, red tide, and green tide can be highly and efficiently removed.
- Oxidization of pH in nitrificating reaction can be neutralized by alkalinity in denitrificating reaction, solids-liquid separation can be smoothly performed with improved coagulation capacity of microorganisms, and clearness of treated water can be improved.
- In contact aeration process, since water clearness increases in reaction vessel and sludge discharge can be controlled even at peak time if separated sludge is circulated within anaerobic filter tank, clear treated water and stabilized efficient treatment capacity can be maintained.
- Unusual increase of large vertebrates, such as cladocera, aseli, and gastropods, and offensive microorganisms, including sphaerotilus that can form bulking can be controlled.
- In anaerobic and aerobic circulation methods, nitrificating and denitrificating activations increase due to dilution effects, denitrification effects of inlet raw water by circulation, and effects of improved contact frequency with microorganism groups, and biological nitrification and denitrification can be advanced.
- Either by anaerobic or aerobic circulation, generation of global warming gasses such as CH_4 and N_2
tank, and near-future type water treatment that is familiar to the globe can be executed.



Where potentiality of greenhouse effect gasses causing global warming is assumed as 1 CO2, CH4 has global warming potentiality of 20 to 30 times and N20 has that of 200 to 300 times, and its reduction technology is extremely important.

Figure 8-1-10 N_2O generation mechanism and optimum control system at nitrification and denitrification reaction of biological wastewater treatment

The conventional combined treatment septic tank is aimed at removing only the BOD as an organic substance, and therefore, is impotent as a measure against water-blooms and red tides; in the Lake Kasumigaura basin, it has been confirmed that the diffusion of conventional septic tanks has been of no use in preventing eutrophication. Therefore, the high nitrogen and phosphorous removing function, which is an outstanding feature of the advanced combined treatment septic tank, has has a great impact on the creation of a healthy water environment.

In addition to the nitrifying, denitrifying and dephosphorylating reactions during the treatment process that incorporates anaerobic and aerobic conditions, the system has a great effect on restraining the generation of greenhouse gases as shown in Fig. 8-1-1 and 8-1-10. Thus, the system has versatile and important features of removing nitrogen and phosphorous as a preventive measure against eutrophication and restraining the generation of CH_4 (methane) and N_2O (dinitrogen monoxide), and exercises a great effect on advanced treatment functions.

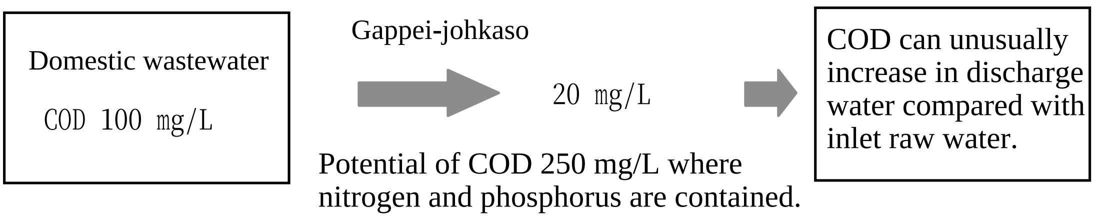
8-1-2 Performance of the System

The performance of the advanced combined treatment septic tank system lies basically in providing water qualities below BOD10 mg/L, T-N10 mg/L and T-P1 mg/L. Thanks to technological development, small-scale systems are capable of providing qualities below T-P1 mg/L in addition to BOD10 mg/L and T-N10 mg/L. In order to prevent eutrophication in particular, the system is required to provide qualities below 10 mg/L on T-N and 1 mg/L on T-P. Such requirements are clearly shown by a comparative analysis of the nitrogen and phosphorous loads that will be

Table 8-1-2 Typical AGP in final effluent discharged from combined aeration-type septic tank

Provided *Cyanobacteria* \ Facilities	AGP (mg/L) A	B	C	D	Average
Selenastrum capricornutum	430	520	590	580	530
Chlorella sp.	290	370	440	370	368
Chattonella sp.	450	430	430	390	425

If AGP measured is 500 mg/L or less, CODMn of 250 mg is produced from one final effluent from septic tank.



AGP Test : This is an evaluation method of potential algae increasing capacity that evaluates specimen water for capacity of increasing algae in public water areas through testing with flasks filled with treated wastewater to inoculate the specimen water with algae and to measure the increased number of algae at maximum after cultivation of 10 days under direct lighting.

imposed on the water area when vault toilets are converted into flush toilets. That is, the primary units relating to the residential wastewater discharged daily per person from flushed human waste and from the kitchen, bathroom, laundry, etc. are: 50L and 200L(250L in total), respectively in the amount of water; 13 g and 27 g (40 g in total), respectively in the BOD; 8 g and 2 g (10 g in total), respectively in the T-N; and 0.7 g and 0.3 g (1 g in total), respectively, in the T-P.

In the case of vault toilets, residential gray water is discharged untreated; however, human waste is collected and cleared completely of nitrogen and phosphorous through high-tech treatment at human waste treatment facilities. In this case, concentrations of nitrogen and phosphorous that are discharged as residential gray water are calculated from the primary units in the following manner:

For nitrogen 2 g ÷ 200L = 10 mg/L

For phosphorous 0.2 g ÷200L=1 mg/L (use of phosphorous-free detergents is taken into consideration)

At present although gray water is discharged untreated, human waste is rendered almost completely free from nitrogen and phosphorous at treatment facilities; then, the above calculations indicate that converting vault toilets storing such treated human waste into flush toilets for a more advanced lifestyle will not reduce the nitrogen and phosphorous loads in the water areas unless the treatment performance of residential wastewater consisting of both human waste and gray water is capable of lowering the concentrations of nitrogen and phosphorous below T-N10 mg/L and T-P1 mg,/L which are equivalent to the concentrations of gray water discharged untreated. Consequently, in closed water areas such as lakes, marshes, inland seas and inland bay basins, it is essential for the system to be provided with a feature that ensures water qualities below T-N10 mg/L and T-P1 mg/L; otherwise, pollutant loads to the environment will not be reduced below the level maintained by vault toilet systems.

There is an evaluation test called the AGP (algal growth potential) test to analyze and evaluate, prior to its discharge into public waterways, the potential of treated residential wastewater to cause algal proliferation. In this method, samples of various kinds of wastewater are collected before and after treatment, placed in triangular flasks, inoculated with algae, irradiated by light (bright for 12 hours, dark for 12 hours) and cultured for ten to fourteen days at a controlled temperature of around 20°C until algae reach the maximum proliferation that is close to the actual conditions of lakes, marshes, inland seas and inland bays. Then, by checking the samples' capacity to cause proliferation, a prior evaluation can be made to show the potential of the discharged water to cause algal proliferation in water areas.

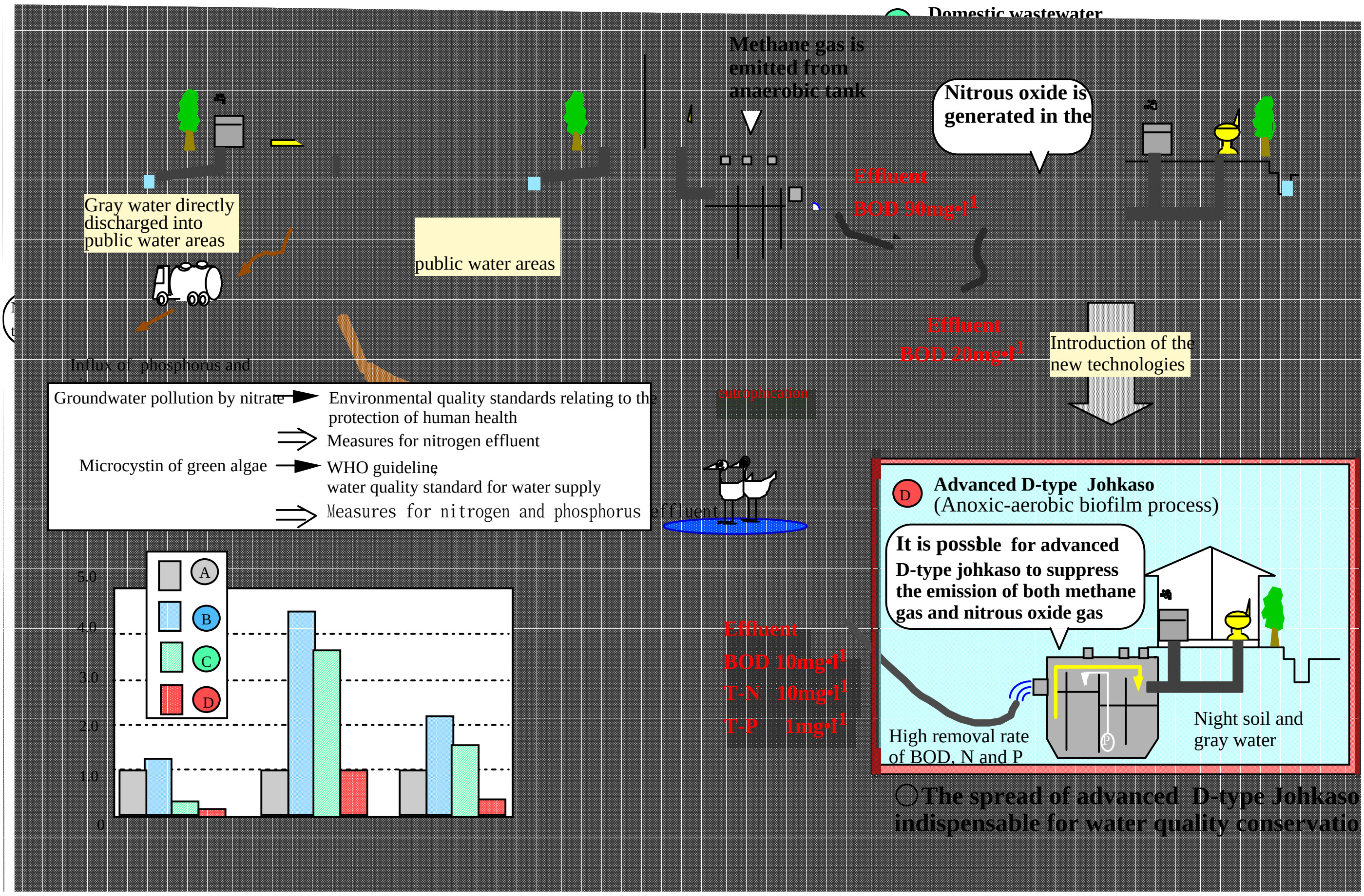
The effects of removing nitrogen and phosphorous from residential wastewater based on AGP tests are shown in Fig. 8-1-2. The results indicate that similar tendencies are observed on the algae that compose water-blooms appearing in lakes and marshes, and the algae that form red tides appearing in inland seas and inland bays. Such AGP tests show how measures aimed at removing the BOD alone are impotent in sewerage systems, small-scale wastewater treatment facilities in agricultural villages and septic tanks. This leads to an understanding of the essentiality of changing to nitrogen and phosphorous removal.

8-1-3 Ripple Effect of the System

There has been remarkable progress in the technological development of septic tanks that are positioned as a key measure of residential wastewater treatment as opposed to the sewerage system. As the conventional BOD- removing tanks are incapable of preventing the progressive acceleration of eutrophication, the 1995 amendment to the standards on septic tank structures added a nitrogen and phosphorous removing structure in place of the BOD removing structure. For small-scale combined treatment septic tanks, the technically established nitrogen- removing method was introduced while for medium- and large-scale combined treatment septic tanks, the combination of the nitrogen-and phosphorous-removing, nitrifying liquid-circulating and anaerobic-aerobic activated sludge process, and the coagulating sedimentation process was introduced.

Table 8-1-3 Outline of method and performance of small-scale advanced combined treatment septic tank

Treatment method	Quality of dis-charged water (mg/l)	Representative features	Representative operating conditions
Flow-controlled anaerobic filter bed biofilm filtration circulation method	BOD 10 T-N 10 SS 10	Treated water is circulated from an aerobic to anaerobic condition; is sent to an aerobic biological treatment chamber in a constant controlled volume; then, is highly cleared of nitrogen through biological filtration combined with the above process.	BOD space loading in bio-logical filter chamber: 1 Rate of carrier packing: 70% Circulation ratio: 4 Packing carrier: made of porous ceramics
Flow-controlled anaerobic filter bed carrier fluidized aeration and highspeed solid-liquid separation method	BOD 10 T-N 10 SS 10	Treated water is circulated from an aerobic to anaerobic condition; is sent to an aerobic biological treatment chamber in a constant controlled volume; then, is highly cleared of BOD, nitrogen and SS through fluidized aeration packed with small cylindrical carriers and high-speed solid-liquid separation using the carriers in combination with the above process.	BOD space loading in fluidized carrier aeration chamber : 0.4 Circulation ratio: 2 Packing carrier: made of polyethylene
Flow-controlled agitating filter bed biofilm filtration circulation method	BOD 10 T-N 10	Treated water is circulated from an aerobic to anaerobic condition; the water level fluctuates in all chambers; the discharged water is controlled in a constant volume and cut at its peak; and furthermore, through biofilm filtration, the water is highly cleared of BOD, nitrogen.	BOD filter material space loading in biological filtration chamber: 0.2 Circulation ratio: 4 Packing carrier: made of porous ceramics



Discharge of untreated wastewater regarding

nitrogen and phosphorous

・Make a comparison on the assumption that at present, gray water is discharged untreated while human waste is 100% dipped and treated at human waste treatment facilities, thus giving pollutant loads of 100.

・Show the increase or decrease in pollutant loads due to the difference in applied treatment methods when vault toilets are converted into flush toilets

・Set up the percentage of nitrogen and phosphorous removal at each treatment facility

Treatment facilities	BOD	T-N	T-P
Human waste treatment facilities	100%*	100%*	100%*
Individual treatment septic tank	65%	12%	25%
Combined treatment septic tank	90%	27%	37%
Advanced combined treatment septic tank	95%	80%	90%**

* Set at 100% because the rate of removal obtained for the concentration of treated wastewater to the concentration of primary wastewater is higher than 99.9%.

** Percentage obtained by advanced combined treatment septic tanks when iron materials are added.

○ The diffusion of combined treatment septic tanks that put into effect the advanced treatment greatly contributes to improving water environments.

○ In residential wastewater treatment, this comparative evaluation commonly applies to septic tanks, sewerage systems and small-scale wastewater treatment facilities in agricultural villages; the evaluation indicates the essentiality of advanced treatment.

Fig. 8-1-11 Importance of the spread for installation of advanced domestic wastewater treatment Johkaso for the conservation of closed public water bodies.

A particularly higher performance, compact size, energy conservation, low cost and easier maintenance and management are important tasks for proceeding with future technological development; therefore, by allowing such new technology to be freely implemented, new technology septic tanks are positioned as type Notification No.13. Table 8-1-3 shows the method that enables this small-scale advanced combined treatment septic tank to provide water qualities below 10 mg/ using such new technology.Furthermore, in and after June 2000, technical evaluation will be conducted additionally based on performance criteria, or evaluation based principally upon the ideas incorporated into Type 13. The new evaluation criteria are expected to give a great impetus to the development of technology for removing nitrogen and phosphorous. In view of all this, it is important to promote the development of technology for advanced combined treatment septic tanks aimed at creating healthy water environments and their diffusion, in such a manner that the general public may become aware of the importance and the promotion be conducted, not in a system conducted vertically among government ministries and agencies, but across all ministries and agencies. Fig. 8-1-11 shows how healthy water environments should be created through the diffusion of advanced combined treatment septic tanks. The provision and installation of advanced combined treatment septic tanks is also important as a measure not only against eutrophication, but also nitric acid pollution of underground water. In February 1999, the concentrations of nitrous acid and nitric acid lower than 10 mg/ were positioned among the health items of the environmental standards. In such circumstances, Tokyo has put into effect guidelines that require the installation of advanced combined treatment septic tanks in underground water-permeating areas that are capable of providing water

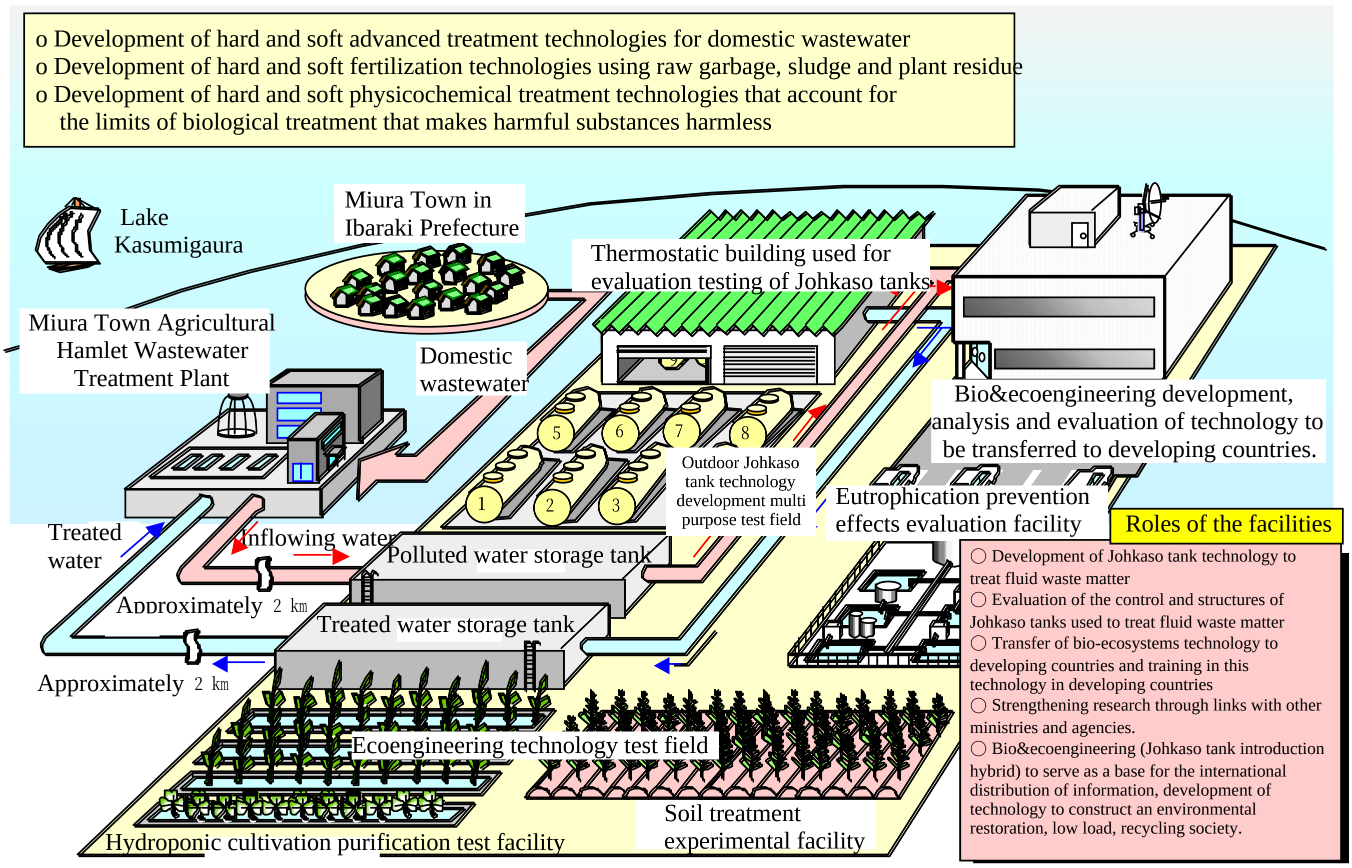


Fig.8-1-12 The Bio&Ecoengineering Research Center Positioned to Perform Hard and Soft Development and Reseach on Soil and Fluid Waste Matter

qualities below BOD10 mg/L and T-N10 mg/L to ensure that such tanks keep within the environmental standards and observe the quality of underground drinking water below 10 mg/L as stipulated in the guidelines.

It is also very important that in relation to the use of disposers stated in the Comprehensive Technological Development Project (Comprehensive Project drawn up by the Ministry of Construction ─ now the Ministry of Land and Transport), an agreement was reached on septic tanks described in the latter part with advanced treatment methods to provide water qualities below BOD10 mg/L, T-N10 mg/L and T-P1mg/L so as not to increase loads on the sewerage systems. Concurrently, with the above system, advanced combined treatment septic tanks have been developed for disposers that provide water qualities below BPD10 mg/L and T-N10 mg/L. Thus, disposers are expected to play an important role in building a recycle-oriented society with less load on the environment, provided that the installation of individual disposers is prohibited and proper arrangements are made in areas where vault toilets or independent treatment septic tanks are in use. Bioecoengineering research facilities in charge of such technological development were made available at the National Institute for Environmental Studies (Fig. 8-1-12).

Recently, triggered by nitrogen and phosphorous, a certain phenomenon is becoming increasingly patent; at lakes and marshes water-blooms, which form microcystins ─ a toxin stronger than potassium cyanide ─ are proliferating, while in inland seas and inland bays, toxic red tides are spreading more frequently. All this indicates the essentiality of developing technology for advanced treatment septic tanks intended to prevent wastewater treated in septic tanks from affecting the ecosystem.

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8-3. Biopark Aquaculture Purification

8-3-1 Principle of the system and its features

(1) Outline of the system

A. Introduction

Tracheophytes, except free-floating plants and air plants, are normally planted and cultivated in cultivation-beds made of earth, sand or sponge. However, the biopark system sets up an environment with shallow-running water, where each plant is forced to make its own cultivation-bed by its rootstalks, and cultivates the plants amid successively supplied polluted water. The biopark is a system that uses the rootstalks of cultivated plants as filter materials, makes the organisms inhabiting the rootstalks perform bio-accumulation and sludge reduction, and by extracting all of the growing plants and accumulating sludge as well as the fish and shellfish gathering and proliferating there, it extracts nutritive salts and turbidity from the water and puts them to use. The capacity and cost of the system to remove nutritive salts and pollution-indicator substances in eutrophicated lakes and marshes is greater and lower in comparison with those of purification by aquatic plant cultivation or water treatment plants, per area of the facilities and per gram of removed nutritive salts. The system is aimed at producing plants and animals with the highest possible marketable prices to partially recover and reduce the purification cost while contributing to improving the productivity and nutritional state of the area as shown in Fig. 8-3-1(coexistence of purification and production by the biopark system).

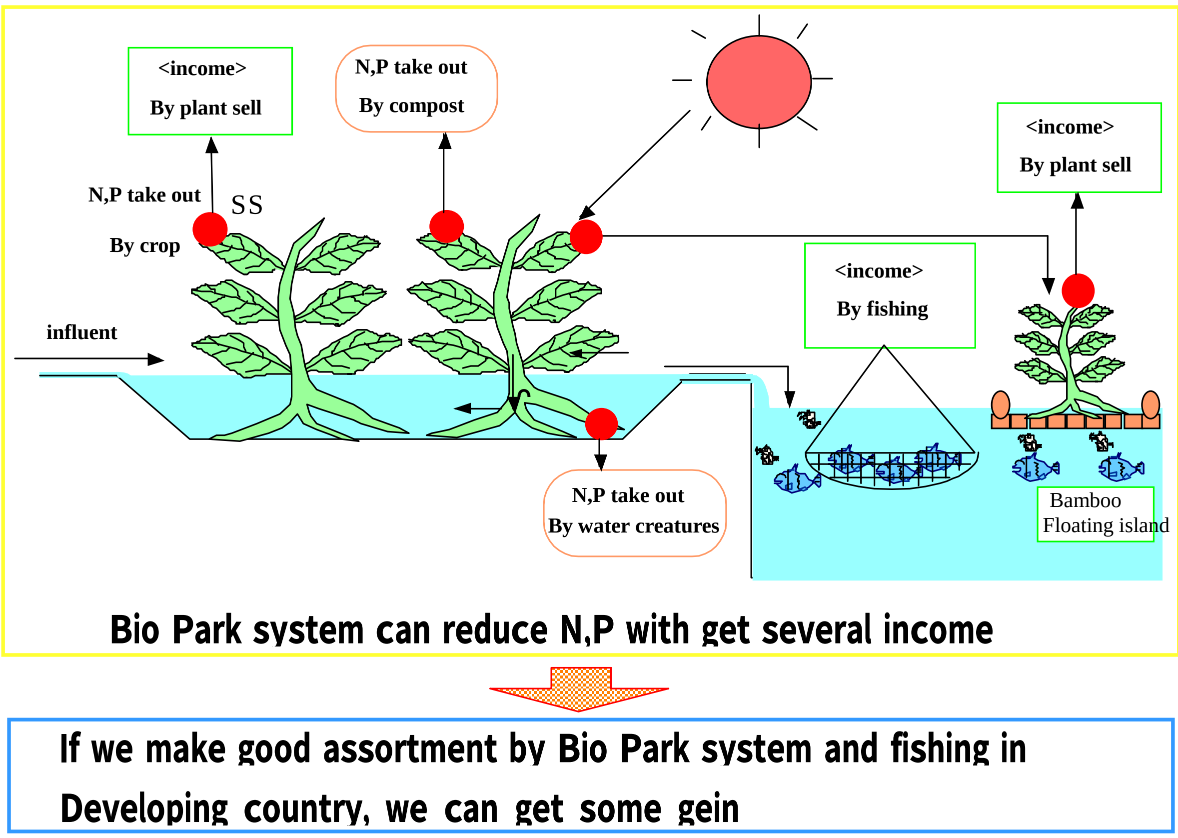


Fig8-3-1 N,P reduce and sell income by Bio Park system

B. Structure of the facilities

In biopark aquaculture purification, plants suitable for the water quality, climatic conditions and market demand are arranged in a shallow and wide waterway, which is inclined 1 to 0.5%, over one meter wide and more or less 20 meters long, and made of materials that permit no water permeation or destruction by plant roots; and through the waterway, the primary water is made to flow at the rate of 3 m^3 per m^2 a day. Several waterways are installed in parallel along with an individual structure that is capable of controlling, stopping completely or draining the water supplied through each waterway (See photo 8-3-1 showing experimental biopark facilities in Thailand). Outlets to discharge treated water into rivers, lakes or marshes attract a large number of fish and shellfish; therefore, it is recommendable to set some devices to capture them as shown in Photo 8-3-2 (a total of 74 crucian carp and other fish gathered in a coop placed at the outlet of the discharged treated water at the biopark).

C. Cultivated plants

Plants to be cultivated shall chiefly be evergreen, perennial, aquatic or wet plants that form flat communities, and mixed with standing plants and/or deciduous plants according to demand or landscaping purposes. For rivers, lakes and marshes polluted as a result of eutrophication, plants suitable for the temperature and the COD can be selected; however, as many species suffer from lack of ingredients in highly treated sewage or underground water rich in nutritive salts, plants other than those that develop tuberous stalks or underground stalks are difficult to cultivate. Community-forming plants that are suitable for cultivation with the highest purifying capacity are watercress for the temperate zones (shown in Photo 8-3-3), and swamp cabbage for the tropical regions (shown in Photo 8-3-4). The plant suitable for purification of underground water and treated sewage in the temperate regions is known as *zantedeschia aethiopica* shown in Photo 8-3-5 (being cultivated at sewage treatment facilities); however, no advanced study has been made regarding the tropical regions. The biopark method has been put into practice in Japan, Thailand and China, and these plants mentioned are known to be obtainable. In diffusing the method in other areas, it will be better to review the maximum and minimum temperatures of the area, obtain and cultivate seeds or inserted ears of watercress or swamp cabbage, trying at the same time to cultivate locally consumed plants.

(2) Principle of purification

A. Biofilm treatment

Water purification in the biopark system starts with microorganisms forming biofilms at the surface of the rootstalks of the cultivated plant and eating the turbidity of the primary water. The rootstalks of the cultivated plant form a mat-like layer so thick that the overall length of the roots contained in 1 cm^3 of the mat may extend to ten meters. It is tiny animals such as *Physidae* shown in Photo 8-3-6 that eat the biofilms formed on the root surface, prompt its metabolism and keep it active, dropping at the same time between the rootstalks, in the form of excrements, the pollution- originated nutritive salts trapped by the biofilms (Photo shows a *Physidae* perched on the root of a swamp cabbage eating the bilofilms). In building and operating biopark facilities, there is no need to inoculate microorganisms that form biofilms; however, small-size snails such as *Physidae* may be collected from the surrounding environments and released in the waterways for a better start-up of the purification.

B. Ecological accumulation and sludge reduction

Leeches that eat snails, crawfish that eat leeches and other diverse animals form an ecosystem; their excrement and bodies turn into sludge and accumulate among plant roots. This accumulation, if compared with the turbidity that is removed in the waterways, has condensed nutritive salts and reduced volume. Animals that form saprophytic food chains such as aquatic insects and aquatic earthworms also appear; they accumulate nutritive salts, reduce sludge volume, mineralize the salts and render them absorbable by plants.

C. Absorption of nutritive salts and harvest

Plants absorb nutritive salts from sludge derived from water turbidity and formed through ecological accumulation, grow new rootstalks in the water and continue to retain sludge; humans harvest the plants that have grown absorbing nutritive salts as vegetables and flowers; as a result, nutritive salts are extracted while simultaneously, a new space is made for plants to grow again actively absorbing nutritive salts.

D. Removing composted sludge and restart of purification

When sludge has accumulated sufficiently, the water supply to the facilities waterways is alternately cut; water is let out and the plants are made to absorb and vaporize the water contained in the sludge. When the sludge has dried up and the plants withered, the remnants in the waterways are extracted and piled up; they ferment at high temperature and turn into useful compost; then, plant seedlings are introduced through the waterways to restart the purification.

E. Catching fish and shellfish and their removal

Part of the microorganisms and small animals that purify water flow out of the facilities on the treated water and amass around the discharge outlet, where fish and shellfish feed on them. If they are captured, the nutritive salts within can be extracted. Many of the fish and shellfish enter the waterways as eggs or larvae, or go upstream through the treated water discharge canals, reach the waterways and grow and proliferate; if captured, nutritive salts can also be extracted. The balance of removing nutritive salts through the above mechanism is summarized in Fig.8-3-2.

Photo 8-3-1 Bio-park facilities in the Kingdom of Thailand

Photo 8-3-2 Fish caught around the discharge outlet

Photo 8-3-3 Watercress

Photo 8-3-4 Swamp cabbage

Photo 8-3-5 *Zantedeschia aethiopica*

Photo 8-3-6 *Physidae*

(3) Features

1) The system removes not only pollution-indicator substances removable by the treatment to decompose BOD, COD, SS, etc., but also removes substances responsible for eutrophication such as nitrogen and phosphorous, turns them into useful products and produces no waste substances.

2) The facilities provide a landscape made up of purified water and low green plants, and are safe and comfortable. As their purifying capacity is little affected by intruding people, the facilities can be opened to the general public as a park.

3) If opened to the public, the facilities can show people how wastewater is purified and have them participate in picking and harvesting vegetables, flowers, compost and fish, all of these being products of the purification process.

4) The system will allow part of the purification expenses to be covered by sales of high-value products.

5) Environmental education can be made available using vegetables, flowers or living creatures that are of great interest to the general public and children. Such education will win popularity that will lead to a deeper understanding of the eutrophication problem.

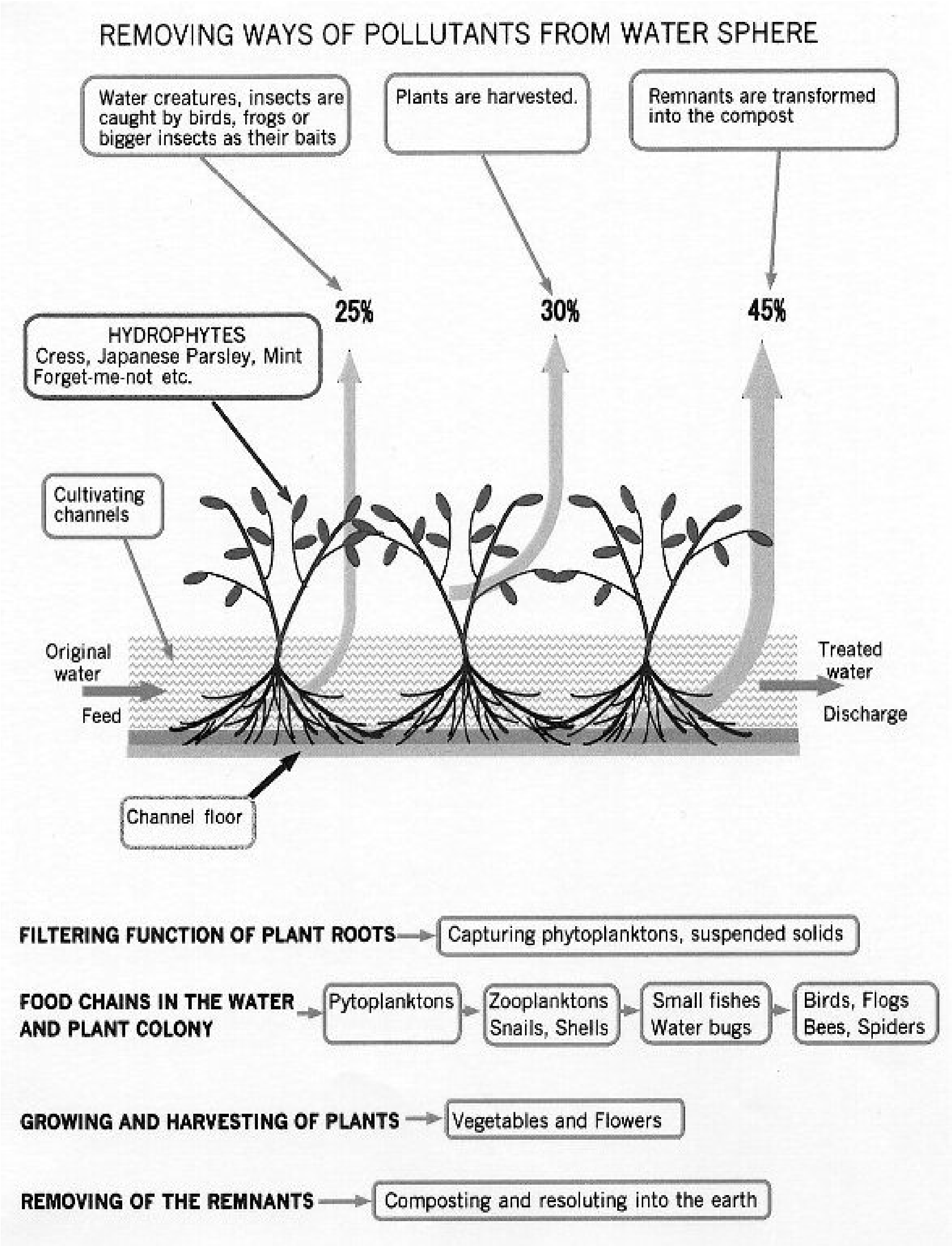


Fig. 8-3-2 Mechanism of nutrient remove in Bio Park

8-3-2 Performance of the System

(1) Purification of eutrophicated lakes and marshes

A. Some examples in Japan

In Japan, ten facilities across the country, including Tsuchiura Biopark shown in Photo 8-3-7 as the largest example, cultivate vegetables and flowers on lakesides and riversides removing nitrogen, phosphorous and turbidity from the water. These are then removed from the facilities by harvesting and consuming flowers and vegetables, and composting and utilizing the accumulating sludge. In recent years, the growth and proliferation of corbiculas has become a new means for extracting nutritive salts. Tsuchiura Biopark is a provisional facility made by building a provisional water supply plant and passages on existing concrete planes. One example of permanent facilities built from basics is Kibagata Biopark shown in Photo 8-3-8.

Photo 8-3-7 Tsuchiura Biopark

Photo 8-3-8 Kibagata Biopark

B. Purification performance

Tshuchiura Biopark has been operating for seven years, Kibagata Biopark for two years. Their average annual purification results are calculated as shown in Table 8-3-1.

Table8-3-1 Annual average purification records at temporary facility of Tsuchiura and permanent facility of Kibagata

Pollutants	Equipment	Influent	Effluent	Removal Rate	Removal Amount
COD	Tsuchiura	9.6 $mg \cdot l^{-1}$	8.3 $mg \cdot l^{-1}$	14%	4.3 $g \cdot (d \cdot m^2)^{-1}$
	Kibagata	8.2 $mg \cdot l^{-1}$	5.6 $mg \cdot l^{-1}$	32%	7.8 $g \cdot (d \cdot m^2)^{-1}$
SS	Tsuchiura	20.9 $mg \cdot l^{-1}$	9.6 $mg \cdot l^{-1}$	54%	50.0 $g \cdot (d \cdot m^2)^{-1}$
	Kibagata	16.0 $mg \cdot l^{-1}$	3.3 $mg \cdot l^{-1}$	79%	38.1 $g \cdot (d \cdot m^2)^{-1}$
T−N	Tsuchiura	3.7 $mg \cdot l^{-1}$	3.1 $mg \cdot l^{-1}$	15%	1.9 $g \cdot (d \cdot m^2)^{-1}$
	Kibagata	1.7 $mg \cdot l^{-1}$	1.1 $mg \cdot l^{-1}$	36%	1.8 $g \cdot (d \cdot m^2)^{-1}$
T−P	Tsuchiura	0.12 $mg \cdot l^{-1}$	0.09 $mg \cdot l^{-1}$	27%	0.16 $g \cdot (d \cdot m^2)^{-1}$
	Kibagata	0.13 $mg \cdot l^{-1}$	0.07 $mg \cdot l^{-1}$	47%	0.18 $g \cdot (d \cdot m^2)^{-1}$

C. Purification capacity and cost comparison

It is difficult to compare the technological efficiency of purification conducted in different conditions; however, one effective comparison of the capacity affecting the balance of pollutants in a water system is that of the removing speed. As the removing speed is proportional to the concentration of the primary water to be treated, purification efficiency will be clearly compared if the correlation straight lines relating to the speed of removing the primary-water concentration of each technology are denoted on the same diagram; then, the removing speed at which each technology treats primary water with a particular concentration will be known. There are few systems applicable to practical use that are capable of purifying eutrophicated lakes and marshes and removing nitrogen, phosphorous and so forth. The systems that do publish detailed comparable data consist of only a system that combines biomodules and the denitrification and phosphorous-removing devices, and a system that purifies polluted water in vegetation wetland. Data collected at the Tsuchiura and Kibagata bioparks are shown in Fig. 8-3-3~4 together with the data obtained at the Thai biopark. The biopark system is known to have better removal efficiency than other systems in the shown range of concentrations. In terms of cost, there are no large-scale systems put into practice that have the combination of biomodules + denitrification + phosphorous removal; therefore, it is only possible to compare the cost of Kibagata Biopark with the cost estimated in a trial design of a large-scale combined system. The cost of the facilities installation measured on the basis of pollutant removal capacity per gram of pollutants per day for the biomodule system is on average 12 times that of the biopark; electricity consumed to remove 1 g of pollutants for the biomodule system costs on average 10 times as much. Data variations in Fig. 8-3-3~4 show that the biopark system is not suitable for cases that require assured quality on the treated water or only a high removal percentage; it is suitable the cases that require as many pollutants as possible to be removed from the water.

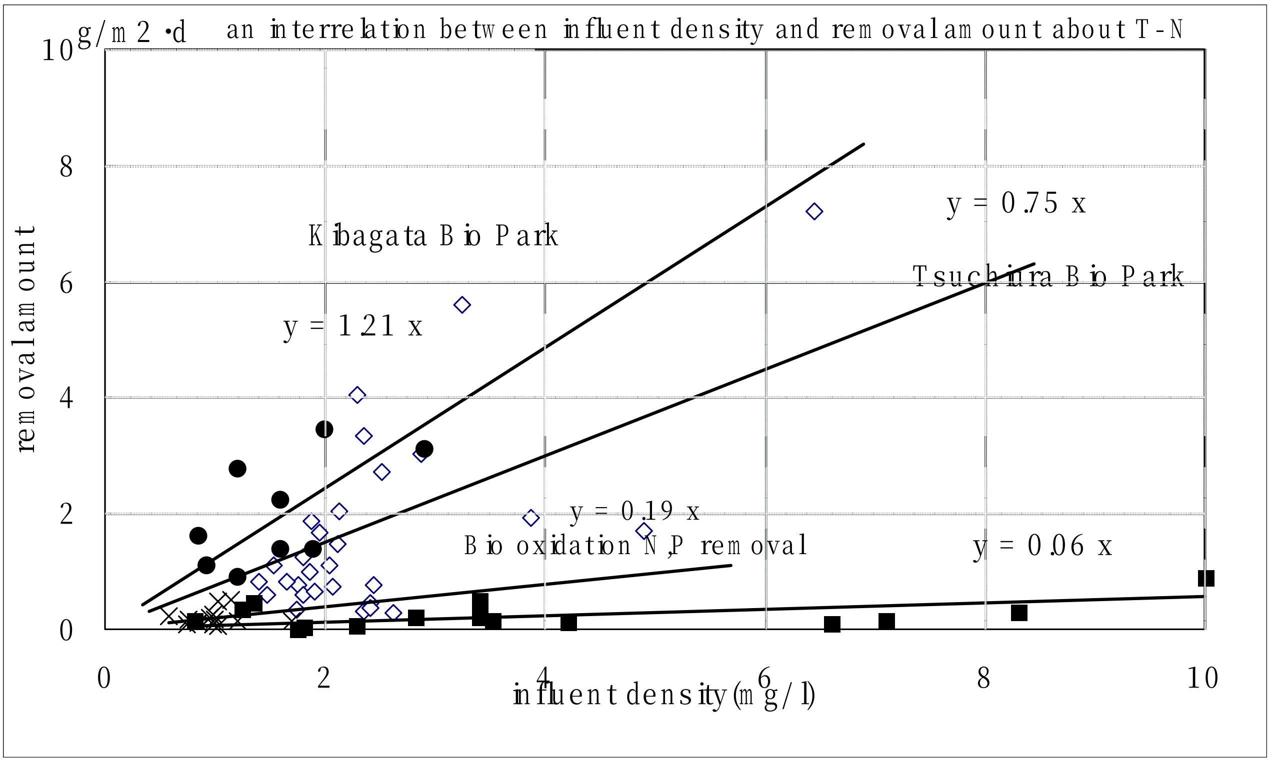
(2) Removing water-blooms

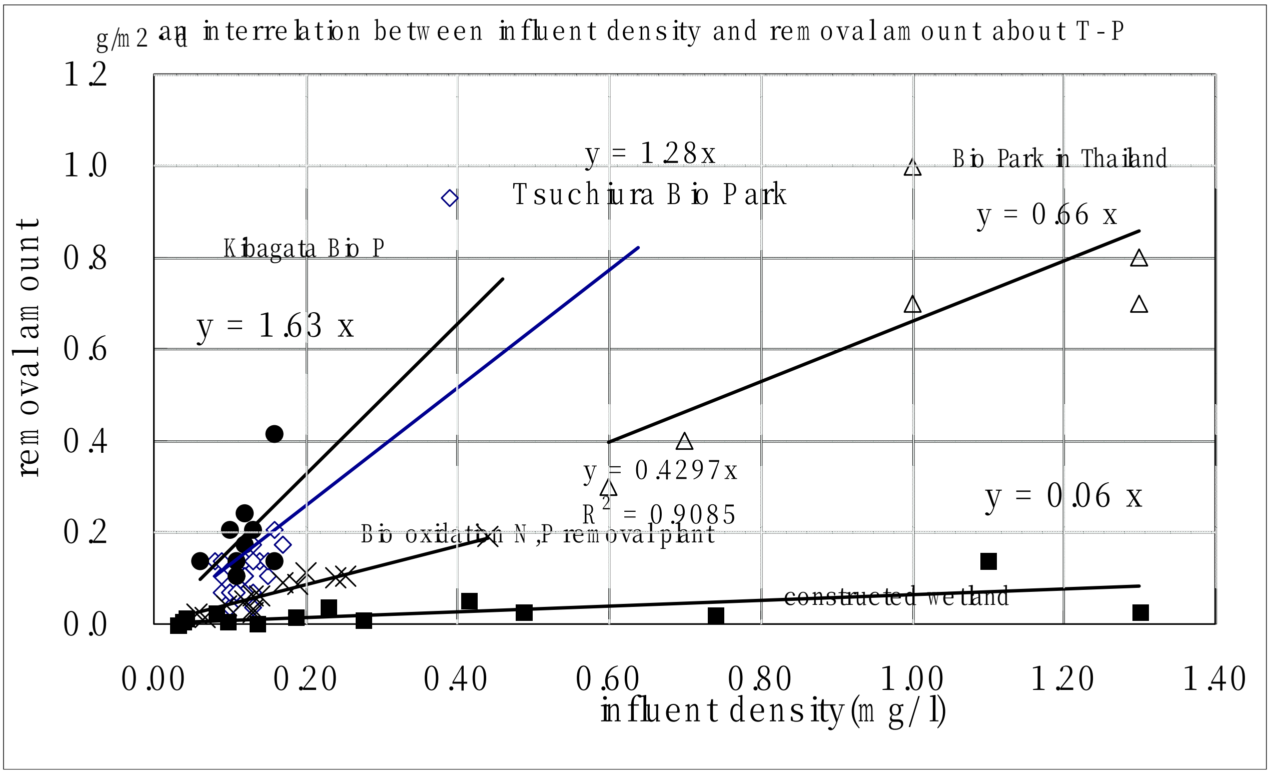
A. Mechanism of removing water-blooms

At a biopark, the ecosystem formed by rootstalk mats is densely inhabited by animals such as creeping-nektonic rotifers and aquatic earthworms that eat relatively dispersed water-blooms. Small snails such as *Physidae* or *radix japonicus* that normally eat biofilms devour water-blooms that are attached to rootstalk mats in large masses or dammed up afloat on water surfaces by stalks. Water-blooms are consumed by these actions, while at the same time microcystins are digested by these animals or decomposed by the action of microorganisms.

B. Japan's examples and their effects

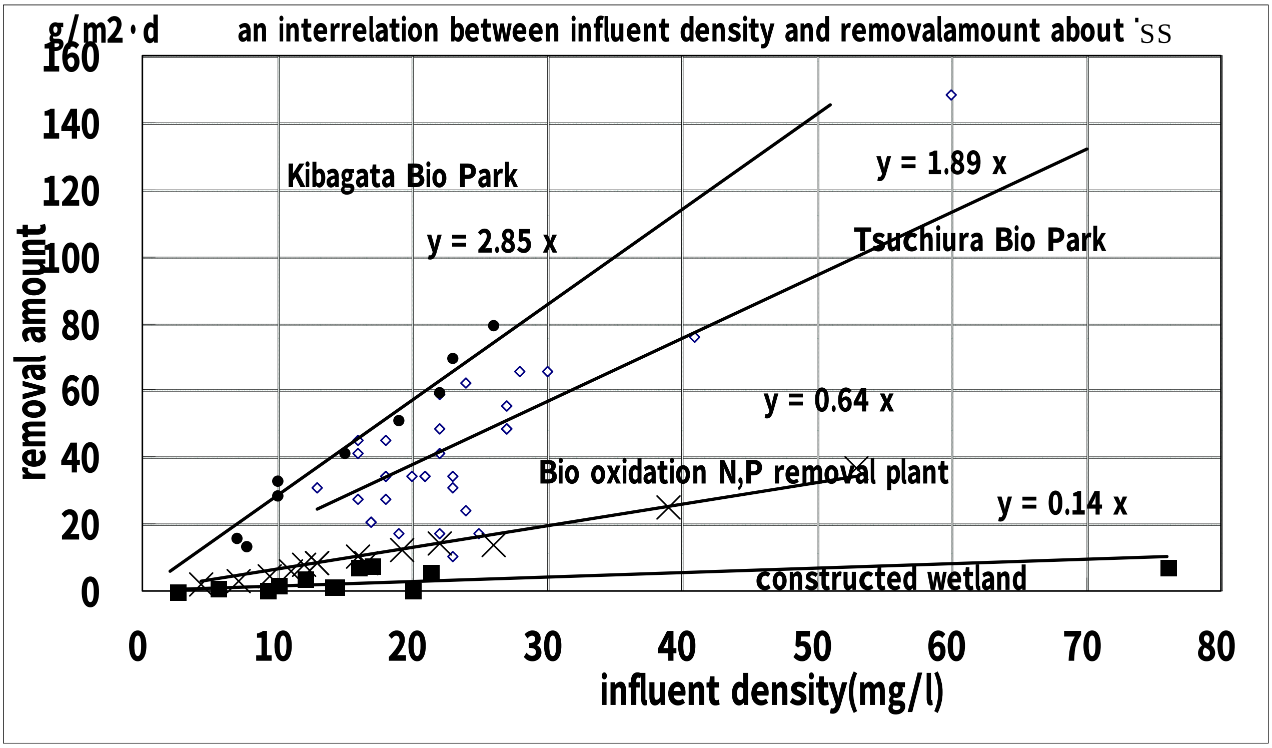
At Tsuchiura Biopark and Teganuma Experimental Biopark lake water containing water-blooms is supplied as the primary water to the biopark for treatment of the water-blooms. At Tsuchiura Biopark, the concentrations of SS, T-N and T-P rose when the water-blooms were mixed with the primary water, resulting in high removal percentages and removing speeds shown in Fig. 8-3-2. Based on the moisture content of the water-blooms assumed to be 98% from this SS-removing speed, the raw weight of the water-blooms to be removed is calculated as being 7.4 kg per m^2 per day.

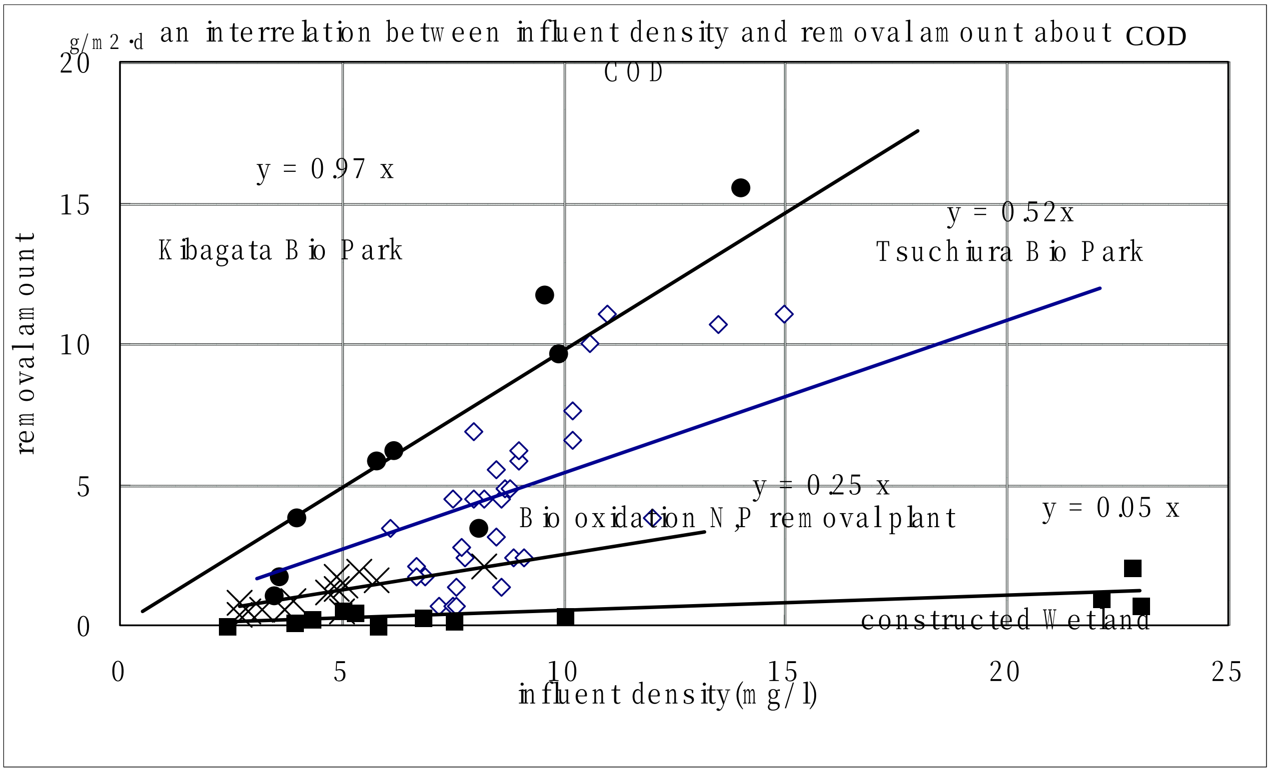




◇：Tsuchiura ， ●：Kibagata ， ×：Bio oxidation and NP removal, ■：Constructed Wetland, △：Thai AIT

Fig8-3-3　Interrelation between influent density and removal amount about T-N, T-P in Bio Park





◇ : Tsuchiura , ● : Kibagata , × : Bio oxidation and NP removal, ■ : Constructed Wetland,

Fig8-3-4 Interrelation between influent density and removal amount about SS, COD in Bio Park

Table8-3-2 Water purification performance on the Blue-green algae bloom at Tsuchiura Bio Park

Pollutants	Influent	Effluent	Removal Rate	Removal Amount
ＳＳ	５６mg･l^{-1}	１４mg･l^{-1}	７５%	１４８g･(d･m^{2})$^{-1}$
Ｔ－Ｎ	６．５mg･l^{-1}	３．５mg･l^{-1}	４６%	１０．６g･(d･m^{2})$^{-1}$
Ｔ－Ｐ	０．４１mg･l^{-1}	０．１５mg･l^{-1}	６４%	０．９３g･(d･m^{2})$^{-1}$

At Lake Tega, variations of microcystin concentrations checked on each isomer while the primary water containing water-blooms was being treated provided the results shown in Fig. 8-3-5. YR, which had a low concentration in the primary water, showed a concentration in the treated water below the detection limits; however, on LR, the removal rate was 76% with a removing speed of 3.84 mg/(d/m^{2}), and on RR, the rate was 68% with a speed of 7.14 mg/(d/m^{2}). All figures showed high removal efficiency.

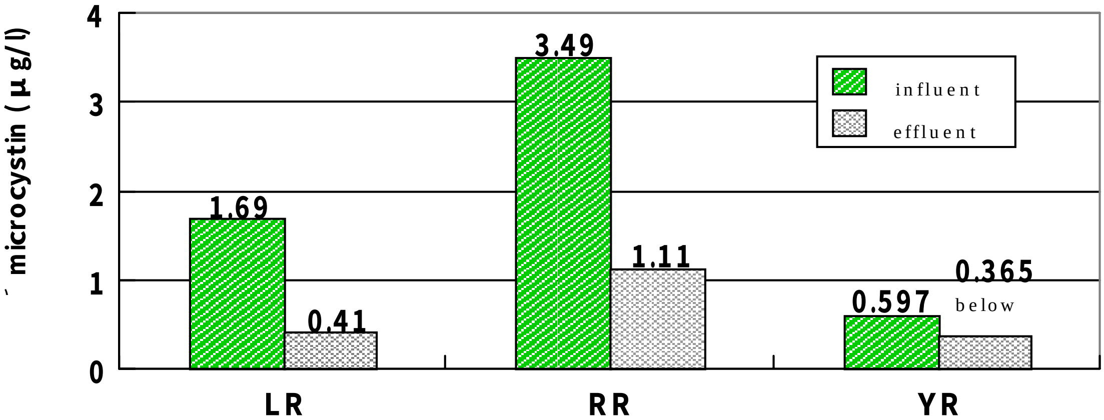


Fig8-3-5 Bio Park performance to reduce microsystin in Teganuma

(3) Purification of the treated sewage

A. Outline

The biopark method is applicable to the water treated as being below BOD20 mg/l (below 50 mg/l if swamp cabbage is used) in which plants can be cultivated. In Japan, at three settlement-wastewater treatment facilities, the final treatment by the biopark method is performed based on the experiment conducted in sewage disposal plants. One example is shown in Photo 8-3-5 (*Zantedeschia aethiopica* growing in treated sewage, directly after picking flowers) where *Zantedeschia aethiopica* is cultivated in the waterways, removing nitrogen and phosphorous, and producing flowers.

B. Purification results and revenues obtained

As the wastewater from settlements is used as the primary water, there are many variations in the amounts of supplied water and their qualities, and only fragmentary data are available. Table 8-3-3 shows the achieved purification results at facilities where *Zantedeschia aethiopica* and watercress are cultivated in a mixed manner.

Table8-3-3 Bio Park performance 50days after constructed attached to the sewage disposal plant at Kochi prefecture

Pollutants	Influent,apparatus treated	Effluent,Bio Park treated	Removal Rate
ＳＳ	１．8mg・l^{-1}	１．0mg・l^{-1}	４4%
ＣＯＤ	４．7mg・l^{-1}	３．5mg・l^{-1}	２6%
ＢＯＤ	２．1mg・l^{-1}	１．3mg・l^{-1}	３8%
Ｔ－Ｎ	７．０7mg・l^{-1}	５．５6mg・l^{-1}	２1%
Ｔ－Ｐ	１．３5mg・l^{-1}	１．１1mg・l^{-1}	１8%

Table 8-3-4 shows the trimonthly average removing speeds at the biopark attached to the Tomita Purification Center at Takagi-mura, Ina-gun, Nagano Pref. The biopark went into operation in April 1996, cultivates only *Zantedeschia aethiopica* and crops and then sells their flowers, but does not remove any sludge. The report does not state the concentration of the primary water nor the treated amount of water; it reports that the pollution indicators such as SS, BOD and COD have worsened slightly.

Table8-3-4 Bio Park seasonal Removal Amount by Bio Park consutructed attached to the sewage disposal plant (g・(d・m^2)$^{-1}$) in Nagano prefecture

Month	１９９７		１９９８	
	Ｔ－Ｎg・(d・m^2)$^{-1}$	Ｔ－Ｐg・(d・m^2)$^{-1}$	Ｔ－Ｎg・(d・m^2)$^{-1}$	Ｔ－Ｐg・(d・m^2)$^{-1}$
１～３			０．５６	０．０８
４～６			１．０１	０．１２
７～９	０．５４	０．０３	０．８１	０．１５
１０～１２	０．５７	０．０５	０．７５	０．１５

Table 8-3-5 shows revenues and expenses realized at the same facilities. The shown balance, which does not include electricity and the salaries of personnel for maintenance and control, concludes that the other maintenance and administration expenses can be covered by the sales of flowers. The flowers are purchased by local mini-size plant and flower dealers far from the centers of consumption; therefore, their unit selling prices are a half to one quarter that of normal producer prices on the market. However, in other places the flowers are expected to bring in more revenues.

Table8-3-5　Incom(sale of cut flower) and out go of the operation of a Bio Park constructed attached to the sawage disposal plant in　Nagano prefecture（1,000Yen）

		１９９５	１９９６	１９９７	１９９８
Incom			１５	２０５	３６２
Out Goes	Initial	１５，３２４		５８１	１８９
	Materials		３７５	２８３	
	Plant		１，５０６	７７	
	Heating		１５	６７	４４

8-3-3 Ripple Effect of the System

(1) Diffusion of the system in developing countries

A. Introduction

As stated in the section relating to the performance of the system, in some cases aquaculture purification by the biopark system results in low costs and adequate sales. The system requires no special devices, materials or consumables; therefore, if its technology is transferred to developing countries, the system will probably result in low installation costs, and reduced control and maintenance expenses by utilizing locally available low-cost materials and labor; and if model facilities are successful in low-cost purification, the system will be widely used by municipalities. Local production of high-value vegetables and flowers, if possible, may bring about economic success and persuade farmers in the surrounding areas to willingly adopt the system.

B. Thai example and trial calculations

When the 100 m^2 concrete biopark, shown in Photo 8-3-1, was constructed on the premises of AIT (Asian Institute of Technology) located in the northern suburbs of Bangkok, the Kingdom of Thailand, it cost approximately ¥250,000, which is one-twentieth of 5 million yen that it would cost in Japan. Due to the hot climate, watercress cannot be cultivated by conventional agriculture in the suburbs of Bangkok where it sells for about ¥580 per kilo at supermarkets; however, the plant can be cultivated by the biopark method. Based on a producer price assumed to be half that of Japan, by way of trial sales for 100 m^2, the cost can be calculated on the basis of the average monthly production of 2.5 kg per m^2 obtained in Japan, and then the period required for the repayment of the construction cost: the result is 2 months. Due to low quality and low productivity, in reality, it will take more than one year to repay the construction cost; however, if combined with floating-island cultivation and a fishery utilizing the system in a comprehensive manner, the system will easily secure its economic merits.

C. China’s example and trial calculations

In China, bricks were arranged as shown in Photo 8-3-10, the stalks of swamp cabbage, stretching out of the field and into the channel as shown in Photo 8-3-11 were bought, snails were collected from the channel and the stalks and the snails were placed together in the waterway, and water was pumped up from the lake and released into the waterway. All this was done by utilizing the concrete planes of the pier projecting into lake Wu Li Hu located within lake Tai Hu that faces the city of Wuxi in the Province of Jiangsu. In two months, swamp cabbage had flourished well as shown in Photo 8-3-12 and helped to purify the lake water that was mixed with water-blooms. As full-scale facilities have never been built in China, no cost evaluation is possible; however, the present author made trial calculations on the assumption that the cost of construction for 100 m^2 is ¥500,000 (one-tenth of Japan's cost) and watercress and swamp cabbage are alternately cultivated depending upon the season. Revenues that are calculated on 100 m^2 based on the farmer's direct-selling price of ¥150 per kilo as observed in the market and the average monthly production of 2.5 kg per m^2 show that the construction cost is repayable in 13 months. One problem would be the low price of swamp cabbage in summer time and the limited popularity of watercress; however, if combined with the floating-island cultivation and fishery, the system seems to secure easily its economic merits.

(2) Supply base of seeds and seedlings

A. Seed and seedling base for floating islands

Fig. 8-3-1 shows the idea of growing plants at the biopark, prompting them to make their own cultivation-beds by rootstalk mats and placing them on floating islands as seedlings. As detailed in "8-4 Aquatic plant cultivation purification system," the use of biopark seedlings for floating cultivation is expected to assist in the making of lower-cost floating islands, improve the productivity of floating cultivation in creeks and inner lakes, amplify the range of water qualities applicable to floating cultivation and produce a ripple effect of facilitating on-land disposal or exchange of the entire stumps.

B. Interchange of seeds and seedlings

Swamp cabbage grows fast in summer time in the temperate regions; however, it has difficulty in the winter and is slow in its initial growth if cultivated from inserted ears that have few developed seeds or roots. Watercress is so sensitive to high temperatures that in summer time, it deteriorates in quality or withers; growing from seeds is difficult and it grows slowly in its initial stage if cultivated from inserted ears. Both plants show excellent growth from the start if introduced as seedlings while growing at the biopark. For quarantine reasons, seedlings of swamp cabbage grown at bioparks cannot be introduced into Japan from the subtropical regions; however, in vast countries such as China or Thailand that possess both plateaus and lowlands, seedlings can be easily transferred from one region to another depending upon the season. Thus, "right season, right crop" will be realized contributing to the maximization of productivity and purifying efficiency.

(3) Proliferation of plants and animals useful for purification and fishery

A. Proliferation and diffusion of animals and plants useful for purification

At Tsuchiura Biopark, it has been confirmed that five kinds of bivalves that had been almost extinct have settled in Lake Kasumigaura targeted for purification; they have been revived in the peripheral areas as well. The bivalves survived in the rivers that flow into the lake, but had died out at the entrance to Tsuchiura due to the deteriorated qualities of its bottom sediment and low-level water; eggs and larvae released from inflowing rivers have proliferated at the biopark and the now fully-developed bivalves lay eggs and release larvae in the peripheral areas. The environment created by the water qualities improved by the biopark allowing the existence of the bivalves in the peripheral areas seems to have helped them revive in such areas. The same situation applies to submerged plants; they flourish in the waterways that return the treated water into the lake, and are occasionally observed flourishing at the peripheral bottom of the lake. Likewise, it was confirmed that Rotifera, water fleas and *Physidae* flow out into the peripheral areas on the treated water; however, it is not known how much they contribute to improving water qualities. Similar ripple effects can be expected in developing countries if the biopark technology is introduced.

B. Gathering of fish and shellfish and their capture

It has been discovered that a large number of corbiculas gather if whirlpools are formed at the entrance that supplies the primary water to the biopark waterways where plants are cultivated. As shown in Photo 8-3-2 also, lots of fish have been observed gathering at the point where the treated water is released from the biopark into rivers, lakes or marsh. These fish can be easily captured, and by selling them, nutritive salts are taken out of the water system, bringing in some revenue at the same time. The eggs and larvae of fish and shellfish are released from the biopark, and they are captured when fully mature while microorganisms serving as their food are being scattered from the biopark. This cycle allows fishery that has no worries about the negative impacts of excessive fishing.

(4) Accumulation of know-how and its exchange

The basic principle and effect of the biopark system are known; however, different animals appear and different plants grow depending upon the environment where the facilities are built and the quality of the water supplied to the facilities. For instance, corbiculas have proliferated explosively for the first time at the biopark built on the lakeside of Lake Biwa. The phenomenon makes similar proliferation predictable and makes possible the planning of purification utilization experiments at other facilities. At experimental facilities in the Kingdom of Thailand, crabs that normally lay eggs in the sea and grow in rivers entered the facilities and matured. The crabs are the same kind as those that are highly appreciated in China as “Shanghai crabs.” This knowledge permits the prediction that a biopark built in the basin of the Chang Jiang River will attract Shanghai crabs and have them enter the park and mature inside. It has been confirmed in Japan that rice fish (swamp eels) that are prized more highly than eels in China have begun to inhabit the biopark. Such knowledge will allow purification facilities to improve profitability.

For information on an experiment using this method and the installation of a biopark system in developing countries, send all inquiries to the authors listed at the end specifying your purposes accompanied with information on the condition of the site, etc. Detailed, latest know-how will be provided.

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8-4. Purification by Aquatic Plant Cultivation

8-4-1 Principle and features of the system

(1) Principle and classification of the system

A. Basic principle

Eutrophication is a phenomenon where nutritive salts, which are indispensable for growing plants and if deficient may limit their growth and proliferation, are excessively present in water causing phytoplanktons to be over-present, water to be turbid and various problems to occur. Salts that are nutritive to phytoplanktons are fertilizer to tracheophytes, and therefore, the salts are fought over by both. If tracheophytes grow thick in or over water surfaces, they will cut off light indispensable for phytoplanktons to proliferate. From this perspective, studies have been conducted and put into practice regarding the methods of causing aquatic plants to flourish and deprive phytoplanktons of nutritive salts and light.

B. Classification

The purification system by aquatic plant cultivation is roughly divided into the creation and control of an aquatic plant-growing environment, and the cultivation of floating plants; the creation of such an environment is classified into various types by the life form of the plants used. Purification by the use of submerged plants is specially dealt with in 8-7. Purification using free-floating plants such as water hyacinths has been attempted in various parts of Japan; however, in many cases, such plants have turned into weeds with the resulting non-diffusion of the method due to poor efficiency. In developing countries, water hyacinths are treated as weeds; therefore, their use in such countries is not dealt with here. Purification using floating-leaved plants has never been put to practical use. The cropping of water chestnuts and water shields appears to be helpful in collecting nutritive salts; however, they are not aimed at purification. In China, a large number of water chestnuts and water shields are cultivated and consumed, and they seem to be applicable to purification purposes; however, no details about such a possibility are known. Therefore, this section deals with purification by the creation and control of an emerging plant-growing environment and floating plant cultivation.

C. Principle of creation and control of an emerging plant-growing environment and its merits

This is a system that introduces polluted lake- or river-water into vegetation wetlands such as existing flood plains or artificially created flood control basins; it purifies the water through the capture and decomposition of organic substances by biofilms developed at the rootstalks of vegetation and by the absorption of nutritive salts by the vegetation, while emerging plants cut off light and prevent phytoplanktons from proliferating; and thus, the system releases the purified water into rivers, lakes or marshes. Cultivated plants are mainly reeds; however, where water is deep and has a high BOD concentration, wild rice or cattails are more suitable. If not initially planted, these plants may flourish in a few years in place of reeds. Plants that better suit the quality of the water absorb nutritive salts more aggressively for their growth; therefore, it is better if the three plants are planted in a mixed manner for competition. A water supply and drain system, and a dike to direct water need to be constructed; however, if water can be supplied by natural down-flow, no energy will be consumed; and if pumps are used for supply or drainage, the maintenance and control cost will be reduced. Many of the emerging plants, as shown in Fig. 8-4-1, supply oxygen from their leaves to rootstalks and release oxygen from the roots and stalks to peripheral water and mud to protect their organizations. Reeds, water rice and cattails have such ability; this ability results in creating within the mud a condition close to anaerobic-aerobic conditions and promotes denitrification. The anaerobic condition is dissolved and the generation of greenhouse gases such as methane gas and dinitrogen monoxide is restrained. Such an effect has been confirmed. One sewage treatment method easily practicable in developing countries is the lagoon process; however, the water that is treated as having a BOD concentration of more or less 50 mg/l and is capable of growing emerging plants is purified more efficiently through the creation and control of an emerging-plant growing environment than through the lagoon process. In this way, the harmful generation of greenhouse gases will be restrained.

Another process for curbing the generation of greenhouse gases and enhancing the removal percentage of pollutants including nitrogen and phosphorous is the seepage process. This system causes the primary water to be treated to seep into wetland soil and the water level of the wetland to be lower than the soil surface; on top of the soil layer where the water under treatment is filling pores, an aerobic layer is formed causing the pores to be shared by water and air. The resulting effect is that methane gas is oxidized and the reducing zone that generates dinitrogen monoxide is reduced. In the process where the water surface is above the soil, an amount of water, not well treated, passes through the stalks of the emerging plants and flows out; however, in the seepage process pollutants are filtered and absorbed while the water passes through the soil particles; thus, a high removal percentage is obtained. However, this process is not recommendable to developing countries because in the first place, the amount of water treated in the seepage is so small that the removing speed is much slower than the speed of the surface flow, and in the second place, a significant distance is necessary between the point of the primary water supply and the point where the treated water is extracted; it requires costly installation and the operation of facilities and pumps.

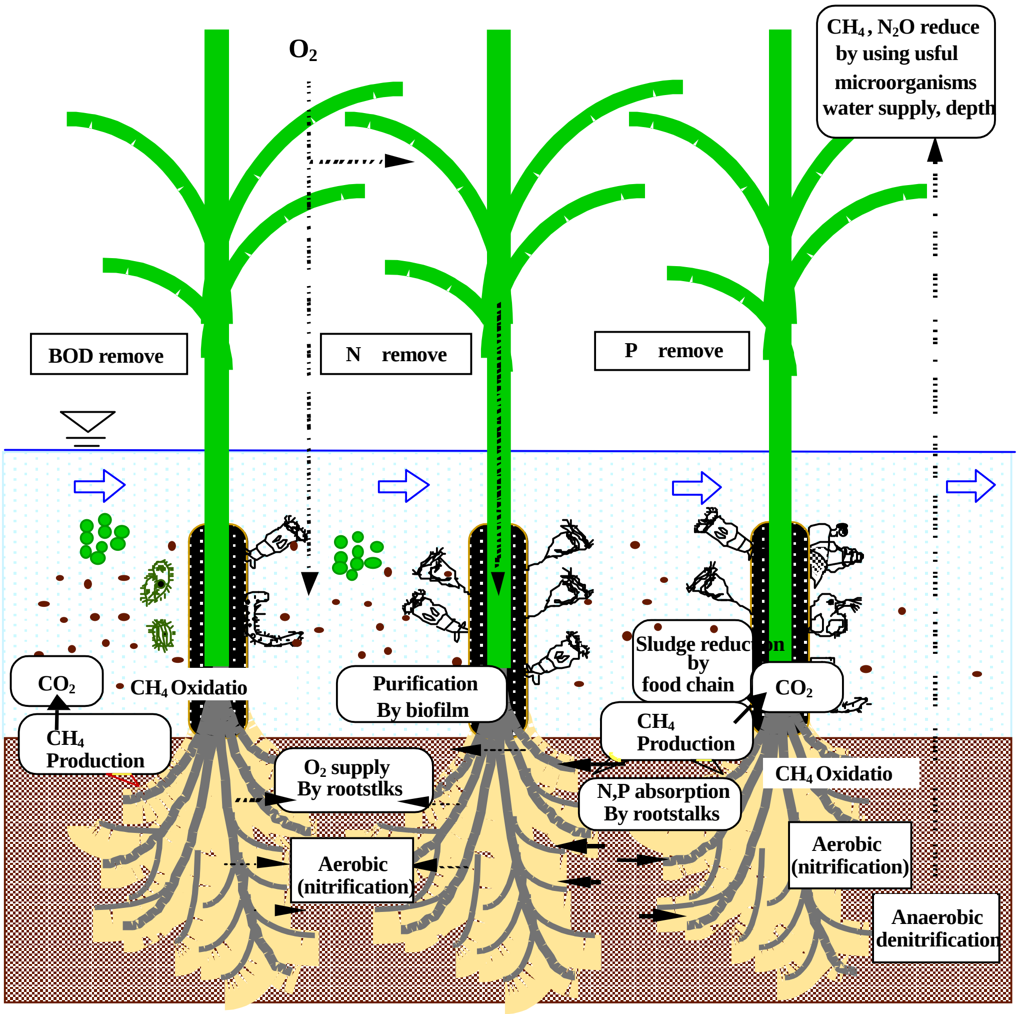

Fig.8-4-1 A model of water purification and reduce CH_4, N_2O Generation by Plant and Eco-engineering

D. Problems involved in the creation and control of the emerging plant-growing environment

Of the nutritive salts that are absorbed directly by plants or trapped by biofilms on their rootstalks and, converted into mud, submerge to the water bottom, nitrogen is removed through dinitrification by the oxygen supplied by plant roots and digestive bacteria; however, phosphorous does not vaporize and though absorbed by plants, it remains inside the wetland ecosystem and will be extracted only in the process where insects fly out or birds feed in the wetland and excrete droppings outside. In another case, sludge grows so thick that it forms a stratum and breaks away from the ecological cycle; emerging plants have the function of absorbing phosphorous from heaped mud and bringing it to the earth (called “nutritive salt pump”); however, not much removal can be expected from the stratum-forming in purification by aquatic plant cultivation. To maintain the removing capacity of the emerging plants, it is necessary to cut down plants or dig out heaped mud for on-land disposal; however, because of the low utility value and high cost of the disposal, such maintenance is not conducted in Japan. As shown in Fig.8-4-1, the emerging plants supply oxygen in the mud; yet, they seldom take root on the mud surface or in the water, and supply very little oxygen to the water running through the wetland while they successively renew leaves and stalks, shedding them in the water. If the water introduced in wetlands is eutrophicated river-, lake- or marsh-water, or water treated in the lagoon process, it often retains supersaturated oxygen and organic substances as well; the oxygen is consumed in an oxidative decomposition process. If the flow process or the time required for the water introduced in the wetland to flow out of the vegetation wetland is too long, old stalks and leaves may consume oxygen to decompose and cause the water to become anaerobic, although no photosynthesis is conducted because of light being cut off by the emerging plants. Photo 8-4-1 shows an outlet in the Kingdom of Thailand, from which sewage flows out after it has first been treated through the lagoon process, and then introduced into purifying wetlands for another treatment. The water-bottom is entirely covered with white sulfur bacteria indicating an anaerobic condition.

Photo 8-4-1 Treatment water of wetland

E. Principle and merit of floating islands

This is a system that cultivates plants on float-equipped cultivation beds afloat in rivers, lakes or marshes; it catches turbidity by biofilms developed at plant rootstalks, and through ecological action, converts the turbidity into mud, which is deposited. This causes nutritive salts to be absorbed by growing plants, restrains the proliferation of phytoplanktons by preventing light from going into the water and is intended to dissolve the turbidity. Afloat on the water surface, free-floating plants can grow only by absorbing dissolved nutritive salts by their roots dangling in the water. Other life-form plants stretch out roots into the soil and grow by absorbing nutritive salts and an infinitesimal amount of essential minerals through the roots; therefore, their growth would be impeded by lack of ingredients if they had their roots only dangling in the water. Emerging plants can be cultivated afloat on a water surface that only has cultivation-beds planted on it made up of sponge, bundles of ropes or palm-shell mats placed under water. Biofilms attached to the cultivation-beds, animals that eat the films and earthworms that decompose organic substances accumulate mud containing nutritive salts and an infinitesimal amount of essential minerals on the cultivation-beds. The emerging plants absorb for their growth deficiencies, complementary ingredients from the cultivation-beds by their roots dangling in the water.

F. Problems of floating cultivation

Some plants may die when mud piles up on cultivation-beds and causes oxygen deficiency inside the beds. The floating cultivation will sink under the burden of accumulating mud and growing plants, and will surface when plants are cropped or wither in winter; such unstableness limits the plants that can grow on the beds. For that reason, an unattended floating cultivation that had diverse plants initially would be covered with reeds in a few years (Photo 8-4-2); however, if for instance, seedlings of swamp cabbage are introduced and properly controlled, they will grow well (Photo shows a floating island covered with reeds). Rootstalks of plants are useful as filter materials that develop biofilms, as spawning beds for fish and shellfish or hiding places for juvenile fish and shrimps; however, if fish and shellfish are not caught or mature plants are not cropped, floating islands will not be of much use as a nutritive-salt removing measure after the first year when seedlings grow.

Photo 8-4-2 Floating island covered with reeds

8-4-2 Performance of the System

(1) Performance of creation and control of an emerging-plant growing environment

A. Summary

In the biopark system as described in 8-3, many plant roots work as biofilm carriers and cause the biofilms to occupy vast surface areas. On the other hand, large-size emerging plants used for purifying purposes extend most of their roots in the mud and not much in the water, and therefore, the biofilms attached to their roots occupy a much smaller area. Consequently, emerging plants purify or remove a much smaller amount of water or pollutants per unit area per day, and to significantly improve mass balance in a water system, a vast area would be required; so, this is a defect (See Fig. 8-3-3~4). If purification continues for a prolonged period of time without extracting mud piled at the bottom and mature plants, it will not be possible to remove the nitrogen and phosphorous that cause eutrophication.

B. Examples

The largest example in Japan can be found at the Watarase Flood Control Basin on the border of the three prefectures, Tochigi, Gunma and Saitama. To improve the quality of the water in the basin, in the 20-hectare facilities of the basin, reed-covered fields were partitioned with banks, and driving and drainage canals were built to direct the water of the basin into the reed-covered fields, shown in Photo 8-4-3, and drive it back to the basin (Photo shows reeds fully grown on supplied water). The basin treated 260,000 m^3 a day, and initially achieved removal rates of 27% for nitrogen, 6% for phosphorous and 57% for chlorophyll on average annually; however, in and after the second year, almost none of the nitrogen or phosphorous had been removed. Other examples are the facilities constructed across the country where water is taken from rivers, introduced into waterways covered with reeds or other plants, passed through vegetation waterways and returned to join the river; however, collecting and removing grown plants is difficult and there is no way of utilizing them either. Furthermore, the amount of nutritive salts and organic substances removed per unit area is small. There might appear to be some restoration work of the natural environments; however, natural conservation groups have so far pointed out the problem that only reeds are growing abnormally, causing other plants to disappear. Because of low construction and maintenance costs, many examples have been put into practice.

(2) Performance of floating plant cultivation

A. Summary

Evaluating floating-plant cultivation is difficult. Causing biofilms developed at plant roots to trap turbidity, changing it into mud and depositing it leads to the purification of water; however, it also leads to a worsening of the bottom sediment. Although nutritive salts are absorbed by growing plants, they stay there unless extracted. Preventing light from filtering down under water will be of little use if the ratio of the affected area to the lake surface is small. It is difficult to evaluate the role played in water purification by the fish and shellfish that hide and feed in plant roots while they are young, or to evaluate their fishery when they are matured. It is similarly difficult to grasp the amount of nutritive salts that are returned to the land by the insects that fly away from the ecosystem formed on the water surface or in the form of birds' droppings. For such reasons, very few reports have been made on the effect produced by floating cultivation.

B. Reports on examples and their performance

In the case of Japan, there are relatively large-size floating islands in Lake Kasumigaura, and experiments and practice are under way at Hachirogata (Akita Pref.), Teganuma and Inbanuma (Chiba Pref.), creeks in the plains of Saga and so forth. In relatively heavily polluted creeks in Thailand, floating cultivation is widely conducted by farmers; this method binds swamp cabbage or other plants to stakes or floating bamboo. They began the cultivation by dividing stumps that are repeatedly cultivated on the water surface in heavily polluted creeks; biofilms are developed at their roots, which are inhabited by aquatic insects. In Japan, cultivation is made by attaching cultivation-beds to rafts and planting seedling or seeds on the beds. One report states that at Inbanuma, waterways having little inflow or outflow became clear; however, building rafts requires much labor and cost, and a long time is required before seedlings and seeds grow large enough to be cropped; furthermore, collecting and removing old stumps poses a difficulty.

The current author inquired about the amount of plant growth at the cultivation project installed at Lake Kasumigaura. The calculations that the writer made based on the data provided indicate the removing speed of T-N at 0.4/(d/m^2)and T-P at 0.02 g/(d/m^2)relating to the amount of nutritive salts absorbed in the growth period of the first year. The average annual removing speeds achieved at the adjoining Tsuchiura Biopark during the same period were 1.9 g/(d/m^2)on T-N and 0.0 8g/(d/m^2)on T-P. This indicates that the removal efficiency of the floating cultivation was one-quarter that of the biopark. Such difference resulted because at the biopark plants are frequently cropped and mud is entirely extracted. Cropping plants from floating cultivations is extremely difficult as such work is done on an unstable foothold at a place reached only by a boat, which should be able to transport bulky objects; therefore, almost no plant collection is made.

At the Watarase Flood Control Basin, the Ministry of Land and Transport has built three isolated water tanks each having a water surface of 24 m^2 and a depth of 2 m; one of the three is a controlled tank, and on each of the remaining two, a floating vegetation island of 8 m^2 or a light-interrupted floating island of 8 m^2 was put afloat to measure subsequent variations in water qualities. The result was: chlorophyll a increased its concentration in the controlled tank to 60 μg/l, while in both of the remaining tanks, the concentration decreased to around 10 μg/l. The total nitrogen concentration was 1.6 mg/l in the controlled tank while it was 1 mg/l in the light-interrupted island tank and 0.4 mg/l in the vegetation island tank, both showing improvement.

8-4-3 Ripple Effects of the System

(1) Ripple effect of creation and control of emerging-plant growing environment

A. Diffusion of the system

Diffusion of the system varies depending upon the value of the emerging plants themselves and of the fish and shellfish that proliferate in the plants' growing environment. In Japan leaves and stalks of reeds are utterly valueless; in China, however, they usefully serve as raw materials for paper and feed. In China, edible wild rice is widely cultivated and this plant can be used for water purification and vegetable cultivation at the same time. In the areas extending from China to Southeast Asia, they eat much freshwater fish and shellfish; so, one idea would be to utilize wetlands as fishing grounds while they are being purified by emerging plants. However, as in these areas low wetlands are completely utilized for paddy field cultivation, fallow land may be used. In the areas where wetlands are not cultivated much or freshwater fish and shellfish are not much used for food, diverting low wetlands to purification wetlands would be relatively easy; however, as no technology exists to utilize the products and consumption routes, the introduction of such technology would be necessary.

B. Impact on the surrounding environments

Although wetland themselves may not be profit-earning, they could become a sanctuary for animals and plants that inhabit them and work for water purification; such animals and plants flow out with the treated water into the peripheral areas and enhance the areas' capacity to purify water. Serving as a sanctuary for useful fish and shellfish, wetlands may supply the peripheral areas with eggs, larvae and young fish. However, if the flow-process of the vegetation purification facilities or the length of stay in the process is too long, water downstream may become oxygen-deficient and cause useful organisms to die while they are going downstream, or treated-water receiving areas to become devoid of oxygen.

(2) Ripple effect of floating cultivation

A. Diffusion of the system

Floating islands that endure lake waves were built on a large scale in Japan and China as shown in Photos 8-4-4~5; however, as compared with their costly anti-wave structure, no economically valuable products are obtained (Photo8-4-4: floating cultivation in lake Xuan Wu Hu, Nanjing. Photo 8-4-5: floating island placed in lake Wu Li Hu within lake Tai Hu facing the city of Wuxi). In Thailand, swamp cabbage and *Neptunia oleracea* are popularly cultivated on floating islands in creeks as shown in Photo 8-4-6 and are economically viable (photos show how

Photo 8-4-3 Reed-covered fields of Watarase Basin

Photo 8-4-4 Floating cultivationin lake Xuan Wu Hu

Photo 8-4-5 Floating island in lake Tai Hu

Photo 8-4-6 Floating cultivation in Thailand

Photo 8-4-7 Easy cultivation raft

Photo 8-4-8 Use of bamboo at a construction site in China

swamp cabbage is cultivated and cropped in creeks in the suburbs of Bangkok). Communities that are linked by stalks are fixed with bamboo stakes at two points or the stalks are bound to the bamboo floated between two stakes. The cultivated plants receive nutritive salts through the action of biofilms attached to rootstalks and animals; therefore, this cultivation is put into practice only in relatively polluted creeks. Fertilizers are employed when the plants are cultivated in channels dug out in fields.

From the perspective of expanding the range of water qualities applicable to cultivation and facilitating the removal of old stumps at the same time, the author designed a simple floating island made of bamboo woven in the form of a drain board and equipped with a float, and confirmed that the cultivated swamp cabbage placed on the island grew well; the author also confirmed that old stumps can be easily separated from the rafts (Photo 8-4-7: bamboo-woven cultivation raft having PET bottle floats). The clearer the water, the larger the required amount of mud formed on the island for growing plants is; therefore, circular-arc shaped large vegetation rafts formed inside the split bamboos are used. In China, a large number of bamboo woven in the form of a drain board is used as footholds or horizontal boards at construction sites. As such woven bamboo has shapes applicable to a wide range of water qualities, used bamboos structures can be applied to realize very economical water surface cultivation (Photo 8-4-8: bamboo drain boards most suitable for rafts). It has also been confirmed that if the plants that have developed mat-like rootstalks and biofilms at the biopark are cut separately and placed on board the rafts as seedlings, they will show faster initial growth.

B. Impact on the surrounding environment

A floating island serves as a place for hiding and proliferation for animals that work to purify water. Such animals proliferate and scatter themselves in the peripheral areas and enhance the capacity of the water to purify. The island serves as a spawning ground for useful fish and shellfish, is a hiding place for larvae and young fish and improves the productivity of fishery in the peripheral areas. Floating islands may impede photosynthesis in the water by cutting off light and cause oxygen deficiency; however, an experiment with the biopark system showed that swamp cabbage supplies oxygen to water also at nighttime. If plants having such characteristics are cultivated on floating islands, there will be no worries about fish and shellfish suffering from oxygen deficiency.

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8. Aerated Circulation Purification

8-5-1 Principle of the aerated circulation purification system and its features

(1) Features of the aerated circulation system

In lakes, marsh, dams or impounding reservoirs when phosphorous and nitrogen are present in sufficient amounts (0.02 mg/l or more for phosphorous and 0.2 mg/l or more for nitrogen), primary production or phytoplankton production occurs, according to their concentrations and loads per area causing a number of obstacles to water utilization.

Phytoplanktons are roughly divided into three kinds of algae; blue-green algae, green algae and diatoms. Of the three, blue-green algae have many species that cause obstacles to water utilization: for instance, microcystis that produce toxic matter and Phormidium that produce musty odorants. These blue-green algae are sensitive to light intensity, and therefore are restrained by light. Because of this, blue-green algae are known to accumulate in surface layers as do the most representative microcystis; others are generated when the water becomes relatively transparent.

Consequently, as compared with diatoms and green algae, blue-green algae are more likely to be restrained from proliferating in weak light conditions. Promoting their circulation in a direction vertical to the lake-water will reduce the average light intensity and is therefore convenient for controlling harmful planktons that produce toxic water-blooms or musty odors.

On the other hand, lakes and marshes that have become heavily eutrophic in recent years are facing the problem of increasing soluble organic substances. Production of soluble organic substances by proliferating phytoplanktons and dissolution of dead phytoplanktons over a long time as putrefactive matter in the water are regarded responsible for such problems.

These organic substances are known to form carcinogenic trihalomethane by the action of chlorine, and therefore are regarded problematic in securing safe water. Prevention of their generation is an urgent necessity.

Apart from the above problems, massively generated phytoplanktons consume oxygen dissolved in the water when they die, and form anaerobic water masses; they accumulate on the lake-bottom and create anaerobic conditions in the depths. The anaerobic conditions of the lake-bottom cause various nutritive salts as well as heavy metals to re-elute. The aerated circulation method has a large capacity to supply oxygen to the bottom layer and at the same time it can cause the depths to become aerobic.

Why phytoplanktons need to be restrained can be summarized as follows. The aerated circulation method is theoretically effective for such restraint.

- It restrains the production of trace toxic materials
- It prevents fish gill disease and death
- It restrains anaerobic water mass formation
- It prevents promotion of nutritive salt regression
- It prevents the promotion of heavy metal elution due to anaerobic condition
- It restrains the ability to form trihalomethane due to increasing soluble organic substance

(2) Principle of the aerated circulation purification system

The principle of lake-water circulation by an aeration pipe (the intermittent air-lift pipe is called hereinafter "aeration pipe") lies in density current formation process through jet formation by an air-bubble shot and a hauling mixture as described below. The lake-water circulation mechanism consists of the following prime mechanisms:

1) Compressed air is sent;

2) The air chamber located in the lower part of aeration pipe is filled with compressed air;

3) After it is filled, the air-bubble shot rises due to a siphon effect;

4) Simultaneously with the rise of the air-bubble shot, lake-water is hauled from the lower part;

5) The water mass inside the pipe is pushed up by formation of the next air-bubble shot and simultaneously the water mass of the lower layer is hauled;

6) Steps 4) and 5) are repeated intermittently;

7) The air-bubble shot forced from the pipe-head rises and simultaneously expands due to falling water pressure; the air-bubble shot is broken by the water resistance and rises as it bubbles;

8) Simultaneously, water inside the pipe is forced out, and joined by the water, it rises as a jet;

9) At this point, the jet hauls the surface-layer water, and because of the temperature of the lower-layer of water which has been sucked and temperature of the hauled water, a water mass less dense than the lower-layer water is formed and reaches the upper layers; and

10) This water-mass becomes a density-current and disperses a slightly lower even-density layer as a horizontal density-current.

The above mechanism of the lake-water is illustrated in Fig. 8-5-1. The state of the jet forced from the aeration pipe is shown in Photo 8-5-1. The diameter of the jet area on the water surface is 20 to 30 meters. Initially it was feared that boats would be in danger of capsizing in this jet area; however, the safety of rowboats was later confirmed.

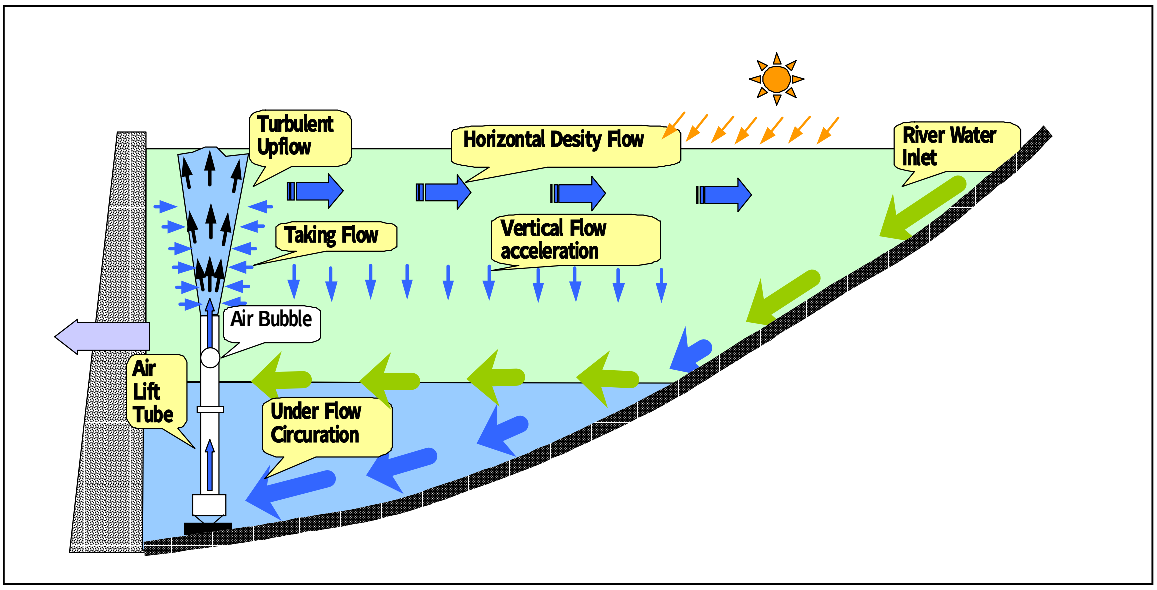

Fig 8-5-1 Fllow pattern of Air bubble gun system

Photo 8-5-1 State of jet by aeration pipe

8-5-2 Performance of the Aerated Circulation Purification System

The principles of phytoplankton proliferation restraint by lake-water circulation are the following:

- Light control effect
- Surface-layer water dilution effect
- Sedimentation promotion effect

Which is the greatest of the three effects depends upon the form of inflowing nutritive salts, hydraulic condition of the lake or impounding dam or types of generating phytoplanktons; however, in general, the “light control effect” is regarded as the greatest. Following is an explanation of the performance of the aerated circulation purification system relating to each of the above principles:

(1) Light control effect

The deeper the water from the water-surface, the greater the exponential decay of light intensity becomes due to the absorption of light energy by water and light- scattering by suspended particles. The light-reaching range (for phytoplankton production) is generally called the productive layer, and the water depth of 2 to 2.5 times the transparency is empirically regarded as this layer. The productive layer then gives the following approximate values depending upon the degree of eutrophication.

Nutritional state	Transparency (m)	Productive layer (m)
Hypertrophic lake	below 1 m	below 2 m
Eutrophicated lake	1 - 1.5 m	2 - 3 m
Mesotrophic lake	1.5 - 2 m	3 - 4 m
Oligotrophic lake	over 3 m	over 5 m

Thus, in eutrophicated lakes below the 3m-depth lies a layer where no light reaches (aphotic zone); if phytoplanktons circulate in this layer, the average light density will be reduced and restrain them from proliferating. The degree of such proliferation restraint will depend upon the targeted phytoplankton’s light properties (Fig.8-5-2).

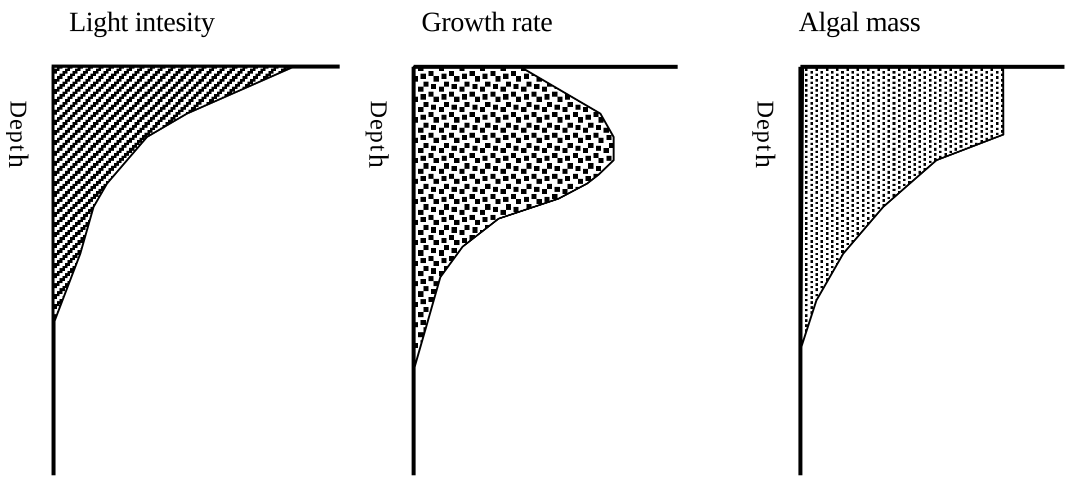

Fig 8-5-2　Relationship between light intensity,growth rate and algal mass

The relationship shown in Fig. 8-5-3 show the following pattern between mixed depths and algal concentrations. Further, Fig. 8-5-4 shows the pattern of relationship between depth and existing quantities shown, and this relationship restrains the proliferation of phytoplanktons by artificially providing greater mixed depth. The methods of giving greater depth are:

1) Aeration pipe (intermittent airlift pipe)
2) Continuous aeration (diffused air aeration)
3) Pump circulation method
4) Surface-layer water circulation method

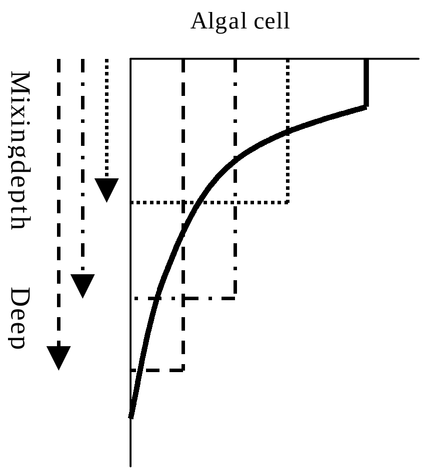

Fig 8-5-3 Mixing depth and algal cell no

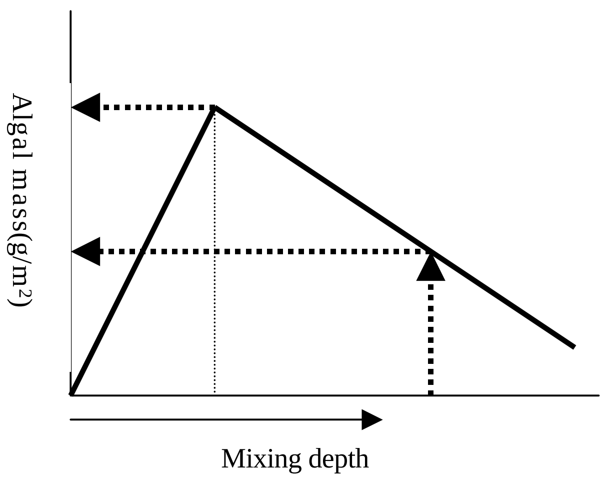

Fig 8-5-4 Mixing depth and Algal Mass

Generally, on lakes or marshes, the surface-layer water mixes at a depth of approximately 3 meters by wind-driven currents or free convection due to diurnal temperature change; therefore, unless the depth is twice this depth or greater than several meters, light-limiting will not be effective in most cases. Restraining phytoplanktons by lake-water circulation therefore will be effectively targeted only to lakes and marshes with a depth of more than several meters.

However, as shown above, the lake-water circulation method is effective not only for light-limiting but also for improving the DO of the bottom-layer water and promoting sedimentation by a vertical circulation current; therefore, it is important to properly design and plan in accordance with the quality of the water, topography and condition of phytoplankton generation in lakes and marshes targeted for improvement.

(2) Dilution effect of surface water

Lake-water circulation causes the dilution of the euphotic surface zone by lower-layer water scarcely populated with phytoplanktons. The depth being the same, the aerated circulation method causes the amount of circulation water to be proportional to the amount of the air sent, or the rated current of the compressor. The following approximate values have been calculated on the amount of circulated water in lakes which use the aeration pipe method:

Capacity per compressor 22 kw amount of pumped water 800,000 m^3/day

(N.B.) Pumped water includes the net pumped amount and hauled amount.

The dilution effect is calculated in the following manner where one aeration pipe is installed per km^2 of the lake area, the epilimnion being 3 m thick:

Dilution effect = amount of aerated circulation／volume of surface water

= (800,000 m^3／day x pipe) ／(1,000,000 m^2 x 3 m)

= 0.26／day

The above result indicates that 26% of the lake-water is changed per day. Supposing that without circulation, the surface-layer water is detained for 1 month on average; dilution will shorten such a detention period to 4 days or less.

(3) Effect of promoting sedimentation

As stated above, lake-water circulation leads to shortening the detention period of the epilimnion; however, as the water itself shifts to the lower layers as vertical circulation currents, even downflow currents are formed. The downflow currents promote sedimentation of suspended solids and the settling of immotile phytoplankton as well.

Similarly to the above example, the sedimentation promotion effect on the installation of one 22 KW aeration pipe per km^2 of the lake area is calculated in the following manner, provided, however, that the net pumped amount is used to calculate the downflow currents. The net pumped amount is 110,000 m^3/day.

Average downflow current speed = (net pumped amount)／(epilimnion)

= 110,000 m^3／day x pipe／1,000,000 m^2

= 0.11 m／day

For relatively slow sedimenting phytoplanktons such as microcystis, this sedimentation promotion effect varies greatly.

8-5-3. Plan and Design of the Aerated Circulation Purification System

(1) Way of thinking about planning and designing

The following six purposes are significant in artificial lake-water purification, corresponding to water features to be improved:

1) Restraining the proliferation of specific harmful phytoplanktons such as blue-green algae
2) Restraining proliferation by internal production (phytoplanktons)
3) Improving water quality stipulated in environmental standards such as COD
4) Improving the DO of bottom-layer water
5) Preventing elution of Mn, NH_4 −N etc.
6) Dilution and dispersion of toxic substances such as microcystins

Aeration pipes are applicable to the solution of all these problems as a concrete counter-measure system; however, as applicable principles vary according to each quality problem, the number of aeration pipes, aeration energy and amount of air that are required will be different.

This manual outlines planning and designing relating to 1), 2) and 4) of which the design method is generally disclosed, together with one design example. The basic planning and designing ideas for each three is described:

a. Restraining proliferation of specific harmful phytoplanktons such as blue-green algae

The following are the design conditions, based on the three principles—light-limiting, improvement of surface-layer water detention period and destratification—that are necessary for restraining proliferation of phytoplanktons that prevent water utilization.

a) Light limiting

Light-limiting conditions serve for designing the amounts of aeration and numbers of aeration pipes to necessary to maintain sufficient mixed depth based upon the relationship between the light intensity and production characteristics of the phytoplanktons (Fig. 8-5-3).

In this case, the necessary design factors are: 1) the number of harmful phytoplanktons to be controlled; 2) the necessary mixed depth; and 3) the amount of aeration to maintain the thermocline at the necessary mixed depth. For this purpose, the relationship between the mixed depth and the existing algal quantity needs to be obtained as shown in Fig. 8-5-4; however, it is usually difficult to clarify such a relationship in actual lakes or impounding dams; further, it is a different matter whether any formula obtained from laboratory experiment data on proliferation is applicable to actual lake conditions.

Therefore, in planning and designing aerated circulation that properly reflects light-limiting effects, planning and designing based on a forecast simulation of an ecological model is necessary.

b) Shortening the detention period of surface-layer water

The epilimnion is the upper part of the thermocline where vertical mixing progresses through free convection mixing caused by wind-driven currents and diurnal changes. This definition is usually applied as it can easily be observed, and also corresponds to the applicable principle.

By diluting the water of this epilimnion area with the lower-layer water, the amount of diluting water required for restraining the speed of proliferation can be calculated.

At normal concentrations of nutritive salts, phytoplanktons need from one week to ten days until they reach their maximum proliferation. Shortening the proliferation time to approximately one-third of this period will restrain their proliferation. The calculation, then, requires the amount of circulation water to be secured at a speed that enables the surface-layer water to be replaced in 2 to 3 days, provided, however that this dilution rate is higher than the speed of proliferation. The proliferation speed varies according to the type of phytoplanktons and the concentrations of the nutritive salts; therefore, the 2 to 3 days required for the dilution serve just as guidelines.

c) Destratification

Destratification is the state in which the temperature stratification is completely destroyed and mixed until the same vertical density is reached. Under conditions where the temperature stratification develops, the water mass with a lower specific gravity is on top of the density causing the center of gravity to be in the lower layer. The destratification is nothing other than increasing the potential energy until the overall density becomes even.
Therefore, injection of energy equal to the changing speed of potential energy by aeration forms the basis of design calculations for destratification.

d) Improving DO of the bottom-layer water

There are two methods to improve DO: dissolving directly oxygen into the water by the air-bubble aeration method, and advecting DO-rich surface-layer water into the lower layer for replenishment. The latter is more energy efficient. Therefore, the below-mentioned design method is described based on this latter method.

To improve the DO of the bottom-layer water, securing water for oxygen supply is the basis of calculation which satisfies the following DO balance formula:

Necessary oxygen amount (O) = oxygen-consuming speed of bottom sludge (R_s)+ oxygen-consuming speed in the water (R_w)

Necessary circulation amount(Q) = necessary oxygen (O)／oxygen concentration of surface layer (C)

In the above formula, the most important design condition is the oxygen-consuming speed of the bottom sludge; in principle this must be obtained by measurement. In some actual lakes, variation in the existing DO that are obtained from values observed in the DO vertical distribution may be given as measured values of oxygen-consuming speed; however, it should be noted that the actual DO variations are the values under rate-determining conditions. Normally, DO variations are diffusion-controlled, and therefore, the oxygen-consuming speed of the bottom sludge, which is regulated by diffusion, may appear to be slower than the real speed. Care should be taken so as not to under-design.

(2) How to calculate for design

Here, the concrete design calculation method is shown based on the ideas mentioned above.

a. Light-limiting effect

Simulation-based design

Fig. 8-5-5 shows the light-limiting effect of the design flow based on an ecological simulation that is capable of handling plural phytoplanktons.

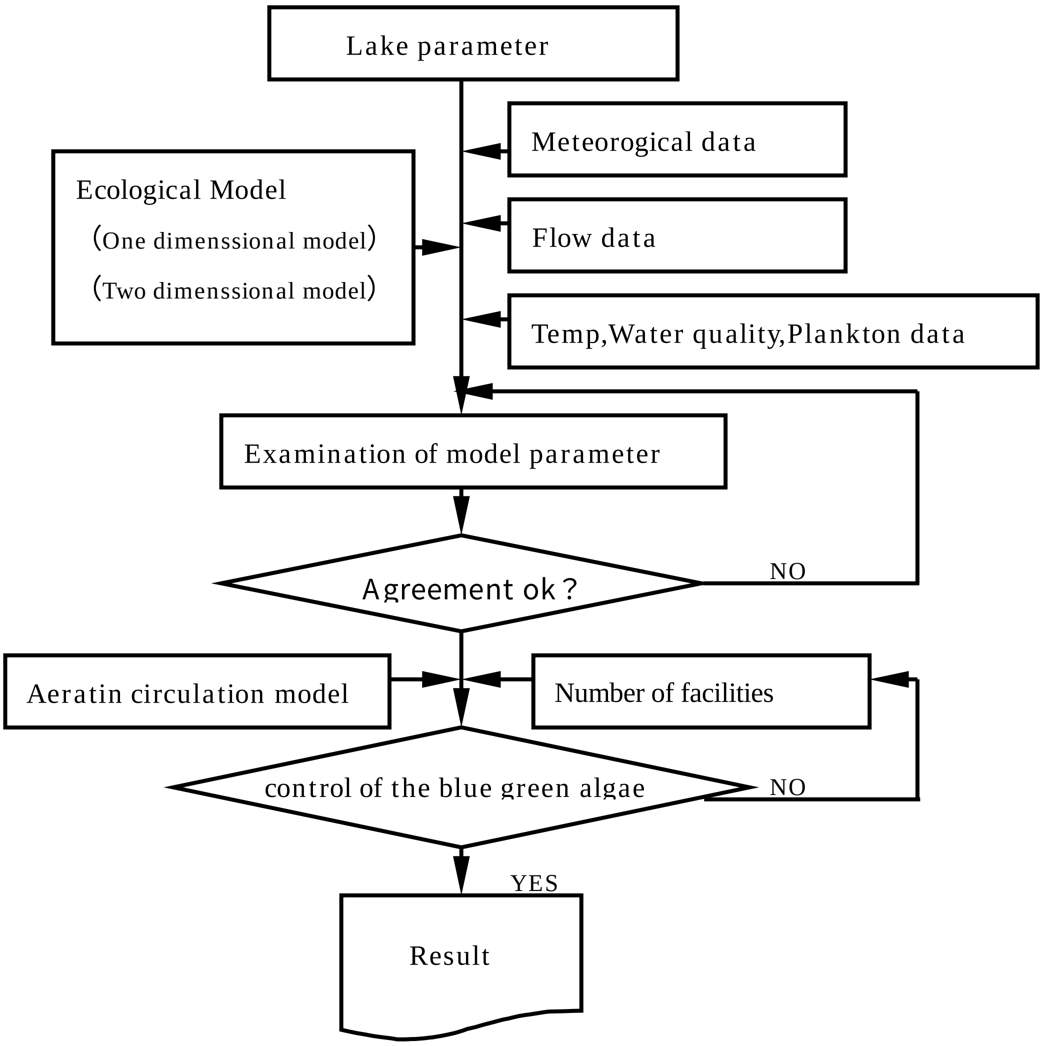

Figure 8-5-5 Optical limitation effect forecast calculation flow by aeration circulation

The formula for the proliferation speed of the ecological model is given by functional formulae on each limiting factor of water temperature, light and nutritive salts as shown below:

proliferation speed = f (water temperature)・f (light)・(nutritive salts)

This formula forecasts the effect that corresponds to 1) variation in light conditions, 2) variation in water temperature, and 3) variation in vertical advection that is caused by aerated circulation and determines the necessary specifications of aeration pipes.

[Design example]

The design of Kamafusa Dam (Tohoku District Development Bureau) is given below as a design example. Kamafusa Dam is a multipurpose dam having an effective pondage of 36 million cubic meters and a maximum depth of 27 meters.

Fig. 8-5-6 shows forecast calculations as of 1985 based on the installation of aeration pipes. The three 22 KW aeration pipes installed (equivalent to 12 single-type pipes) would result in almost completely restraining the Phormidium of blue-green algae. Under this plan, currently aeration pipes equivalent to 9 pipes are installed, and they have been able to restrain generation of "musty odor" almost perfectly except in years of unusual weather. The adequacy of the forecast has actually been verified.

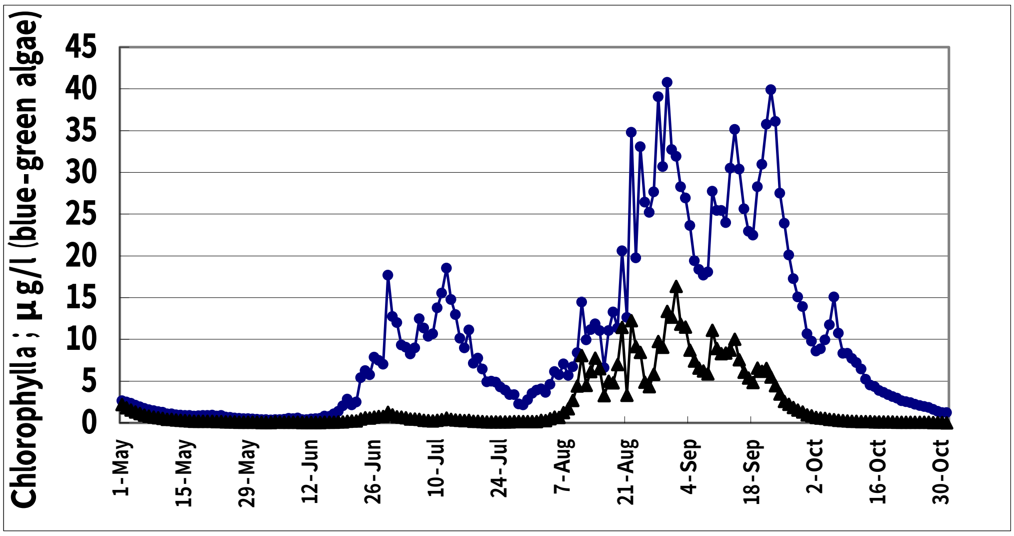

Figure 8-5-6 Effect of control of algae blue-green of aeration circulation of KAMAFUSA dam

b. Design to shorten the water layer detention period

Below are shown design calculation procedures to improve the detention period of the epilimnion.

a) Design variables

- Volume of epilimnion (depth at upper temperature stratification x lake area) ; V
- Set detention period ; T (days)

b) Design specifications

- Single type: output 7.5 KW, aeration pump up capacity；Q=25,000 m^3/day
- Dual type : output 22.5 KW, aeration pump up capacity；Q = 110,000 m^3/day
- Surface-layer water hauling rate ； α = 5 (measured coefficient)

c) Calculation of necessary aeration pipes

From conditions (1) and (2):

Number of necessary aeration pipes (N)

= (amount of epilimnion to be replaced／pump up capacity x (1+ α)

= (V／T) ／(Q x (1 + (1 + α))

d) Design example

Lake Sagami is taken as an example:

○Capacity of epilimnion (V) =lake area (2.58 km^2 x 3 m) = 7.74 x $10^6 m^3$

○Set detention period T = 2 days

○Aeration pipes required

N = (V／T) ／(Q x (1 + α))

7.74 x $10^6 m^3$／(110,000) x (1 + 5))

= 11.7 units 12 units

c. Design to improve DO of the bottom-layer water

For improving the DO of the bottom-layer water, the basis for the design calculations is to secure amounts of water for oxygen supply which satisfy the following DO balance formula:

Necessary oxygen amount (O) = oxygen-consuming speed of bottom sludge (R_S) + under-water oxygen-consuming speed (R_W)

Necessary circulation amount (Q) = necessary oxygen (O)／(oxygen concentration of surface layer C_u - oxygen concentration of lower layer C_d)

An example calculation on a lake having the described oxygen-consuming characteristics below is shown:
[Example]

Assuming that the lake area is 2.58 km^2, the surface-layer water DO(C_u) is 9 mg/1 and the lower-layer water DO(C_d) is zero, the design calculation is as follows:

1) Bottom sludge oxygen-consuming speed (R_S) = 120 mg/m^2 /day

2) Under-water oxygen-consuming speed (R_W) = 25 mg/m^2 /day

3) Necessary oxygen amount (O) = (120 + 25) x 10^{-6} x 2.58 x 10^6 = 374 (kg/day)

4) Necessary circulation amount $Q = O ／ (C_u - C_d)$

$= 374 \times 1000 ／ (9-0) = 41,600\ m^3/day$

5) Necessary aeration pipes = 41,600／25,000　　2

One thing to be noted here is that the pumped water should be calculated not on the amount of water after hauling, but on the net amount pumped up from below the aeration pipes. The above example, on the assumed scale of Lake Sagami, indicates that 2 single-type pipes will be enough for improving the lower-layer DO.

(3) Installation plan of aeration pipes

There are two required aeration pipe installation plans; a plan for plane arrangement and a plan for the distances between the installed aeration pipes.

a. Plans for plane arrangement

For efficient aerated circulation by aeration pipes, the proper positioning of installation is important. Needless to say, the positioning depends upon what water qualities are to be improved; however, a basic key factor is the principle of the artificial circulation utilizing density current. That is to say, for the efficient generation of horizontal density current, the following are the necessary conditions:

- Pumping up the highest density water
- Causing such water to mix with the lowest density water of the surface layer

The first condition pumps up the highest density or heaviest water to cause a circulation current to be generated in the range that reaches the lowest layer; the latter causes horizontal density current and enables it to replace as much light as possible, and to improve the high-temperature surface-layer water.

Therefore, in principle, aeration pipe arrangement plans should start by installing aeration pipes in the deepest part of the lake or impounding dam; however, flat- bottomed lakes require other reasons for shortening the detention period such as the dissolution of dead water.

b. Distance between pipes installed

Air-bubble jet forced out of the aeration pipe top rises while hauling and mixing with the peripheral water to reach the surface. The area where this turbulence has sufficiently developed is called the “jet area.” When these jet areas overlap, low-temperature water masses mix with each other and are likely to form higher-density water. In these circumstances, these formed masses are lower in temperature than the surrounding water, and submerge to lower layers; no horizontal circulation is caused and energy is lost.

For this reason, the distance between the installed aeration pipes needs to be set at least greater than the diameter of the air-bubble jet areas. As the diameter of these jet areas is between 20 and 30 meters, preferably the pipes are safely separated 50 to 70 meters apart.

8-5-4. Examples of Measures

(1) Examples at Kamafusa impounding dam

Kamafusa Dam is where for the first time in Japan full-scale blue-green algae restraining measures by aeration pipes were applied to a large-scale impounding dam. At this multipurpose dam with a total pondage of 45.3 million cubic meters and a lake surface of 3.7 km^2, in and after 1975, the Phormidium of blue-green algae was producing a musty odor, causing much harm to primary tap water, and therefore required activated carbon to be injected for purification treatment. Based on an applicable principle, aeration pipes were introduced. At present, five 7.5 KW pipes and one 22 KW pipe are at work. The musty odor at the dam is specified as “2MIB.”

Photo 8-5-2 The position of aeration pipesin Kamafusa dam

As shown in Photo 8-5-2, Kamafusa Dam was built along the deepest part of an ex-river course considering the circulation effect. The aerated circulation devices were installed in September 1984, and, as shown in Fig. 8-5-7 after that year Phormidium was drastically reduced and the musty odor “2MIB” decreased to under 5ng/l.

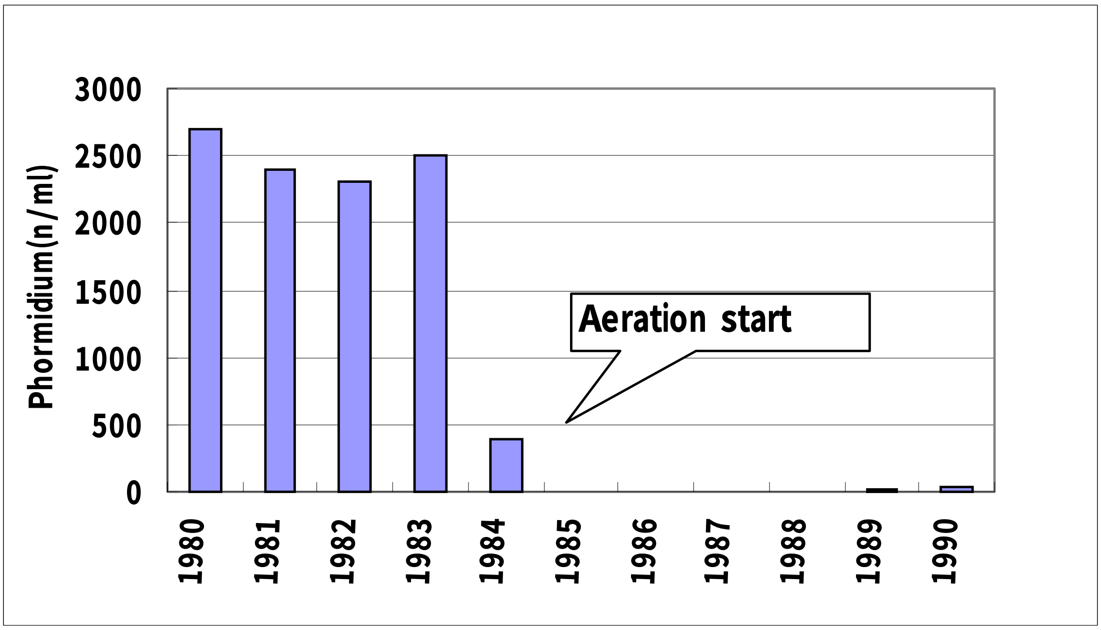

Fig 8-5-7 Effect of *Phormidium* control by aeration circulation in KAMAFUSA Reservoir

(2) Examples of Lake Sagami and Lake Tsukui

The lakes Sagami and Tsukui, with a pondage of 63.2 million cubic meters and 62.3 cubic meters respectively, are multipurpose impounding dams that supply primary tap water and electric power. The two older dams became significantly eutrophic around 1965 as shown in Photo 8-5-3, and every year large amounts of “water-blooms” were generated, urgently requiring implementation of full-scale measures to be. A full-scale investigation started in 1989, and aeration pipes were introduced at Lake Sagami between 1991 and 1993. At Lake Tsukui also, air-blow aerated circulation devices were introduced later in parallel with aerating the upper layers to good effect. The secular changes of microcystis in the peak years are as shown in Fig. 8-5-6. The microcystis drastically decreased due to the installed aeration pipes.

Photo 8-5-3 Water-blooms at Lake Sagami

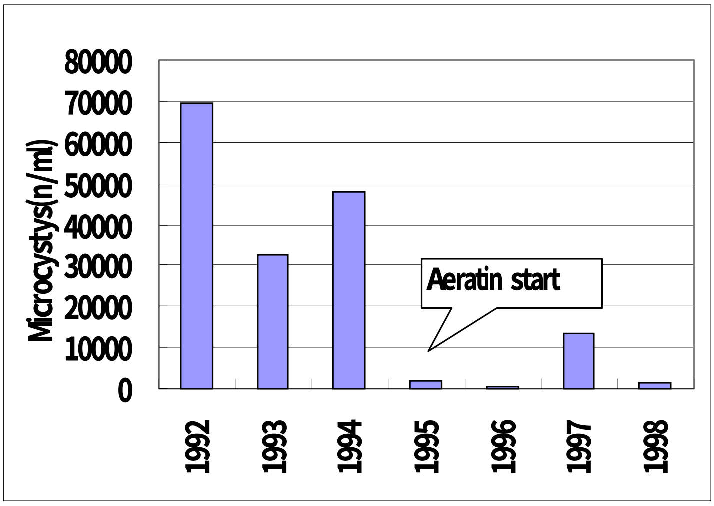

Fig 8-5-8 Effect of *Microcystys* control by aeration in Lake Sagami

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8-6. Lagoon Purification

8-6-1 Principle of the system and its features

The lagoon purification or the oxidation pond process is a treatment method that detains wastewater in a pond, maintains an aerobic condition using the oxygen generated by algal photosynthesis and dissolved from the air, causing bacteria to degrade organic substances contained in the wastewater. Due to its low construction and maintenance costs and very easy control, this lagoon process is widely used overseas for treating domestic sewage and industrial wastewater of various sorts; however, it requires a large space due to its long detention period, often gives rise to mosquitoes and odors but requires only a little rainfall. These are few examples put to use in Japan. This process consists of the facultative pond process or the high rate lagoon process, of which usually the former is used. The facultative pond has an effective depth of 1.5 to 1.8 meters, and usually operates at a depth between 0.9 and 1.2 meters. As photosynthesis does not take place deeper than 0.9 meters, a shallow pond is more effective. However, if the pond is too shallow, aquatic plants are likely to flourish, and in summertime, the temperature may rise too high; therefore, it should be at least 0.7 meters deep. The pond bottom is preferably made of the soil not easily permeated by water. The lagoon purification causes bacteria to decompose organic substances utilizing the oxygen generated by photosynthesis; therefore, bacteria and algae are directly involved in purification. In the pond, bacteria and algae are coexistent (Fig. 8-6-1).

Table 8-6-1 Types of oxidation pond

	Water depth(m)	Detention period(d)	BOD load ($g/m^2/d$)
Facultative pond	0.7 ~ 1.5	10 ~ 50	2 ~ 6
High-rate pond	0.2 ~ 0.3	2 ~ 6	10 ~ 30

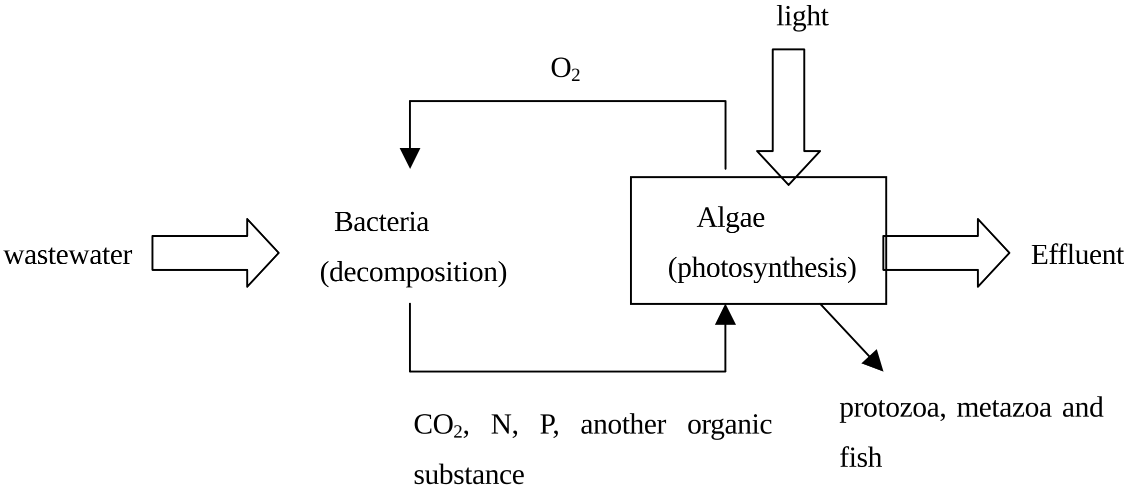

Fig. 8-6-1 Co-existence of bacteria and algae in lagoon

The bacteria decompose organic substances contained in the inflowing water using the oxygen produced by algae. Thus, produced inorganic substances serve as nutrients for the algae. Produced algae serve as food for protozoans, metazoans and fish. Purification efficiency in the pond improves significantly if the algae are collected; therefore, coagulating sedimentation or floatation in the outflowing water to remove algae will greatly improve the quality of the treated water. Multistage treatment having three or more ponds connected in a series provides discharged water with a low algal concentration if it allows fish to proliferate in the last pond. Proliferating fish are taken out of the pond from time to time. The algae that appear frequently in the ponds are green algae such as *Chrolella, Chlamydomonas* and *Scenedesmu*s and blue-green algae such as *Oscillatoria* and *Phormidium.* Likewise appear protozoans: they are *Flagellata* such as *Bodo* and *Oikomonas, Ciliata* such as *Cyclidium* and *Vorticella*. Metazoans are also reported to appear: they are *Rotifera* such as *Brachionus, Keratella, Colurella, Lepadella* and *Lecane or Cladocera* such as *Moina, Daphnia* and *Alona.* These protozoans and metazoans play a role in capturing, consuming and removing bacteria and algae; and further serve as food for fish.

8-6-2 Performance of the System

The most important manipulating factor in the lagoon process is the BOD load. The facultative pond is operated at a BOD load of 2 to 6g/m^2/d and the high-rate lagoon at a BOD load of 10 to 30g/m^2/d. Plural ponds are connected in a series to enhance the removal rate of proliferated bacteria and algae and obtain good-quality treated water. As the oxygen produced by photosynthesis is greater than the oxygen transferred from the water surface, sufficient algal proliferation is required to maintain an aerobic condition. When oxygen production is deficient in wintertime, artificial aeration is performed. The oxygen production at the oxidation pond is 0 to 0.6 g O_2/m^2/h with an approximate respiration speed of 0.1 to 0.23 g O_2 /m^2/h. At the pond, the dissolved oxygen is subject to heavy fluctuations that are at the highest in the afternoon and the lowest in the early morning. The BOD removal rate is heavily dependent upon temperature, being high in summertime and low in

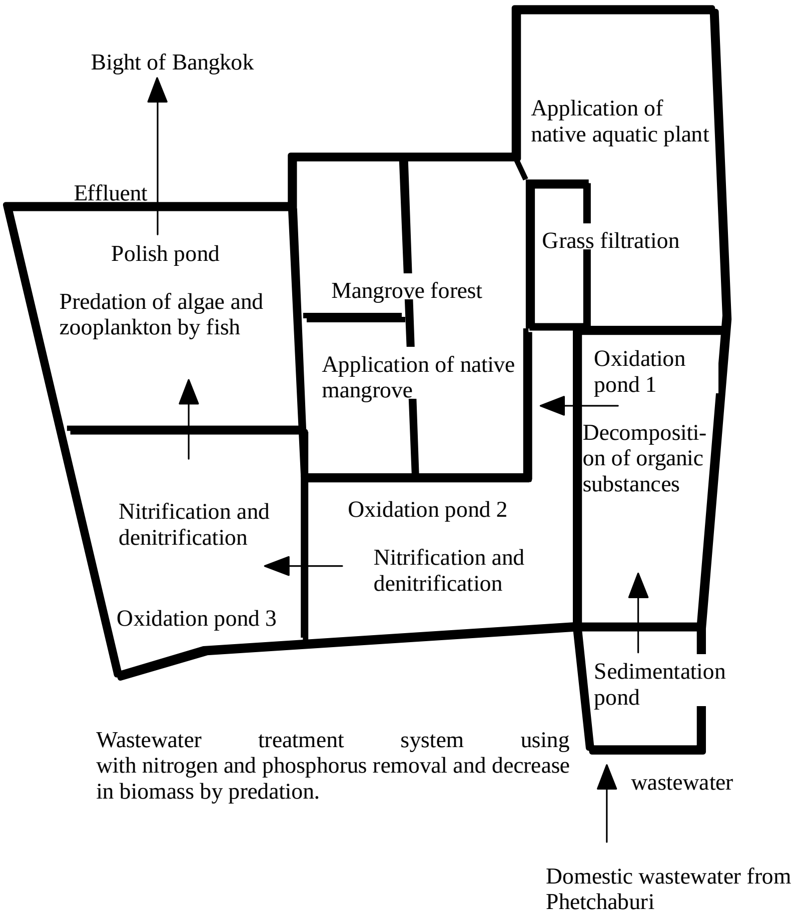

Fig.8-6-2Wastewater treatment facility constructed at Phetchaburi for the King's wintertime. The annual average removal rate is mostly around 80% and in summertime it may reach 98%.

Tropical regions such as Thailand have a temperate climate throughout the year and have vast land available in provincial cities so the lagoon process is regarded effective. The results of an investigation conducted at an oxidation pond at work in Phetchaburi, Thailand, are given below. The treatment flow at the facilities is shown in Fig. 8-6-2 and the capacity and depth of each pond in Table 8-6-2. The facilities are constructed with a designed gray water capacity of 10,000 m^3/day and a BOD of 200 mg/l; however, the actual amount of gray water (average) that inflowed each day was 1731 m^3/day while the inflowing water contained a BOD of 200 mg/l, a T-N of 22 mg/l and a T-P of 3.77 mg/l. The water quality at the outlet of each pond is as shown in Table 8-6-3.

Table 8-6-2 The volumes and depths of each lagoon constructed at Phetchaburi for the King's project

	Depth (m)	Area (m^2)	Volume (m^3)
Sedimentation pond	2.3	10217	23499
Oxidation pond 1	2	30408	60816
Oxidation pond 2	1.9	34898	66306
Oxidation pond 3	1.8	35424	63763
Polish pond	1.7	43132	73324

Table8-6-3 Treatment characteristics of lagoon constructed at Phetchaburi for the King's project

	BOD	T-N	T-P
Wastewater	145	22.0	3.77
Sedimentation pomd	45	19.5	3.48
Oxidation pond 1	31	11.8	3.09
Oxidation pond 2	21	7.5	1.37
Oxidation pond 3	12	6.8	0.71
Polish pond	14	6.1	0.51
Removal（%）	90	72	86

A system that utilizes ecoengineering which removes nitrogen and phosphorous and reduces biomasses through food chains. The overall removal rate obtained from the water qualities in the final pond is 90% of BOD, 72% of T-N and 86% of T-P. These reveal excellent treatment ability. The BOD removal rate at the sedimentation pond was calculated as 16.9g/m^2/d, which shows a removal rate three times higher than the rate so far reported in the oxidation pond. It shows how organisms are active and how the system is suitable for tropical regions. A great variety of algae, protozoans and metazoans are observed in the oxidation ponds. It is presumed that the food chains composed of these organisms have been so active that such high removal rates are possible. The microalgae that appeared at the facilities are 19 genera and 22 species (Table 8-6-4).

Table 8-6-4 Algae observed in lagoon constructed at Phetchaburi for the King's project

Cyanobacteria	
Oscillatoria sp.	*Anabaenopsis* sp.
Merismopedia punctata	
Green algae	
Coelastrum microporum	*Scenedesmus acuminatus*
Chlorella sp.	*Scenedesmus quadricauda*
Pandorina morum	*Tetraedron trigonum*
Ankistrodesmus falcatus	*Pediastrum duplex*
Eudorina elegans	*Botryococcus braunii*
Phacus caudatus	*Chroococcum* sp.
Scenedesmus sp.	*Tetraedron minimum*
Scenedesmus bicaudatus	*Golenkinia radiata*
Diatoms	
Navicula sp.	

Especially biota peculiar to oxidation ponds such as *Pandorina morum, Eudorina elegans* and *Phacus caudatus* were observed. Also observed were 10 genera and 10 species of microanimals: they are *protozoans ciliatas Vorticella sp., Paramecium sp., Zoothanium sp., Acineta sp.; protozoans Flagellatas Ocicomonas sp.; metazoans Flagellata Brachionus sp., Keratella sp, Philodina sp., Cephalodella sp.* and *metazoans Crustacea Cyclops sp.* It is inferred that these microanimals function as high-level predators, promote minimalization of organic substances and enable stable and highly activated purification. Photo 8-6-1 shows how residential wastewater is treated at an oxidation pond at Petchaburi.

Photo 8-6-1 An oxidation pond at Petchaburi

8-6-3 Ripple Effect of the System

In developing countries including Thailand pollution of water areas is becoming apparent because of wastewater deriving from activated industries and population increase. Rivers, lakes, marsh and reservoirs located in densely populated areas have been suffering heavy pollution. Residential wastewater is great majority of pollutant load, which indicates serious sanitary problems. Lakes and marsh that play an important part as drinking water supply sources are also becoming increasingly eutrophic. Water-blooms that contain microcystin, in the WHO (World Health Organization) guideline items on drinking water, have unusually been proliferating. Therefore, establishing and reinforcing counter-measures against toxic water-blooms is very important position for the remediation of water environments in every country including developing countries. However, measures against eutrophication that fit the conditions of each country are delayed, including those applicable to pollution sources and direct purification. The lagoon process utilizes solar energy and no motorized power, and is energy- and cost-saving and highly practicable. The process further enables fishing the fish that proliferate in the pond, and thus changes residential wastewater into fish-producing water. Instituting the lagoon process and building the basis for its diffusion will be of great effect in water reservoir areas in developing countries where improvement of water qualities is very necessary.

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8-7 Submerged Plant-based Purification

8-7-1 Principle of the system and its features

The aquatic plant-based purification method positively utilizes aquatic plants for purification. Included in this aquatic plant-based purification are principally the method that utilizes emerging plants such as reeds, water rice and *Typha angustada,* and the method that utilizes free-floating plants such as water hyacinths and duckweed. The submerged plant-based purification method here presented is features the utilization of submerged plants, not widely-used emerging or free-floating plants, for direct purification of water areas. In some cases, according to the particularities of the water area to which the method is applied, floating-leaved plants are used in combination with submerged plants. The definition "submerged plants" applies collectively to plants that unfold their leaves and photosynthesize under water; it is not a taxonomic definition. The submerged plants unfold their leaves usually only under water; however, some of them stand above water surface and develop air leaves. Among the submerged plants most popularly known are members of *Hydrocharis asiatica* such as *Vallisneria asiatoca, Hydrilla verticillata* and *Ottelia alismoides*, and members of *Potamogeton distinctus* such as *Potamogeton malaianus, Potamogeton crispu, Potamogeton oxyphyllus* and *Potamogeton maackianus.* The floating-leaved plants that are widely used in combination with these plants are *Potamogeton distinctus, Nymphoides peltata, Nuphar japonicum* and *Trapa japonica.*

The principal members of submerged plants are given in Table 8-7-1, and the members of the floating-leaved plants used in combination, in Table 8-7-2. Some of the submerged plants such as *Potamogeton malaianus* can subsist, even in an environment where water has dried up showing the bottom sediment, by stretching air leaves. Attention should be paid as the forms of under-water leaves and air leaves are significantly different. The submerged plant-based purification method has a basic principle of causing plants to absorb nutritive salts and likewise microorganisms such as organisms attached to the plant surface to effect purification, in just the same way as purification by utilizing emerging plants or free-floating plants. Some of the features of using submerged plants is that although artificially planted, they do not flourish above surface and present no notable difference to the landscape; they provide greater surface area than emerging plants; they contribute habitats, as submerged structures, to large crustaceans such as water fleas and small fish; and they are not moved by wind or waves as are free-floating plants.

Table 8-7-1 Submerged plants utilizable for submerged plant-based purification

Family	Japanese vernacular name	Nomenclature
Isoetaceae	mizunira	*Isoetes japonica*
Hydrocharitaceae	yanagisubuta	*Blyxa japonica*
	ookanadamo	*Egeria densa*
	kokanadamo	*Elodea nuttallii*
	kuromo	*Hydrilla verticillata*
	mizuoobako	*Ottelia alismoides*
	kougaimo	*Vallisneria denseserrulata*
	sekishoumo	*Vallisneria asoatoka*
Potamogetonaceae	sasabamo	*Potamogeton malaianus*
	ebimo	*Potamogeton crispu*
	sennninmo	*Potamogeton maackianus*
	yanagimo	*Potamogeton oxyphyllus*
	itomo	*Potamogeton pusillus*
	ryuunohigemo	*Potamogeton pectinatus*
Najadaceae	ibaramo	*Najas marina*
	torigemo	*Najas minor*
	hossumo	*Najas graminea*
Ranunculaceae	baikamo	*Ranunculus nipponicus var.*
Ceratophyllaceae	matumo	*submerses*
Droseraceae	mujinamo	*Ceratophyllum demersum*
Haloragaceae	hozakinofusamo	*Aldrovanda vesiculosa*
	fusamo	*Myriophyllum spicatum*
	tachimo	*Myriophyllum verticillatum*
	suginamo	*Myriophyllum ussuriense*
Hippuridaceae	kikumo	*Hippuris vulgaris*

Lentibulariaceae *	tanukimo	*Limnophila sessiliflora*
Characeae	shajikumo	*Utricularia vulgaris*
Nitellaceae	hurasukomo	*Chara braunii*
		Nitella japonica

* Although a free-floating plant, it often sticks to the bottom sediment; close to a submerged plant.

Table 8-7-2 Floating-leaved plant used in combination with submerged plants for submerged plant-based purification

Family	Japanese vernacular name	Nomenclature
Potamogetonaceae	ohirumusiro	*Potamogeton natansa*
	hutohirumusiro	*Potamogeton fryeri*
	hirumusiro	*Potamogeton distinctus*
Menyanthaceae	asaza	*Nymphoides peltata*
	kagabuta	*Nymphoides indica*
Trapaceae	hishi	*Trapa japonica*
	onibishi	*Trapa natans var. japonica*
	himebishi	*Trapa incisa*
Onagraceae	mizukinbai	*Ludwigia peploides*
Nymphaeaceae	kouhone	*Nuphar japonicum*
	himekouhone	*Nuphar subintegerrimum*
	junsai	*Brasenia scherberi*
	onibasu	*Eurya ferox*
Nelumbonaceae	hitujigusa	*Nymphaea tetragona*
Marsileaceae	hasu	*Nelumbo nucifera*
	tenjisou	*Marsilea quadrifolia*

8-7-2 Performance of the System

One of the features of the submerged plant-based purification is the great improvement in transparency. Photo 8-7-1 shows a landscape at the lake Xuan Wu Hu, Nanjing City, Province of Jiangsu, China where submerged plant-based purification is in a demonstration test. In a water area enclosed by liner sheets, submerged plants such as *Egeria densa* and *Myriophyllum spicatum*, and floating-leaved plants such as water chestnuts are cultivated. It is clearly seen that transparency is 20 cm in the targeted water area while it is 80 cm where submerged plants are cultivated.

Contributing to maintaining high transparency are attached organisms such as *Vorticellae* that are attached to roots and stalks of aquatic plants, and free-floating organisms such as water fleas that inhabit the habitats created by leaves and stalks. Photo 8-7-2 shows magnified sections where the submerged plant *Myriophyllum spicatum* grows in the

Photo 8-7-1 Landscape of submerged plant-basedpurification test (China)

Photo 8-7-2 Cultivated submerged plant and attached biomembrane

submerged plant-based purification area. Attached organisms (periphyton) are observed to from around leaves. These periphytons are composed of attached protozoans such as *Vorticellae, Stentors* and *Suctorias;* attached *Rotifera* such as *Melicertoida* and attached diatoms. They feel slimy to the touch. They are the same kind as those formed on the surfaces of submerged pebbles or wooden stakes. Also, the stalks of submerged plants and floating-leaved plants that are present under water form new niches. In these habitats, filter-feeding floating organisms (planktons) such as water fleas and *Rotifera* exist in large numbers seeking escape from plankton eaters. Due to their predatory activity, free-floating plants are filtered and high transparency is achieved.

Fig. 8-7-1 shows the relationship between existing amounts of plankton and transparency. The figure indicates that the area that is densely inhabited by filter-feeding plankton such as water fleas, high transparency is achieved. Fig. 8-7-2 indicates the relationship between the existing quantity of periphytons and plankton. It shows the close relationship between the number of existing plankton and that of existing periphytons. In other words, the figure indicates that in the water areas where aquatic plants live, they play an important role in physical structure. Free-floating plants that

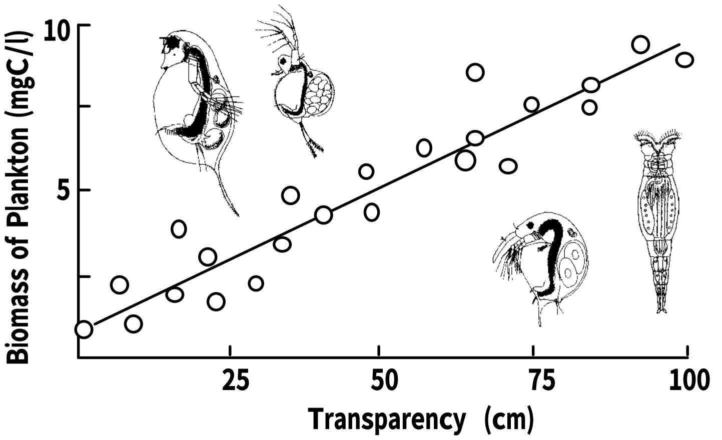

Fig 8-7-1 Relationship between existing quantity of plankton and transparency

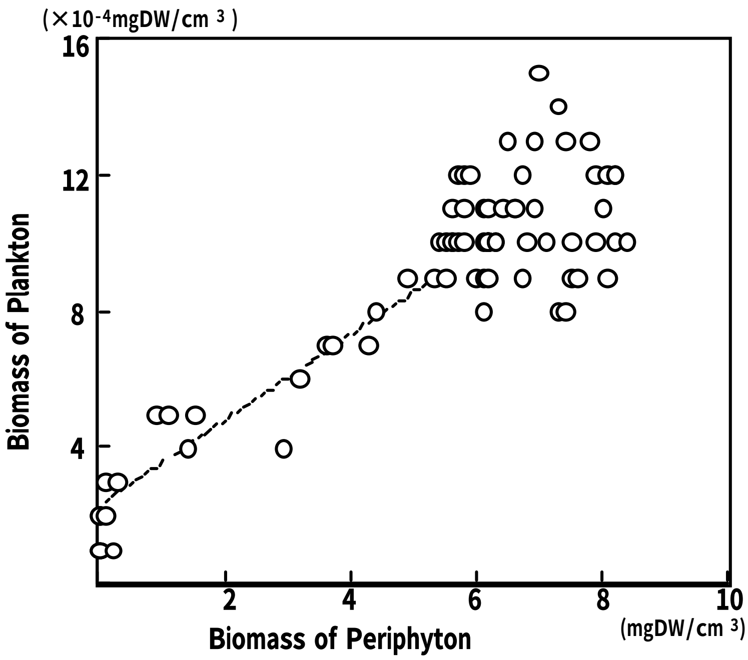

Fig.8-7-2 Relationship between existing quantity of plankton and of periphyton

contribute to water purification are free-floating microalgae such as blue-green algae and green-algae and flocks composed of bacteria and fungi. Algae absorb dissolved nitrogen and phosphorous and proliferate. The high activity of periphytons and plankton that eat the algae means that soluble inorganic nutritive salts are shifting from microalgae to periphytons and plankton. Also, in the submerged plant-based purification system, snails such as *Radix japonicus* and *Physidae* that eat periphyton and planktons, and large crustaceans such as shrimps and young fish coexist; further, *Amphibia* such as tadpoles and dragonfly nymphs, aquatic insects that eat these microanimals, birds such as ducks and herons and large-size carnivorous fish, are all involved in building a system which removes pollutants from the water area to the outside system through ecological food chains.

The submerged plants that play the leading part in this system have difficulty growing in an environment which lacks a sufficient amount of light for photosynthesis; therefore, they cannot be well utilized eutrophically in a significant way, and therefore contribute little to water transparency. This limits their use. Nevertheless, Photo 8-7-3 shows a submerged plant that has successfully adapted itself to a given environment as have *Potamogeton malaianus* in the lake Tai Hu in China; even in such a poor transparency conditions, the plant can grow its stalk more than five meters long to unfold its leaves on the water surface to photosynthesize. At lake Tai Hu, such plant communities are present in patches, and it has been confirmed that each of them functions as an ideal habitat for protozoans, *Rotifera*, water fleas, shell-fish, aquatic insects and young fish. The water purification characteristics of this system can be divided into the absorption and removal of inorganic nutritive salts by growing the submerged plants themselves, and the part played by aquatic plants as under-water physical structures. Fig. 8-7-3 shows results of a small-scale experiment using a hydrosphere where string-like contact materials were used as dummy submerged plants that neither absorb nor remove inorganic nutritive salts. The results show that in the hydrosphere where aquatic plants are present, the concentrations of organic substances and inorganic nutritive salts decreases by approximately 20% more in an experiment with no fish, and 30% more with an ecosystem involving fish than in the world with dummy submerged plants. The results suggest that, apart from the absorbing effect of aquatic plants themselves, the plants creates

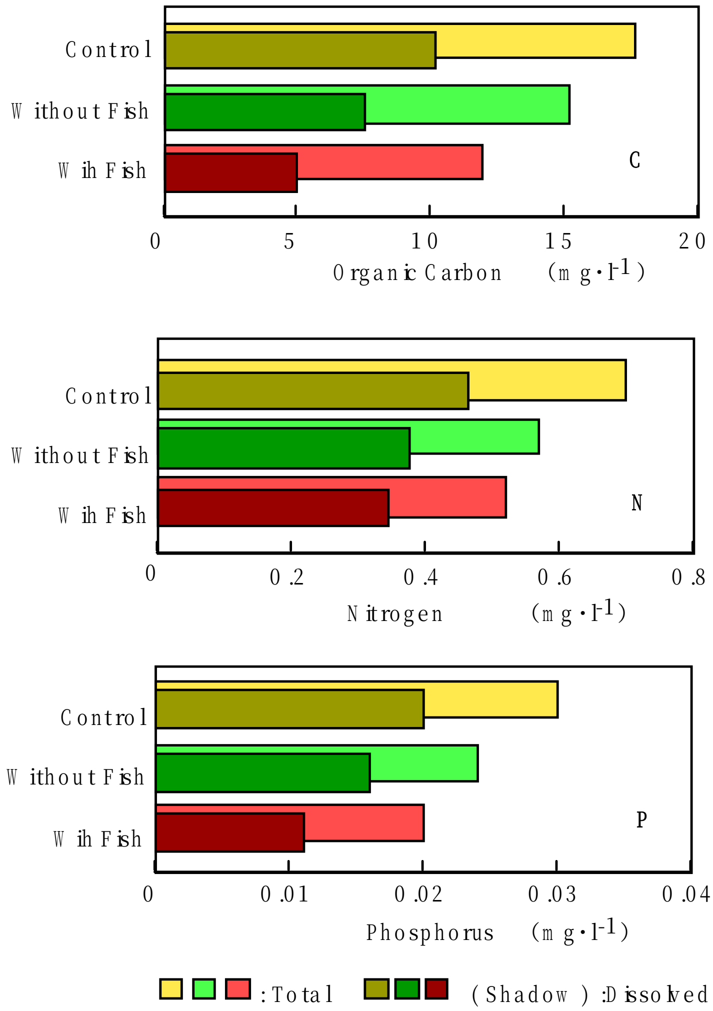

Fig.8-7-3 Comparison of water purification abilities in case of packed with artificial submergent

habitats allowing various animals to exist in larger quantities and that they greatly purify the water in a complex manner. In the actual submerged plant-based purification, a complex food web is formed by various organisms such as shell-fish, large fish, amphibians, reptiles, insects and birds besides small fish used in this experiment, and they keep the ecosystem stable. Once a stable ecosystem has been built, it has a buffering effect against environmental change and exercises its low-cost, sustainable water-purifying quality.

Photo 8-7-3 *Potamogeton malaianus* stretching stalks up to surface in search of light

8-7-3 Method of Applying the System

There are many types of submerged plants. Some, like *Potamogeton malaianus*, flourish in summer and die in winter; some, like *Potamogetn crispu*, flourish in winter to die in summer; and some, like *Egeria densa*, flourish throughout the year. The type that flourishes all through the year is easier to apply; however, there are types that let their leaves or stalks die when the season comes, yet form turions and store nutrients in their underground stalks; they allow nutritive salts to elute at a limited rate even when their leaves and stalks die. The most important thing in applying submerged plant-based purification is to understand the properties of the plant to be selected and select plants suitable to the water area.

Evidently, in applying this submerged-plant purification, plants will have difficulty growing if planted directly where their growth is difficult. It is necessary to choose adaptable plants from the native species of the same water area, and give them preliminary breeding, or the so-called “culture for adaptation” to the water environment. In this adaptation work, an important point is not to cultivate or reproduce control plants taken from distant places even though they belong to the same species. It is important to culture the stumps of the species growing native in the subject water area, cultivate, reproduce and divide them, and then plant them as regional genetic information of the species should be respected; the regional particularities are an important property. Yet, settling aquatic plants in a water area that has extremely poor transparency is a difficult task. In such a case, the purpose may be accomplished by using auxiliary contact materials. Photo 8-7-4 shows a string-like contact material that is placed in places difficult for cultivating submerged plants; the materials work as dummy submerged plants in such places. The material is made of braids of fine polypropylene plastic yarn woven into rings and is quite strong. The photographed material is 6 cm in diameter.

Photo 8-7-4 String-like contact materials utilizable as dummy submerged plants

Contact materials have been developed in a wide variety of materials, diameters and structures. During the period following the planting, submerged plants are subject to damage from various organisms such as crayfish and the tadpoles of bullfrogs; therefore, a method has been designed to protect the plants from enemies by weaving a float into the braids or placing string-like contact materials having a float in the upper part as dummy submerged plants and planting real plants between them; thus, the plants will be protected from enemies at the initial stage of planting. Another idea being studied is building string-like contact materials of biodegradable plastic as dummy submerged plants, which decays of itself to disappear after protecting the submerged plant in its initial stage, and shifts in a natural way to the community of planted submerged plants.

When this system is applied in deep water, dangling string-like contact materials from an artificial floating island is also being tried as an irregular application. This method does not use submerged plants; however, it makes the structure invisible above the water by positioning a floating island, which dangles string-like contact materials, under water fixed with an anchor; by broad definition, this is regarded as submerged plant-based purification. Photo 8-7-5 shows an assembled artificial module with dangling string-like contact materials. Anchoring this module under water and connecting plural modules will create new niches under water. A defect of this irregular use is that it does not cause plants to absorb and remove inorganic nutritive salts. However, it has been confirmed that conferva such as pond scum has adapted to flourish in the upper part of the water near the floating island; it causes water birds such as coots that selectively eat conferva to fly over and greatly contribute to removing inorganic nutritive salts from the ecosystem.

Photo 8-7-5 Artificial floating island utilizing string-like contact materials as dummy submerged plants

The mass balance attributable to water-purifying characteristics of the submerged plant-based purification, confirmed so far, varies according to the scale or type of the composed ecosystem. However, generally, the amount of pollutants absorbed and removed by plants and the amount removed by the work of animals are almost equal. The water-purifying characteristics of the submerged plant-based system are shown in Fig. 8-7-4.

In other words, the submerged plant-based purification system uses to the utmost the ecological food web and causes a great variety of animals to participate in it. For instance: (1) the bottom sediment is oxidized by rootstalks of the submerged plants enabling freshwater clams to settle; clams eat phytoplanktons, which decrease in quantity causing the transparency to improve. (2) submerged plant communities protect young fish from their carnivorous predators and contribute to maintaining the existing quantity of small-size plankton-eating fish. It enables the phytoplankton→zooplankton→ plankton-eating small-size fish→carnivorous fish food chain to operate. (3) the system attracts aquatic insects such as dragonfly nymphs nymph and giant water bugs that eat small fish fly and settle down. The emergence and flight of the insects builds a system of removal toward the outside, which operates as follows: phytoplankton → zooplankton → small-size plankton-eating fish → carnivorous aquatic insect → emergence to the outside system. (4) tadpoles inhabit the system, eat plankton and detritus, and when grown up they move to the land; thus building a system of removal toward the outside. (5) plankton-eating fish increase in quantity and cause plankton and periphytons to renew earlier, be more active in proliferation, and thus increase their ability to purify. (6) organisms such as shrimps, fish and shell-fish that serve for fishery increase in their existing numbers; fishing professionally, humans are positioned on top of this ecosystem. Thus, the cycle of the continuous pollutant-removing system is promoted. Through all these routes, it is clear that dissolved organic substances and inorganic nutritive salts are removed from the system.

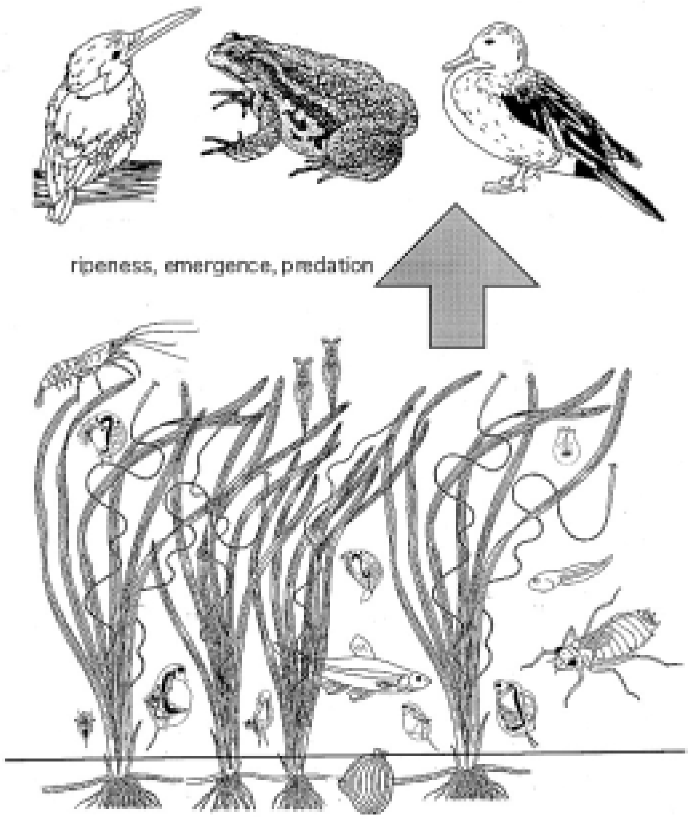

Fig.8-7-4 Total effects of ecosystem created with submergent

Thus, a submerged plant-based purification method utilizes the ecosystem to the maximum, producing no significant changes in the landscape; further, it is a low-cost, easy-to-maintain environmental ecological engineering method. Though the system is applicable to limited water areas, these defects will be corrected over numerous applications. The system will then be given increasing attention.

8-8 Resident-Participation Measures relating to the Kitchen

8-8-1 Principle and features

In public water areas suffering from water pollution, the main pollutants mostly derive from residential wastewater. So the real problem is lack of awareness of the problem on the part of residents responsible. It is necessary, more than anything, that each resident make an effort not to discharge polluted water.

In our country, the quality of water in rivers, lakes and marsh and sea areas have shown some improvement due to regulations on plant effluents, etc.; however, the environmental standards (living environment items) have accomplished no more than 70%. Approximately 50% of the pollutants flowing into these water areas derive from untreated discharged gray water; therefore, reducing the gray water load is essential in improving water quality in public water areas. Gray water is residential wastewater excluding human waste, from kitchens, laundries, bathrooms and so forth, and the greater part of the pollutant load comes from wastewater from kitchen cooking (Fig.8-8-1).

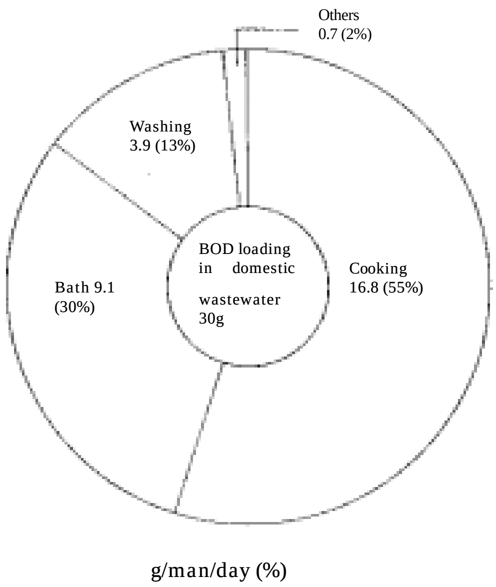

Fig.1 Ingredient ratio of domestic wastewater

The primary units of load from household wastewater, or the amount of pollutants discharged per person per day, were calculated from past measurements as follows: BOD that indicates pollution by organic substances is 27g/person/day; of total nitrogen and phosphorous responsible for eutrophication and contained in nutritive salts are 1.3 g/person/day for T-N and 0.3 g/person/day for T-P. Nitrogen and phosphorous, especially, have a particular situation. In closed water areas, algae proliferate; then internal algal reproduction increases COD in the hydrosphere. Therefore, even if inflowing COD is reduced, the situation results in progressive pollution. In view of this, not to mention the reduction of organic substances, it becomes essential that treatment facilities be diffused for the treatment of gray water from individual households that is currently discharged untreated and for wastewater treated without removing nitrogen and phosphorous. At the same time, measures aimed at reducing loads imposed by kitchens are particularly important. Such measures will help to reduce residential pollutants that are currently discharged untreated, as well as pollutant loads on the treatment facilities. In this section, measures taken against kitchen wastewater and the effects of these measures based upon experimental study are explained.

8-8-2 Effect of Reducing Pollutant Loads by anti-Kitchen Waste Measures

Table 8-8-1 shows pollutant load calculated of BOD, nitrogen and phosphorous on the basis of primary units and each respective condition: the load on the total amount of wastewater obtained after washing pre-boiled rice of 720 ml four times using water of 4500 ml in total and the load on the first time washing water; , on the total wastewater after boiling spaghetti and noodles and buckwheat noodles using hot water of 1,000 ml per person; regarding Chinese noodles and Japanese hotchpotch, on the wastewater equivalent to a glass of soup (180 ml) each; and regarding old cooking oil, on a spoonful (15 ml) of the oil remaining in the pan in the form of slurry.

Table 8-8-1 Pollutant load generated by Cooking

Specimen	BOD concentration (mg/l)	Nitrogen concent. (mg/l)	Phospho. concent. (mg/l)	Discharge Amount (ml)	BOD (g)	Nitrog (mg)	Phospho (mg)
Rice washing w.	2,400	29	7.8	4,500	10.8	130	35
(First washing)	11,100	111	32	700	7.8	78	22
Spaghetti	5,400	55	17	1,000	5.4	55	17
Noodles	1,030	22	6.3	1,000	1.0	22	6.3
Fish (unprepared)	1,300	60	13	2,000	2.6	120	26
Chinese noodle	26,000	1,180	290	180	4.7	210	52
Soy bean soup	37,000	—	—	180	6.7	—	—
Corn cream soup	126,000	1,300	210	180	22.7	230	38
Hotchpotch	95,000	4,200	970	180	17.1	760	175
Soup stock	1,730	210	82	180	0.3	38	15
Pumpkin soup	87,000	5,200	830	15	1.3	78	12.5
Potato & beef	52,000	—	—	15	0.8	—	—
Meat sauce	150,000	2,400	370	15	2.3	36	5.6
Old oil	1,670,000	1,400	30	15	25.0	21	0.5
Detergent (liq)	200,000	3,200	10	7.5	1.5	24	0.1

Noodle boiling water: 1000 m/l to boil each of spaghetti 100 g, noodles 250 g & buckwheat noodles 170 g

Fish preparation: 1medium-size horse mackerel

Discharged water measuring guide: a glassful (180 ml), a spoonful (15 ml)

The Environment Agency made the proposal shown in Table 8-8-2 as -kitchen waste measures that can be put into practice in each household. Of these proposed pollutant-reducing measures, the initial wiping effect and the use of a triangular corner were reviewed.

Measured figures indicate that oil, sauce, mayonnaise and dressing attached to used crockery and utensils have very high primary pollutant load values, and therefore, wiping utensils and dishes will greatly help reduce the load. Table 8-8-3 shows how much the load is reduced by wiping. It shows that the detergent used to wash cooking utensils after they are wiped using a rubber spatula and paper have a load reduced from 1/3 to 1/6 of BOD and from ½ to 1/3 of nitrogen.

Table 8-2-2 In-kitchen pollutant load reducing measures

a) Measures in the kitchen
1) Control cooking refuse.
・ Cook just enough, have no leftovers.
・ Use triangular corner + filter paper to collect food left over.
・ Use fine strainers to collect solids and food left over.
・ Do not dump rice washing water; spray it on plants and in the garden.
・ Wipe sauce, mayonnaise, dressing, etc. left on the dishes after each meal with kitchen paper; then wash them.
・ Do not dump soy bean soup or soup stock.
・ Do not dump beer or other alcohol.
2) Properly dispose of used oil
・ Use up cooking oil each time you cook.
・ When dumping used oil, don’t dump it as it is. Use a commercial oil solidifier or absorb it with newspaper.
・ Wipe used oil attached to the frying pan, then wash it.
3) Properly dispose of collected materials
・ Frequently collect cookery refuse or leftovers in a triangular corner, dump it or bury it underground.
b) Laundry
Use the proper amount and type of detergent.
c) Bath
Use used water for laundry or other things.

Table 8-8-3 Pollutant load reduction by taking in-kitchen measures

Menu	Things washed	How wiped	Water ( )	Amount of pollution			
				SS	BOD	T-N	T-P
Hamburger French potato Seafood salad White stew Boiled rice	Large dish (4 + 1) Medium dish (4), Soup dish(4), Large spoon, Frying pan, Rice bowl Chopsticks, Pan (soup), Bowl, Rice cooker	Wipe dish and pan with rubber spatula, then wash	25	6.3	0.3	0.25	0.048
		Washed without wiping	35	11.2	1.8	0.81	0.158
Pork cutlet Cabbage Boiled seaweed Taro and radish soup Boiled rice	Dish (4) Rice bowl (4) Wok (1) Soup pan (1)	Wiped Wok and dish With paper, then washed	30	1.8	13.5	0.27	0.033
		Washed without wiping	30	21.9	38.4	0.42	0.072

When cleared table for 4 persons.

8-8-3 Promoting domestic wastewater measures

In our country, measures against residential wastewater have so far been aimed principally at the installation of sewerage systems, and septic tanks as measures against pollution sources; however, sole dependence on development of such treatment system on the basis of "area" will require a long period of time before treatment facilities come into wide use; and further, reduction of pollutant loads, even though reduced, will not ensure stable qualities of discharged water below 10 mg/l of BOD, 10 mg/l of nitrogen and 1 mg/l of phosphorous. Therefore, it is necessary to systematically promote domestic wastewater measures; namely, proper measures for sewage treatment and effluent load reduction by taking in-kitchen measures.

In these circumstances, in 1988 the Environment Agency drew up "Guidelines for Promotion of Residential Wastewater Treatment," which were partially amended in June 1990 to incorporate measures for residential wastewater into Water Pollution Control Law. The chief points of the amendment were: 1) definition of government responsibilities and the people involved in measures for residential wastewater (Table 8-8-4), 2) well-planned and coordinated promotion of residential wastewater treatment (Fig.8-8-2), 3) installation and diffusion of residential wastewater treatment facilities, and 4) promotion of awareness and education among the residents. The indication of targeted residential wastewater treatment areas will be made as part of the planned and coordinated promotion of these measures. The municipalities appointed by governors as targeted regions shall draw up "residential wastewater treatment measures promotion plans," through which they shall carry out the measures. As of January 30, 1999, forty prefectures, 171 regions and 414 municipalities are appointed as target areas.

Table 8-8-4 Responsibilities on residential wastewater treatment

Municipalities	・Promotion of installation of residential wastewater treatment facilities ・Fostering staffs in charge of education promotion ・Execution of other measures relating to residential wastewater
Prefectures	・Implementation of wide-area measures ・General coordination of measures drawn up by municipalities
Government	・Propagation of knowledge ・Technical and financial help to local public bodies
People	・Disposal of cookery refuse and used oil; proper use of detergent ・Cooperation with national government and local public bodies

8-8-4. Improvement of Water Environments Through Resident-Participating Residential Wastewater Treatment

For the effective promotion of residential wastewater treatment measures, people need opportunities that raise their awareness about water pollution. For this, it is essential to have people experience reborn nature, purified water or recycled natural resources. Then, utilization of "Ecoengineering," which includes the use of natural energy and plants, will be of great help as it enables residents to enjoy creating and maintaining a biotope. It will also help to purify water and make people more environment-conscious.

At Funabashi City, Chiba Pref., citizens are participating in a project aimed at purifying the Kanasugi River which coexists with a biopark (ecological space) at the uppermost part of the river where some 200 families live in a residential area. Fig. 8-8-3 shows what the facilities of the biopark and how it operates to purify the water. At Kanasugi balancing reservoir No.1 (3,181 m^2 , covered with three concrete planes) a waterway (55 cm wide and 15 cm deep) runs through its central part, and the flowing sewage is purified at a purifying section (50 m long) within the waterway where contact materials made of carbon fiber (50 cm x 2) are installed at 40 points; then, the treated water is pumped up at a speed of 1.7L per second to the biotope purifying pond (636.8 m^2, with average depth of 5 cm where wild rice, watercress, parsley and water feather are cultivated) which is partitioned by concrete planes within the balancing reservoir.

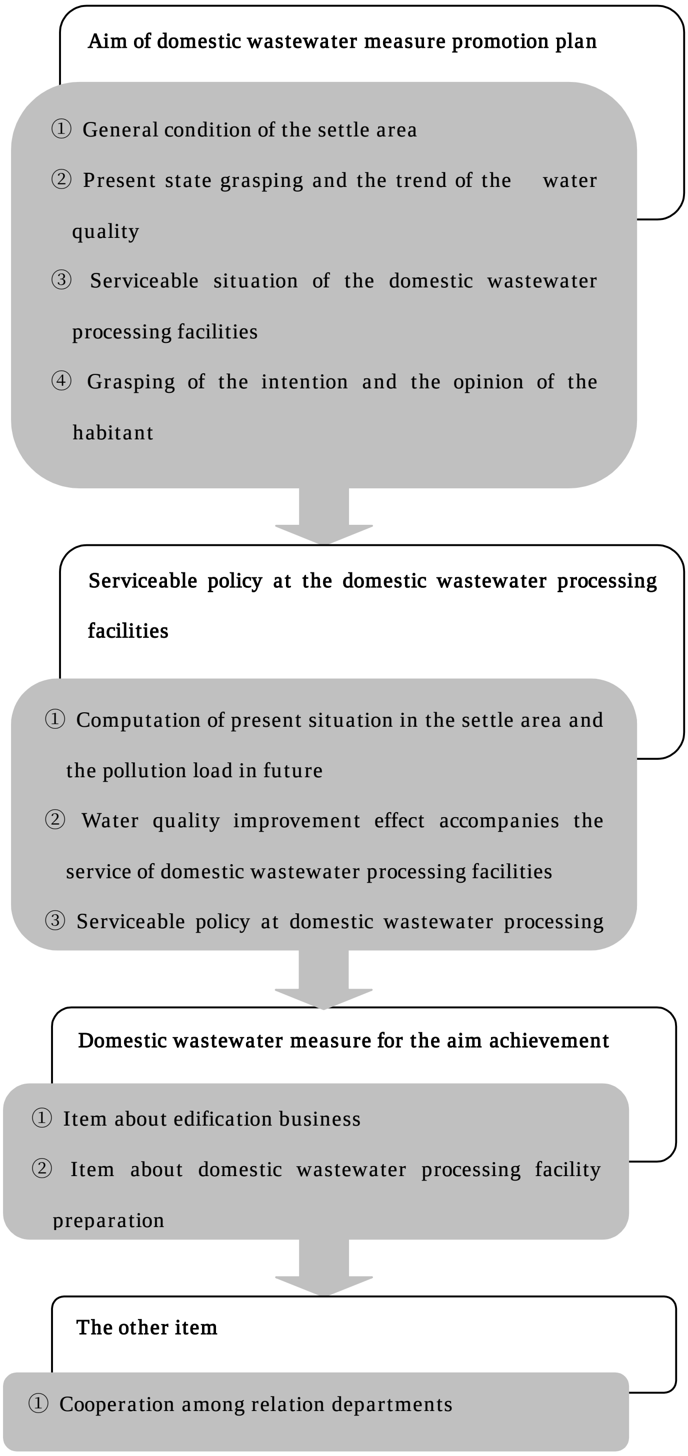

Figure 8-8-2 Flow of the domestic wastewater measure promotion plan

The confirmed purification result is a quality under 5 mg/l of BOD against 30 mg/l before purification. Also, an effect has been seen in the recovery of habitats of organisms. A great variety of birds, fish and insects have recovered their habitats in the biotope including areas downstream of the river. Further, plants that have flourished thanks to purification are being successfully collected as good-quality compost that finds use in green areas or as gardening fertilizer. The biotope also contributes to the improvement of living environments and landscapes; odors have been reduced by purification; unused space is now covered with greenery and the living environment of the neighboring areas has also been improved. Thus, efforts towards purification by this method have been made in conjunction with public works of Funabashi City as a local public body with ample citizen participation; businesses and administration have also cooperated. Such activities have successfully produced diverse environmental improvements other than water purification, leading citizens' interest in putting in-kitchen measures into practice and building the biotope; and therefore, the biotope facilities were constructed and are being operated at a much lower cost than normal river purification facilities. All this is an effect of residential wastewater treatment with active citizen participating. Fig. 8-8-4 is a conceptual picture showing the role shared by citizens, the administration and the resulting effects.

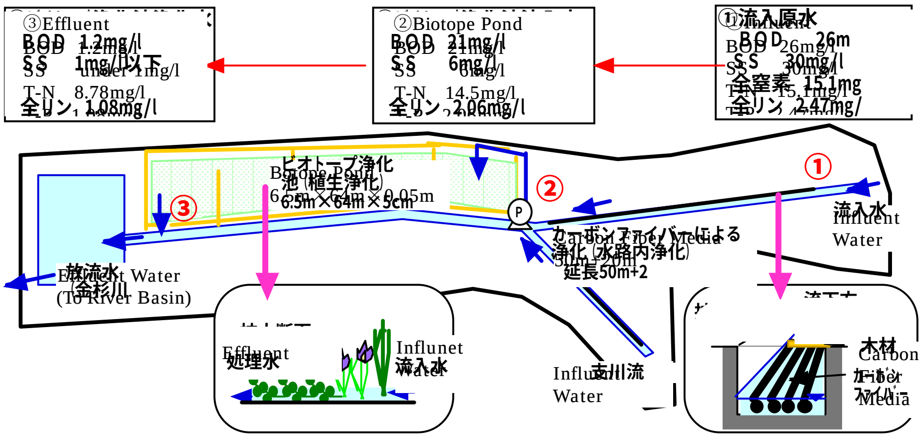

Fig. 8-8- 3 Overview and the purification effect of "water purification facilities with ecological engineering (Funabashi City) "

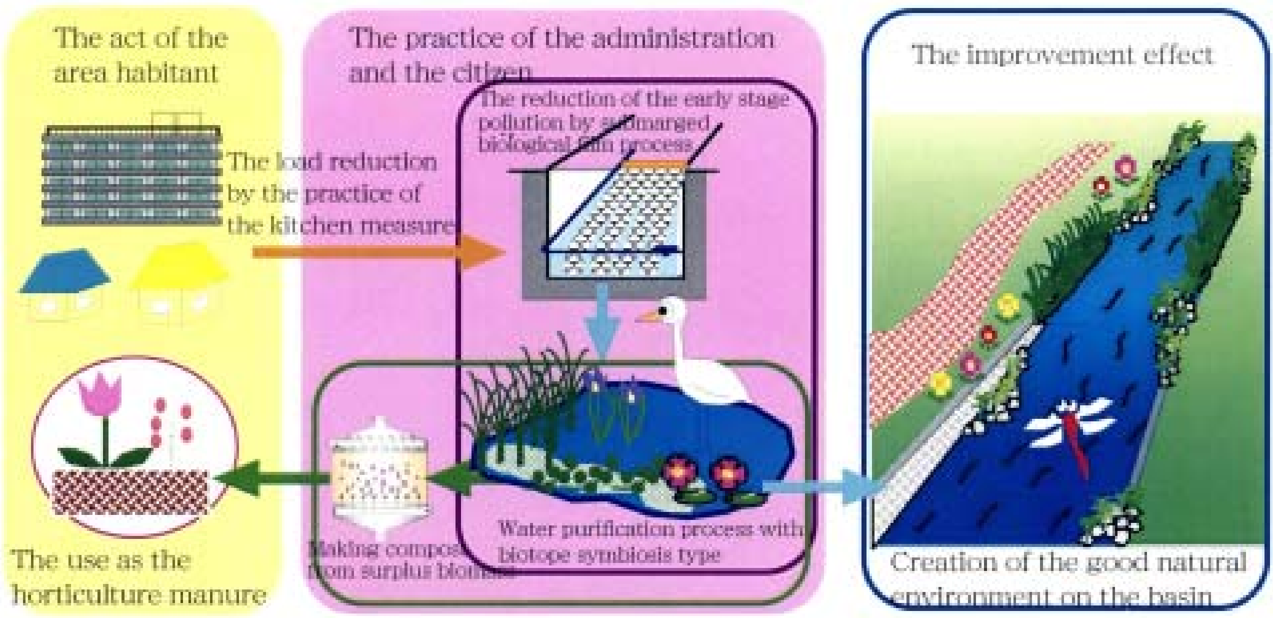

Fig. 8-8-4 The concept of the role share of the domestic wastewater measure and environment improvement effect by the citizen and the administration

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9. Administrative countermeasures for measures against eutrophication

To improve the prevention of eutrophication in lakes and marshes, which is developing progressively, each country, including Japan, is conducting various measures. Some representative samples are presented here.

9-1 Measures against eutrophication

9-1-1 Purpose of measures

In the era when the population was small, productive activities were low and people lived in harmony with nature, the natural purification ability was sufficient to deal with polluted water and industrial wastewater. There is an old saying, "Water becomes pure after flowing for three shaku (a Japanese scale, =0.994feet)," which plainly expresses the self-purification action of rivers. Once the amount of pollutants excreted into a water environment exceeds the content of the surrounding environment, environmental problems such as water pollution occur. Generally, the contents of water pollution are diverse. Roughly, there are harmful substances that have an adverse effect on the human body and pollution by pathogenic bacteria. Representative pollutants are harmful substances such as heavy metals and cyan, and infectious pathogenic bacteria such as dysenteriae. Next, there is pollution by organic substances deriving from everyday life and productive activities and discharge from human lifestyles. As a result, these various water pollutions generate phenomena such as river pollutants and bad odors, which consequently worsen the living environment. Nutritional salts continue to flow into closed water areas for a long period, causing the occurrence of red water and influencing drinking water and water products greatly. The situation is considered representative of water pollution as well, along with the phenomenon of eutrophication.

As for the efforts to preserve the water environment in Japan, keen measures have been taken as a socially urgent duty since the intense development of the 1970's. Consequently, for substances directly associated with human health (health items in the environmental standard) such as heavy metals, cyan, organic chloride compounds and agricultural chemicals in public water areas, the non-achievement rate of the environmental standard was 0.79% in fiscal 1995, almost its goal level. However, the achievement rate of the environmental standard for BOD and COD, living environmental items, has not yet been met sufficiently, and there is such a high proportion of pollution loads by lifestyles, commerce, livestock and small-scale factory wastewaters that measures for the reduction of those wastewaters have not progressed. Actually, the achievement rate of the environmental standard in rivers, lakes and marshes, and sea areas was 81.0% (80.9% in fiscal 1997), 40.9% (41.0%) and 73.6% (74.9%), respectively. The rate has not changed greatly over the past several years and that in closed water areas has tended to decrease. In closed basins such as lakes and marshes, bays, and inland seas and small and middle-sized urban rivers, improvement of the water quality is not progressing, and radical measures to reduce pollution loads have become social subjects that require urgent resolving.

In Japan, a main source of pollution loads on the water environment is living wastewater such as cooking, washing, bathing and excrement, and about 60% of the entire pollution loads flowing into closed water areas are derived from the living wastewater. Especially, the pollution loads from living wastewater excluding excrement are so great that the untreated living wastewater released from individual households has become a major factor of water pollution in public water areas. The great pollution loads of the living wastewater are due to small pollution from using a washing system and the fact that a single type private sewage treatment system from which living wastewater is released accounts for a high proportion of the septic tanks used in Japan. However, when measuring the sources of pollution loads not by BOD but by nitrogen and phosphorus, the proportion of excrement is as high as over 80% and over 60%, respectively. Thus, the degree of pollution indicates the importance of Domestic Wastewater Measures.

Besides the measures against the specific pollution loads of point sources represented by household wastewater, those against non-point pollution loads excreted widely from agricultural lands, forests and urban areas are also important. About 20-40% of the entire loads flowing into lakes and marshes is estimated as non-point pollution loads. When considering the high load of household pollution and the current situation where preservation and remediation of the water environment has become an urgent social issue, however, it is necessary to place stress on addressing the major sources of pollution loads.

Moreover, in Japan, in closed water area such as lakes, marshes and bays, the growth of primary products including algae and blue-green algae are promoted by inflow and the accumulation of nutritional salts such as nitrogen and phosphorus derived from household wastewater, and so-called eutrophication is under way. The eutrophication results from the abnormal growth of algae, especially blue-green algae, which causes the occurrence of water-bloom in lakes and marshes, dam lakes, holding ponds, and that of red water in bays and inland seas. Because water-bloom and red water fix and assimilate CO_2 gas in the air under a light condition to synthesize organic substances, COD deriving from cells increases in lakes and marshes, which becomes a great factor in the reduction of the achievement rate of the environmental standard in closed water areas. Thus, measures against nitrogen and phosphorus in household wastewater have become a major social issue. Lakes, marshes and dam lakes are sources for tap water in many cases, where various problems including 2-MIB (dimethyl isoborneol) produced by blue-green algae, fungus odor caused by geosmin, disturbed filtration by water-bloom and the production of the precursor of trihalomethane are induced. The occurrence of water-bloom causes bad odor and a worsened landscape, and also causes much damage in the utilization of water.

As for the recent situation of water pollution in public water areas in Japan, because the pollution loads flowing into closed water areas such as bays, inland seas, and lakes and marshes with great pollution sources behind the water areas particularly apt to accumulate pollutants while exposed to the inflow of large pollution sources, the achievement rate of the environmental standard is still lower than other water areas. In addition to this, substances containing nitrogen and phosphorus flow in and other aquatic organisms besides algae grow. Looking at the achievement rate of the environmental standard in these closed water areas in fiscal 1988 by COD, a representative index of organic pollution, the rate in Tokyo Bay and Ise Bay is still low and that in Osaka Bay and Hiroshima Bay of the Seto Inland Sea is also still low (Fig. 9-1-1). The achievement rate in lakes and marshes is especially low, 43%. To deal with such a situation, the further promotion of water preservation measures in closed water areas is required.

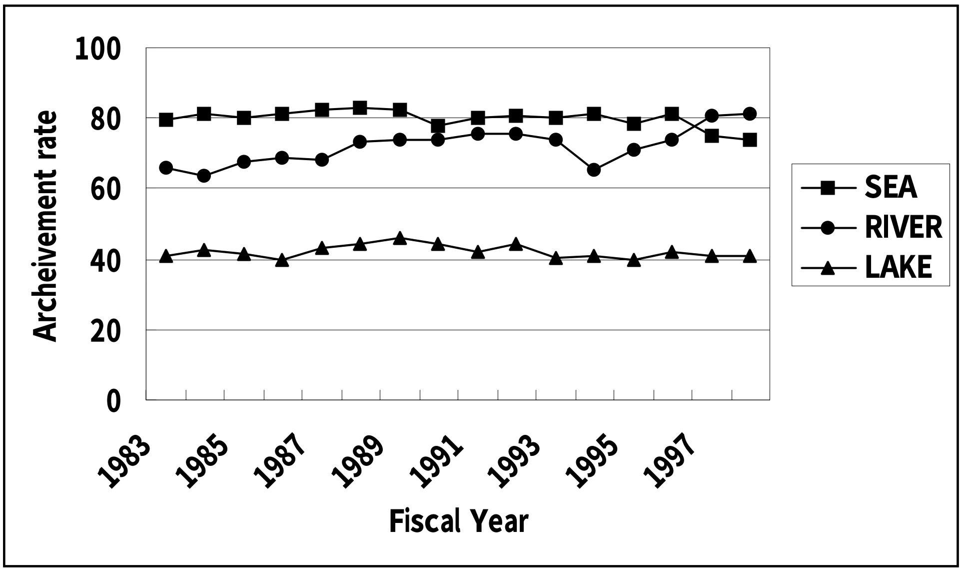

Fig 9-1-1 Succession of Achivement Rate for Environmental Standard in Japan
Succession of Achievement Rate for Environmental S

9-1-2 Outline of measures

Measures against water pollution in Japan are listed chronologically below.

(1) Discussion about the Problem of the Ashio Copper Mine Pollution in the Diet (1891)

(2) Enactment of the Agricultural Chemicals Regulation Act (1948)

(3) Enactment of the Basic Law for Environmental Pollution Control (1967)

(4) Setting of the headquarters for anti-pollution measures and holding a parliamentary session on environmental pollution (1970)

(5) Enactment of the Water Pollution Control Law (1970)

(6) Construction of the Sewage System (1958-1970)

(7) Inauguration of the Environmental Agency (1971)

(8) Enactment of the Law Concerning the Examination and Regulation of Manufacture, etc. of Chemical Substances (1973)

(9) Enactment of the Law concerning Tentative Measures for Conservation of the Environment of the Seto Inland Sea (1973)

(10) Enactment of the Law concerning Special Measures for Conservation of the Environment of the Seto Inland Sea (1978)

(11) Enactment of the Law concerning Special Measures for Conservation of Lake Water Quality (1984)

(12) Setting of a regulation standard for nitrogen and phosphorus related to lakes and marshes (1985)

(13) Amendment of the Law Concerning the Examination and Regulation of Manufacture, etc. of Chemical Substances (1986)

(14) Systemization of the prevention of groundwater contamination (1989)

(15) Systemization of measures against household wastewater (1990)

(16) Enactment of the Environment Basic Law (1993)

(17) Cabinet decision about Basic Environment Plans (1994)

(18) Law concerning Special Measures for Water Quality Conservation at Water Resources Area in Order to Prevent the Specified Difficulties in Water Utilization
(1994)

(19) Law concerning the Promotion of Projects to Preserve Water Quality in Drinking Water (1994)

(20) Strategies for the Purification of Polluted Groundwater (1996)

(21) Amendment of the Waste Disposal (or Management) and Public Cleansing Law (1997)

(22) Amendment of the River Act (1997)

(23) In addition to COD, the Removal Measures for Nitrogen and phosphorus started as the Fifth Total Effluent Control System (2002)

In Japan, water pollution by wastewater and air pollution by smoke from factories occurred due to industrialization during the high economic-growth period, 1955-1970, through the postwar reconstruction period after 1945. Consequently, serious social problems by industrial pollution occurred such as environmental destruction and the disturbance of human health. For example, for water pollution and the disturbance of human health, there was an occurrence of Minamata disease caused by dimethylmercury contained in wastewater from the Minamata factory (producing vinyl acetate) of the Shin-Nihon Chisso Co. in the watershed of Minamata Bay in Kumamoto Prefecture, and Itai-itai disease caused by cadmium contained in wastewater from the Mitsui Kamioka Mine in the watershed of the Jintsu River in Toyama Prefecture. To deal with these pollutions, the Basic Law for Environmental Pollution Control enacted in 1967was amended and strengthened in 1970, and the Environmental Agency was established in 1971. The 64th extraordinary Diet held in 1970 was called the pollution Diet and 14 bills related to pollution were enacted including amendment of the Basic Law for Environment Pollution Control. Thus, the legal system for anti-pollution measures in Japan has almost been established. In the Basic Law for Environment Pollution Control, air pollution, water pollution, soil pollution, noise, vibration, land subsidence and bad odor were positioned as the seven typical pollutions, and the respective related laws were enacted and amended. Among the seven typical pollutions, for air pollution, water pollution, soil pollution and noise, the standard desirable to protect human health and preserve the living environment, namely the environmental quality standard was determined. Moreover, for water pollution, the Water Pollution Control Law was enacted in 1970. Based on the Law, the effluent standard was determined and the emission control over wastewater from factories has been carried out. As a result, water pollution by organic substances and heavy metals derived from the wastewater of factories has definitely been alleviated. However, since more than half a century has passed since the enactment of the Basic Law for Environment Pollution Control, environmental problems have changed greatly in both quality and scale. During this period, the concentration of the population to urban areas has progressed further, and urban life with mass production, mass consumption and mass disposal abolition has settled under a stable economic growth. Consequently, in urban areas, life-style pollution such as air pollution by automobile exhaust gas and water pollution by household wastewater has become serious. In addition to the regional environmental pollution limited to polluted areas, global environmental destruction such as global warming and the destruction of the ozone layer has occurred. The era, where environment problems must be treated beyond one country's boundaries under an international coordination, has come. In such a situation, current environmental problems cannot be treated sufficiently by the Basic Law for Environment Pollution Control, and ideas for environmental measures were determined and the Environment Basic Act prescribing a new framework based on it was enacted in 1993.

The Environmental Basic Act prescribes the basic items of measures to preserve environmental and necessary items to promote the measures comprehensively and systematically under the following three ideas. The basic ideas are: (1) preservation and continuation of the environment formed on ecological balance (the third article), (2) construction of a society, which can sustain development with less loads on the environment (the fourth article) and (3) active promotion of global environment preservation by international coordination (the fifth article). Basic measures for environmental preservation based on these ideas include laying out the Basic Environment Plan (the 15th article), the setting of environment quality standards (the 16th article), laying out environmental pollution control programs (the 17th article), the promotion of Environmental Impact Assessment (the 20th article) and international cooperation for the preservation of the global environment (the 32nd article). To deepen national interest in and comprehension of environmental preservation, June 5 was set as an environmental day (the 10th article).

The Water Pollution Control Law aims at preventing water pollution in public water areas and groundwater by restricting the discharge of wastewater from factories and operation sites to public water areas and water penetration underground, along with promoting the execution of measures against household wastewater. The public water areas referred to in this Act are rivers, lakes and marshes, bays, coastal zones and creeks for irrigation. The wastewater, here, is the water discharged from factories and operation sites (specified operation sites) with specified facilities defined in government ordinance to public water areas. The specific underground-penetrating water is the water penetrating from specified operation sites with specified facilities for the production, use or processing of harmful substances such as cadmium to underground. The government will determine an effluent standard (a uniform standard) for effluent discharged from specified operation sites by ordinance of the Prime Minister's Office. For the areas where the water quality cannot be preserved sufficiently by this standard, the prefectural government can determine stricter standards than the national uniform standard (stringent add-on effluent standards) by individual ordinance (the third article). Moreover, in basins where it is difficult to achieve the environmental standard by only the effluent standard wastewater restricting the concentration, a standard for restricting total pollution loads will be determined (the fourth article). Among the specified water penetrating underground, water containing harmful substances is prohibited from penetrating underground (number three of the 12th article).

Among environmental quality standards based on the 16th article of the Basic Law for Environmental Pollution Control, standards related to water pollution are called the environmental standard of water quality. The environmental standard of water quality is promulgated as a notification by the Environmental Agency, and the current environmental standard of water quality in public water areas has been determined after the amendment in

1971 and at subsequent times thereafter. Moreover, in 1997, the environmental standard of groundwater quality was set. The environmental standards of water quality in public water areas are subdivided into Environmental Quality Standards Related to the Protection of Human Health (health items) and Environmental Quality Standards Related to the Preservation of the Living Environment (items related to the living environment). As for the health items, the standard related to the harmful substances of 23 items including heavy metals such as cadmium and mercury, organochlorine compounds such as trichloroethylene (TCE) and tetrachroloethylene (PCE), and agricultural chemicals such as simazine and thiobencarb has been determined. On the other hand, for the living environmental items, the standards for pH, BOD, COD and others in rivers, lakes and marshes, and sea areas are set with 3-6 steps such as AA, A and B according to the adaptability of the utilization purpose of the basin (type specification). For example, in the case of rivers, the whole watershed is divided into several small watersheds, in which the upper watershed with generally favorable water quality is determined as the AA type, followed by A and B types as the watershed goes down. As such, an achievable standard level is set and after its successful achievement, the types are reviewed to stricter types. As for lakes, marshes and sea areas, from the perspective of eutrophication prevention, the standards for nitrogen and phosphorus have also been set. The environmental standard of ground water is prescribed for health items associated with harmful substances, whose standard items and values are the same as the above.

The effluent standard by the ordinance of the Prime Minister's Office (a uniform effluent standard) is based on the third article of the Water Pollution Control Law and prescribes wastewater from specified operation sites separately for harmful substances and other items. The harmful substances in this effluent standard correspond to the health items of the water environment quality standard, but this effluent standard prescribes the standard value for organophosphorus compounds (4 kinds of organophosphorus insecticides) in addition to the health items. The largest standard values of the items in the effluent standard are set with a 10 times higher concentration than the standard value in the health items of the environmental standard of water quality on the premise that discharged wastewater is diluted more than 10-fold at the discharge point. As for the other items, the standard value of 16 items such as pH, BOD and SS are prescribed. However, this effluent standard is applied to the wastewater from specified operation sites with a mean discharged wastewater level of 50 m^3 or more (not applied to discharge on a smaller scale). There were about 303,000 specified operation sites in fiscal 1996, among which about 38,500 sites (only 13%) had the amount of 50 m^3/day or more. Namely, the standard of discharged wastewater has not yet been applied to many specified operation sites. To improve this situation, some municipalities lower the limit of the regulation of the discharged wastewater level. Also, some municipalities regulate their own effluent standard by adding items of the control subjects by ordinance in addition to the aforementioned stringent add-on effluent standards.

To improve water quality in a wide range of closed water areas, it is important to reduce total pollution loads flowing into the water areas effectively. For that purpose, the Basic Law for Environmental Pollution Control was amended in 1978 to systematize the Areawide Water Pollution Regulation aiming to ensure the environmental standard of water quality in a wide range of closed water areas. Since then, the areawide total pollutant load control has been implemented with chemical oxygen demand as a designated specified item in Tokyo Bay and the Seto Inland Sea.

The first areawide total pollutant load control was implemented with the target year of fiscal 1984. Subsequently, the second areawide total pollutant load control planned and enacted based on the new Fundamental Policy for the Reduction of Total Pollution Load by the Prime Minister was laid out and enacted with the target year of fiscal 1989, and the new Areawide Total Pollutant Load Reduction Plan was laid out and enacted in related prefectural and city governments.　In the fifth Areawide Water Pollutant Regulation, nitrogen and phosphorus were newly added to the regulation subject, besides conventional COD.　Namely, measures for nitrogen and phosphorus from operation sites and households have taken an important position.

As for measures against eutrophication, the environmental quality standard related to nitrogen and phosphorus, the causative substances of eutrophication, was notified in 1982, and a study for type specification was conducted both nationwide and at the local level. Each type was specified in a total of 44 water areas (40 lakes and marshes) including Lake Biwa (2 water areas) by 1989. The type specification of the environmental quality standard for eutrophication prevention in sea areas was implemented by the Environmental Agency by 1999.

As for measures against eutrophication, the general wastewater standard for nitrogen and phosphorus flowing into lakes and marshes was determined and the effluent control of the wastewater was started in July 1985.　In July 1989, some lakes and marshes were added as subjects for regulation of the effluent control. At present, the control is being conducted in 1,066 lakes and marshes for phosphorus and 78 lakes and marshes for nitrogen.

Because lakes and marshes are water areas with a highly closed condition, pollutants accumulate easily and the achievement situation of the environment quality standard is poorer than that in rivers and sea areas. In accordance with eutrophication, various disturbances of water utilization have occurred. Factors causing water pollution in such lakes and marshes vary from industrial activities operated in watersheds with lakes and marshes to people's daily activities. In consideration of the fact that only the conventional regulation under the Water Pollution Control Law is insufficient to preserve the water quality, the Law concerning Special Measures for the Conservation of Lake Water Quality was established in 1984 and was implemented in May 1985. This law intends to preserve the water quality in lakes and marshes; lakes and marshes, where securing the environmental standard of water quality is urgently required, are specified, Plans For the Conservation of Lake Water Quality in the specified lakes and marshes are laid out and projects for the preservation of water quality such as the construction of sewer systems, measures such as regulation against various pollution sources and protection of the natural environment of lakes and marshes are promoted comprehensively and systematically.

Measures against household wastewater based on the Water Pollution Control Law are explained below. Pollution loads on water areas are roughly divided into industrial, household and others. Recently, loads by household pollutant are considered the main pollution source. For example, in Tokyo Bay, about 70% of organic pollution loads are household loads. Although reduction in the loads of wastewater from factories and operation sites is recognized in accordance with strengthened effluent control, because the construction of sewer systems is insufficient, the loads of miscellaneous household effluent from people's daily lives are notable. Especially, kitchen wastewater containing leftovers is estimated to account for 55% of the entire domestic wastewater excluding the wastewater from toilets. Against such a background where the treatment of domestic wastewater is urgently required, in the Environmental Agency, the Guideline on Measures to Cope with Miscellaneous Household Effluent was made in 1988, and the Water Pollution Control Law was amended partially to include measures against domestic wastewater in the Law in February 1990. The main contents are: (1) defining citizens' and administrative responsibility related to measures against household wastewater, (2) promoting systematic and comprehensive measures against household wastewater,

- Environment organic act
  - materialization on November 12, 1993, and proclamation on November 19
- Prescription of the environmental standards (water quality relation)
  - ○ Environmental standards regarding the health of person
  - ○ Environmental standards regarding the living environment
- Water pollution
  - Water pollution prevention law
    - ○ Drainage standard (the addition of regional government)
      - Regulation of a harmful substance
      - Regulation of the pollution of effluent (factory for each type of industry)
    - ○ the appointment of the special institution
  - Lakes and marshes water quality security special measure law, Inland Sea of Japan environment security special measure law
  - Sewerage law
  - Ocean contamination prevention law, Harbor regulation law (discharge regulation etc. of oil) , River law
  - Toxic substance and powerful drug regulation law, Agricultural chemicals regulation law
  - Electricity business law, mine preservation law
- Soil contamination
  - The law regarding the soil contamination prevention etc.

Fig. 9-1-2 Law for water quality preservation in Japan

Table 9-1-1 The law for water management in Japan

The jurisdiction government office； basis law

Prime Minister；

Country comprehensive development law, Country survey law, Environment security law, Environmental standards law, Pollution measure organic act, Countermeasures against calamities organic act, Water resources development public corporation law, Lakes and marshes water quality security special measure law, Lake Biwa comprehensive development special measure law, Seto Inland Sea environment security special measure law, Public civil engineering institution disaster recovery business charge on national treasury law, Heavy snowfall area measure special measure law

Country traffic minister；

Weather business law, Prevention of floods law, Beach contamination prevention and sea disaster regarding the regulation of the picking of the subterranean water for the prevention law, Flood disaster prevention association law, Afforestation and preservation flood control emergency measure law, Special multipurpose dam law, Water resources development public corporation law, Beach law, Surface of the water reclamation law, Sewerage law, Sewerage upgrading emergency measure law, Japanese sewerage corporation law, Purificatory cistern law, Structure such as country traffic minister land organic act, Country comprehensive development law, Water resources development promotion law, Water resources public corporation law, River law, City planning law, Sand arrestation law, Ground sliding prevention law

Environment minister；

Water resources development public corporation law, Industry water for irrigation law, Economy industrial minister industry water for irrigation business law, Water resources development public corporation law, Industry water for irrigation law, Hot spring law, Purificatory cistern law,

Agriculture and forestry marine product minister；

Water resources development public corporation law, Industry water for irrigation law, Forest law, Ground sliding prevention law,

Economy industrial minister；

Industry water for irrigation business law, Water resources development public corporation law, Industry water for irrigation law

Labor Minister of Health and Welfare；

Water supply law, Water resources development public corporation law, Sewerage law, Purificatory cistern law

(3) construction and dissemination of facilities related to the treatment of miscellaneous household effluent and (4) the promotion of public enlightenment. The promotion is expected greatly because of the following reasons: the household wastewater, which had not been considered legally, was included in the Water Pollution Control Law, and citizens may be more familiar with the issue of measures against household effluent because the measures are implemented chiefly by the municipalities. The prefectural governors specify important areas for domestic wastewater measures, based on the Water Pollution Control Law. 171 areas and 414 municipalities in 40 prefectures were specified as of Jan 30, 1998. The legal system related to the preservation of water quality in Japan is shown in Fig. 9-1-2, and the laws related to the water quality issued by the competent authority are shown in Table 9-1-1.

9-1-3 Expected effects of measures

Measures for the conservation of the water quality in closed water areas are conducted mainly in lakes, marshes and sea areas. In the future, to improve water quality, it will be important to spread the advanced wastewater treatment system and make plans to reduce nitrogen and phosphorus and set water quality standards irrespective of water areas. The loads of COD decreased in the three sea areas of Tokyo Bay, Ise Bay and Seto Inland Sea by execution of the first areawide total pollutant control (target year: 1984). However, the water quality did not improve sufficiently. Thus, the second (target year: 1989) and third (target year: 1994) areawide total pollutant controls were implemented, and in 1996, the fourth Plan for the Reduction of Areawide Total Pollutant Load (target year: 1999) was determined. In the third areawide total pollutant control, the goal reduction rate for each different load source was set at 12% for household loads, 9% for industrial loads and 2% for others, and for sea areas, the rates were given as 13% in Tokyo Bay, 8% in Ise Bay and 9% in the Seto Inland Sea, respectively. In the fourth Plan for the Reduction of Areawide Total Pollutant Load, the reduction of the year’s average was intended. As a result of such regulations, the pollution loads in subjected sea areas decreased considerably. Although the occurrence of red water and blue water tends to decrease, the achievement rate of the environment quality standard remains low. The reason for this is attributed to eutrophication. Although the Areawide Total Pollutant Load Control was effective for the reduction of COD, an external load, it didn't lead to a reduction of its internal generation. The COD loads due to internal generations are estimated at 40-60%, and because the reduction of nitrogen and phosphorus will be essential in the future, nitrogen and phosphorus were added as regulation items in the fifth Areawide Water Pollutant Regulation Standard. If various measures function effectively in organic cooperation, the formation of a resource-circulating type society as well as the sustention of its development will be realized. By transferring the environmental conservation and remediation technologies established in Japan to developing countries and feeding back from those countries, a global society coexisting in peace and prosperity can be constructed. As a place to transmit information and develop human resources, there are great expectations for the Bioechoengineering Research Center of the National Institute for Environmental Studies, an independent administrative institution,, and everyone awaits their achievement in the future.

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9-2 Measures against eutrophication in China

9-2-1 Objectives

The land area of China is 9.61 million km^2, which is about 25.3 times larger than that of Japan. China occupies 1/15 of global land area and it is the third in land area, after Russia and Canada. A tenth of the lakes in the world are distributed in China. According to census figures in 1990, the population of China was 1.13 billion, which is more than 20% of the global population. To support this huge population in China, the pollution of China's rivers, lakes and marshes has been increasing due to industrial waste and other waste containing hazardous substances (Table 9-2-1). In consequence of the pollution, the water contamination and eutrophication of lakes has increased at a faster rate and many problems have arisen. The main damages to lakes in China by eutrophication are the following:

1) The eutrophication of the lakes in the suburbs of cities significantly deteriorates the efficiency of water utilization and some lake-water can no longer be used for daily life. The depth of most lakes in the suburbs is shallow and large-scale aquiherbosa have become extinct in such lakes. The development of industry and urbanization has increased the flow of domestic wastewater and the hasty proceeding of eutrophication of algae has caused the eutrophication of the lakes described above. The eutrophication has eliminated the function of the lakes as service water resources and the lakes are now no longer used as water resources. Since the transparency of the lakes has plunged to 0.1 – 0.5 m, and the water has turned to black or brown-green and smells fusty, opportunities for sightseeing have significantly diminished. Moreover, the fishery industry has suffered a great loss due to the death of fish.

2) The development of tourist resources and urbanization near lakes has increased the amount of untreated polluted water and it has accelerated the eutrophication of the lakes. (Ex. The Jingbo Lake in Heilongjiang Province, Dianchi Lake in Yunnan Province, the East Lake in Wuhan Province)

3) Foreign odor and tastes due to the deterioration of filter efficiency caused by a plague of algae have become an

object of public concern. Algae that have bloomed in an intake dam clogged a filter basin of a filtration plant in Fushun city, which wrought great economic loss. Development of eutrophication in the Chao Lake at Anhui Province caused a plague of algae and their consequent elimination was responsible for a disgusting odor. Since the odor still remains after the treatment of a filtration plant, the water is undrinkable and complaints are rife.

Table 9-2-1 The changes in the water pollution index in China

	1983	1984	1985	1986	1987
Chemical oxygen demand	98.82	254.85	296.81	360.57	374.14
Biochemical oxygen demand	52.55	100.14	145.62	152.72	174.42
Ammonia nitrogen	182.14	311.97	377.12	283.34	569.61
Nitrite nitrogen	10.12	94.19	43.36	20.65	24.14
Nitrate nitrogen	0.64	1.26	0	0.15	0
Volatile phenol	155.47	1165.92	588.06	713.67	707.38
Cyanide	1.53	2.99	3.98	3.25	4.89
Arsenic	0	0.1	0.87	2.63	2.55
Mercury	5.92	3	0.22		10.3
Hexavalent chromium	0	0	0	0	0.75
Lead	49.47	29.5	16.66	15.52	4.04
Cadmium	0.66	8.47	0.17	5.53	4.88

4) Some algae in an eutrophicated lake produce toxic substances. If these algae glow in large quantities, the toxic substances produced by the algae could kill domestic animals when they drink the water, and fish will be killed while the toxic substances decompose. It was reported that a lot of domestic animals were killed by drinking the water of Dalai Nur Lake in Hulunbeil, Mongolia. The algae known as toxic algae are *Aphanizomenon flosaquae, Anabaena flosaquae, Microcystis aeruginosa, Anabaena circinalis, Microcystis flosaquae, Gomphosphaeria lacustris, Gloeotrichia echinulata, Lyngbya contorta* etc. Besides this problem, there are many influences such as the radical reduction of the number of fish and water organism species, extinction of high grade fish, and decrease of water resources caused by a build-up of sludge at the bottom of lakes, which silts up the lakesso forth. For example, the Ci Lake in Huangshi, the Hillside Lake in Guangzhou, the Lake Wuliangsuhai in INNER MONGOLIA, and the Nansihu Lake in Shandong have suddenly become shallow. On the other hand, lakes in plateau areas have not yet been affected, probably because these areas have not been so affected by human activities.

The development of the eutrophication of lakes in China is a serious situation and development of laws and implementation of measures are urgent.

9-2-2 The general outlines of the measures

Protection and improvement of the environment are one of the basic policies in China and Article 11 of the

Constitution stipulates that the nation protects environment and natural resources and controls and prevents environment pollution and other kinds of pollution. To control the eutrophication of lakes: 1. Preventive measures, 2. Comprehensive measures, and 3. Proper management of lakes is required.

(1) Preventive measures

(1) Biological septic lagoons are installed at the vents of sewage-treatment plants to eliminate nitrogen and phosphorous by using the functions of water organisms efficiently. (2) Some factories near lakes have moved or closed. (3) Equipment that prevents oil leakage from ships has been installed to reduce oil contamination. (4) Sludge of fish firms in lakes is dredged away to decrease the digression of nutritive salt. (5) Protection of agroecosystem of lakes is required. (6) Afforestation and protection in areas surrounding lakes, and prevention of sediment discharge are required. (7) Administrative structure of lakes is required. (8) Development should be observed. In addition, water quality standards that vary related to the function of lakes need to be established for the partial improvement of water quality. Water quality standards have been established for Lake Gucheng in Jiangsu Province. The standards are different according to the functions of each area of the lake such as water source area, aquaculture area, and wastewater inflow area. Small lakes also require an adequate water quality standard depending on their main function. For example, the main function of the Mi Yun Reservoir in Beijing, Yuqiao Reservoir in Tianjin, and the Chao Lake in Anhui is regarded to be water resources for drinkable water. The main function of the Xuanwu Lake in Nanjing, the West Lake in Hangzhou, and the Jingbo Lake in Heilongjiang are mainly regarded as tourist resources. The Dudu Lake in Hangzhou etc. is mainly regarded as fishery waters (aquiculture using wastewater) and it has no function as either a water resource or a tourist resource. Moreover, the measures to reduce the degree of eutrophication are implemented which harness the ecological environment of lakes. At the Changchun South Lake and the Xuanwu Lake in Nanjing, aquiculture is performed utilizing their high degree of eutrophication and at the same time, measures to remove nitrogen and phosphorous from the water utilizing harvesting aquatic plants are also implemented. At Lake Gucheng, submerged plants are preserved to control the conversion to phytoplankton (algae) type of eutrophication.

(2) Comprehensive measures

The measures for the preservation and improvement of water quality of lakes can be listed according to the process of water pollution that is Source – Reach process – Deterioration of water quality in lakes: (1) Measures for pollution source, (2) Measures for controlling wastewater load, (3) Measures for the reach process, (4) Technologies for the improvement of water quality of lakes, and (5) Others. Results when some measures are implemented may differ depending on the features of each lake. Therefore, it must be noted that technology that is effective for one lake may have no effect on anotherlake. It is important to establish a systematic procedure to select an adequate control method considering the characteristics of lakes similar to the characteristics of the catchment area, hydraulics, water quality, and biotic factors. Comprehensive study is required that focuses on the response mechanism of lakes to the conservation measures for water quality and its control factors through experiments and case studies. Since nutrient salts in wastewater are point sources, it is easy to control compared to fields that are real sources. This is why the importance of denitrogenation and dephosphorization of wastewater has emphasized recently. General methods to reduce nutrient salts flowing into lakes are: (1) High-order treatment (Tertiary treatment) of wastewater (removal of nitrogen and phosphorus,) (2) Alternation of flow paths, (3) Alternation of the method of land utilization, (4) Treatment of river water flowing into lakes, (5) Banning the use of synthetic detergents, and others. Methods to remove the nutrient salts, which already flow into lakes, are; (6) Removal of the nutrient salts resolving into water, (7) Dredging and containment of sludge, (8) Dilution and drawing off water of lakes, (9) Mowing algae and aquatic plants etc. In addition to these measures, symptomatic treatments to maintain eutrophicated lakes at a certain degree of good condition are (10) Treatment using algicides or chemical herbicides, (11) Artificial aerification and circulation and so forth. China has taken measures against eutrophication at important lakes (The West Lake in Hangzhou, The East Lake in Wuhan, the Changchun South Lake etc.) (1) Reduction of wastewater flowing into lakes. Sanitary sewers of 9.1 km were laid down along the west side of the West Lake to drive the wastewater that should have flowed into the lake to a sewage-treatment plant. It eliminated almost all loads from point sources and most loads from area sources. Likewise, in the Changchun South Lake , the pollutional load of the lake was reduced to 26%, and the amount of nitrogen and phosphorous was also reduced by half. (2) Exchange of lake water by feeding clean water and the control of the accumulation and elution of nitrogen and phosphorous from sludge. The water of the Qiantang River (one of the tributary rivers of the Yantze River) is feeding into the West Lake (the amount of feeding water per day is about 1/33 of the total pondage of the lake,) and it greatly changes the water quality of the lake. However, as this kind of project needs a lot of funds, it is possible to apply only important areas. (3) Sediments and sludge of lakes in which nutrient salts are inactive include a great amount of nitrogen and phosphorous and there is the possibility of elution of the substances under an anaerobic condition. Therefore, in some cases, even the source is eliminated, eutrophication is still advanced because of the sludge. The sludge needs clearing out of lakes and could be used as fertilizer for agricultural land. (4) According to the experiments of removal of nutrient salts by using water organisms, Indian lotus reduces T-P from 1.00 mg/l to 0.33 mg/l and T-N from 3.89 mg/l to 0.8 mg/l in an eutrophicated lake. Phragmites, cattail, and water chestnut have a high absorption capacity of nitrogen and phosphorous. The contents of nitrogen per dry weight of phragmites and cattail were 1.176%, and 1.708%, and the contents of phosphorous were 0.264%, and 0.298% respectively. Mowing of these kinds of large aquatic plants could reduce the loads of nitrogen and phosphorous. At Lake Wuliangsuhai in INNER MONGOLIA, 300 km^2 of uliginous phragmites and 100 km^2 of submerged plants absorbed a lot of nutrient salts that come from pastureland and these plants were used as fertilizer after mowing. This enabled the reduction of nutrient salts and the livestock industry at the same time. The measures of reduction of nutrient salts by using water organisms are also applied, and the method of using spirals that consume soluble nutrient salts and algae are effective for purification. (5) Few sewage-treatment plants perform tertiary treatment and the diffusion rate of the sewer system is less than 2% in China. Most sewage-treatment plants in cities use the activated sludge process, but this process requires high energy and high construction cost and it is susceptible to many factors. Technologies of the oxidation pond and oxidation ditch are also used for swage treatment. Rotating biological contactor (RBC) is used for industrial wastewater treatment in dyeing, paper manufacturing, the leather industry, and the petrochemical industry but few are applied to human sewage treatment. Treatment using anaerobic microbes for concentrated organic industrial wastewater produced by fermentation industries (wastewater of alcohol, beer, chemical additive, starch, lemon acid and others), paper manufacturing, sugar manufacturing, and the leather industry have been studied. This method is effective for measures for pollution control and energy saving. Biological treatments (oxidation ditch, two-step aeration, technology of dephosphorization and denitrification of city wastewater, and treatment method using enhanced absorption organisms) have also been studied. These treatments require less energy, few construction costs and easier operation than the activated sludge method. The Tianjin Jishuangzi sewage-treatment plant having 0.26 million $m^3 \cdot d^{-1}$ throughput was built in the early 80s' and then the construction of large scale sewage-treatment plants were implemented in Dairen, Guangzhou, Chengdu, Xiamen, Kunming and others. The researches of sewage treatment technologies (methane septic tank, oxidation tank, soil-crops system etc.) that combine natural biological purification methods based on natural purification and artificial biological purification methods have been studied. Enforcement of legal system is required so that factories must treat their wastewater to meet the effluent standard before draining away to the city sewerage system. The implementation of secondary and tertiary treatment of city sewage will also be important in the future. Catalytic oxidation method combining biochemistry and the technology of physicochemistry has been studied to apply to the treatment of industrial wastewater. The applications of reverse osmosis and ultra filtration to the treatment of industrial wastewater of dyeing, paper manufacturing, and the photograph industry are also being investigated. Oxidation pounds, oxidation ditches, and soil treatment have been introduced for dephosphorization and denitrification. Yunnan has introduced the oxidation ditch method to remove nitrogen and phosphorous from water flowing into lakes and it is having some effect. Many cities don't have sufficient water resources. Therefore, it is essential to control water pollution and preserve water resources. Conserving water, controlling sewage and wastewater, and reasonable utilization of water resources are fundamental measures for the improvement of water quality and the shortage of water resources. For example, the reduction of water consumption, control of the amount of wastewater and its quality, treatment of wastewater, introduction of sewage treatment system to cities, and the technical improvement of sewage disposal facilities are under consideration.

(3) Proper management of lakes and marshes

Every organization, individual, and society as a whole has the responsibility to prevent eutrophication and the elimination of nutrient salts. The Chinese government has made efforts in the management of lakes and marshes to prevent eutrophication based on this awareness. Beijing issued "The Mi yun Reservoir's Water Resource Conservation Regulation," Kunming issued "The Lake Dianchi Conservation Regulation," Nanjing issued "The Xuanwu Lake Pollution Wastewater Standards," Shandong established "The Nansihu Lake Environment Management Office," and Huangshi issued "The Ci Lake Conservation Regulation" for comprehensive management of eutrophication. Among these measures, comprehensive measures and management of the West Lake in Hangzhou was the most effective and showed characteristic changes. They have conducted water from the Qiantang River, tried to reduce feeding water, implemented the dredging of sludge, and strictly regulated the construction of factories. More than 20 factories polluting water were moved or closed. In addition, the management of tourist industry (changed the motor power of tour boats from oil to electric,) and the management of aquiculture (restriction of feeding and breeding) have been implemented. Comprehensive management is effective to control eutrophication. Since the Chinese government delegation attended the United Nations Conference on Environment and Development in 1972, the environment protection process has accelerated rapidly in China. The environment protection process reached a new stage after the "Environmental Protection Law of the People's Republic of China (tentative)" was declared at the 11th conference of the 15th Standing Committee of the National People's Congress on September 13 in 1979. Environmental conservation has become one of the fundamental policies of the Chinese government. The condition of the environment has deteriorated less and become more stable in the last decade, although the GNP of China has more than doubled. The main factor of this result is the reinforcement of the environmental standard system, environment management, and environmental education.

Environmental standards in China prescribe the requirement of unification of related technologies for the prevention of pollution and ecosystem disruption, and health maintenance. It is fundamental to enforce all environmental laws as well as concrete technological measures of national environmental policy. The environmental standards are categorized by their function and target: (1) environmental quality standards, (2) polluted matter emission standards, (3) environmental protection equipment standards and methodology, (4) criteria for sample and its base standard. The environmental quality standard is a main standard that prescribes regulations and limitations of toxic substances and factors in the environment with consideration for technical and economical conditions for to sustain people’s health, preservation of the ecological system, and protection of public property. The effluent standard of polluted matter that is an important index to restrict the discharge of polluted matter (or harmful substances) for the preservation of the environmental quality is grounds for environment management and supervision.

Environmental standards are classified into national environmental standards and rural environmental standards according to the application range and jurisdiction. The national environmental standards are the nationwide (or for specific areas) requirements related to unified environmental protection technology. The rural environmental standards are requirements related to unifying environmental protection technology for provinces, autonomous regions and demesnes (or specific areas). They were established in consideration of rural environmental function, polluting condition, characteristics of geography, organization, and ecological system, and rural economical and technological condition. China has implemented the nationwide standardization of environmental standards since the government published the first environmental standard “Tentative Standard on Industrial ‘Three Wastes’ (Wastewater, Waste Gas, and Waste Material) Discharges” in 1973. The environmental standards have been expanded from simple emission standards to a systematic environmental standard system including environmental quality standards, polluted matter emission standards and methods, base and sample standards. These standards play a big part in the control of environmental pollution, the reinforcement of environmental management, the improvement of environmental quality and others. The environmental standards that China had established grew from 263 items in 1992 to 325 at the end of 1994, which is a 62 item increase. In 1992, 31 items were newly established. A breakdown of environmental standards until 1994 shows: 10environmental quality standards, 59 polluted matter emission standards, 183 analysis methods, 29 standard samples, 7 basic indexes, and 22 other items. These environmental standards are classified by types of polluted matter: water, which is 153 items, makes up 58.2%, air, which is 58 items, makes up 22.1%, noise and vibration, which is 14 items, makes up 5.3%, waste material, which is 18 items, makes up 6.8%, radioactive substances, which is 12 items, makes up 4.6%, and others, which is 8 items, makes up 3% of the standards. Local governments such as province, autonomous regions, demesnes also establish many rural standards according to their characteristics. Scientific researches of environmental standards and educational campaigns have been conducted and have shown great results. The establishment and modification of environmental standard and the development of human resources for research and management that play an important role in standardization of the environmental standard and environmental management are being implementing. Water environment standards are divided into national and rural. The national water environmental standards examined and announced by the State Environmental Protection Administration of China are the indexes used nationwide or in specific areas. It is also a guideline for rural standards. The rural water environmental standards having regional characteristics are the indexes used in prescribed areas and complement the national standards and makes the concept concrete. According to the standardization of administrative regulations published by the Chinese State Council, rural standards should be harmonized with the national standards and it should stay within the range of the national standards. The water environmental standards prescribes the limitation of toxic substances and their sources for the prevention of pollution of rivers, lakes, marshes and sea, the protection of human health, the preservation of aquatic ecological system, the effective utilization of water resources, and the development of industry, agriculture, livestock, and fishing.

The water environmental quality of China is divided into 6 categories according to its function, management, water quality, and intended purpose. Water quality standards are established for each function: a) Nature preserve; protective zone with overriding priority for natural resources and precious animals and plants, which is established by nation or local governments; b) Areas of water resources for drinking water; water resources for drinking and their protective zones including water for people and livestock in firms; c) fishing zone; spawning, feeding, overwintering, and aquaculturing zones, migratory fish path for every fish and shellfish; d) waters for recreation and sightseeing; the areas that the nation preserves and rural areas for sightseeing, swimming and other water sports; e) waters for industrial use; supply source of industrial water; f) waters for agriculture; irrigation water, and supply source of forestry and livestock industries and soil treatment.

As described above, China established 313 items of the standards until the end of 1993, many of the standards are the environmental quality standards and emission standards related to water and air. This section introduces the feature of 8 standards related to water pollution: “Standard on Industrial ‘Three Wastes’ Discharges”; “Standard for Comprehensive Drainage of Sewage”; “Environmental Quality Standard for Surface Water”; “Drinking Water Quality Standards”; ”Standards for Irrigation Water Quality”; ”Water Quality Standard for Fisheries”; “Sea Water Quality Standard”; and “Water Quality Standard for Recreation Area”.

The Standard on Industrial ‘Three Wastes’ Discharges” was established based on the Tentative Standard on Industrial ‘Three Wastes’ (Wastewater, Waste Gas, and Waste Material) Discharges Promulgated by the State Planning Commission, the State Capital Construction Commission, and the Medical Department in November, 1973 before the establishment of the “Environmental Protection Law.” This standard was established for the prevention of air, water, and soil pollution, the protection of human health, and the development of industry and agriculture. For the waste gas, 13 toxic substances are designated tentatively according to the degree of damage to human health defined in Article 10. For the wastewater, the maximum allowable emission standards for toxic substances are classified into 2 categories. The first category contains toxic substances having long-term effects that could accumulate in the body of animals, plants, or the environment. The second category contains toxic substances having less long-term effects to the human body. For waste material, Articles 17, 18, and 19 regulate the reduction of discharge waste material and restrict dumping areas only at the regulated places for the prevention of the air, water resources and soil pollution. Materials including mercury, cadmium, arsenic, sexivalent chrome, lead, white phosphorus, cyanide, or other soluble toxic substances must be kept in specific treatment facilities to prevent leaking of the substances to ground water.

The Standard for Comprehensive Drainage of Sewage was published by the State environmental protection administration of China in April, 1988 and put it in force on January 1 in 1989. The purpose of this standard was the prevention of water pollution, the preservation of good water quality of surface water and ground water such as rivers, channels, lakes, marshes, reservoirs, sea, the protection of human health, the conservation of the ecological system, the development of the national economy, and the acceleration of urban construction. This standard is applied to all companies and organizations in China that discharge wastewater and sewage. The standard for swage flowing into surface water and the city sewerage system is categorized into the 1st, 2nd, and 3rd-class standards according to the purpose of surface water and the place of discharge. The categories of the standard are as follows; (a) Special preserved waters, 1st and 2nd-class waters of the environmental quality standard for surface water. For example, new construction of vents for discharging wastewater is prohibited, and existing companies discharging sewage have been strictly supervised by local environmental preservation departments to maintain the water quality of the first class preservation areas of the water resources for drinking water, priority waters for sightseeing designated by China, preservation areas of rare species of fish, the waters for aquaculture, and swimming beaches. (b) Priority preservation waters. The first grade standard is applied to wastewater discharging into 3rd-class waters of the environmental quality standard for surface water and 2nd-class waters of the sea water quality standard. (c) General preservation waters. The second grade standard is applied to wastewater discharging into 4 and 5th-class waters of the environmental quality standard for surface water and 3rd-class waters of the sea water quality standard. (d) The third grade standard is applied to wastewater discharging into city sewerage systems having secondary biological treatment. (e) The first or second grade standard is applied to wastewater discharging into city sewerage systems without secondary biological treatment based on the regulations described (b) and (c). The standard value of wastewater discharging is classified into 2 categories according to its property. The first category of polluted substances, which are toxic substances accumulating in the body of animals and plants, or environment, and having long-term adverse effects on human health. The sample of the wastewater containing toxic substances from treatment plants must satisfy the concentration of maximum allowable emission standards irrespective of the type of industry, and the methods and places of emission. The second category of polluted substances, which are toxic substances having less adverse effects than the toxic substances in the first category. These must satisfy the standards according to its kind of industry and others. Some industries such as oil resource development, light manufacturing, hospitals have their own standards for wastewater.

The Environmental Quality Standard for Surface Water published on September, 1983 and put in force since January 1 in 1984 was revised in June, 1988. It regulates the Environmental Preservation Law and Water Pollution Control Law for the control of water pollution and preservation of water resources. This standard is applied to rivers, lakes, marshes and surface water that can be used for reservoirs etc. in China. This standard is divided into 5 categories according to the intended purpose of surface water and the target of preservation(Table 9-2-2) .

Table 9-2-2　Environmental Standard for Surface Water in China

(unit：mg/l)

Item		class I	class II	classIII	classIV	class V
Basic environmental condition		All water is never permitted to introduce by artificial causes the materials described below; ・harmful sediment forming materials ・suspended solid, flagment, broken piece, oil, and so on ・bad color, odor, taste, turbulamce ・harmful materials for human, animals, plants ・materials introducing toxic aquatic creatures				
water temperature (℃)		The limit of water temperatute change by artificial causes is described as below; Maximum increase range in summer is under 1°C Maximum increase range in winter is under 2°C				
pH		6.5～8.5				6～9
nitrate[a)] (SO_4^{2-}conversion)	<	250	250	250	250	250
chloride[a)] (C^{l-}conversion)	<	250	250	250	250	250
dissolved Fe[a)]	<	0.3	0.3	0.5	0.5	1.0
total Mg[a)]	<	0.1	0.1	0.1	0.5	1.0
total Cu[a)]	<	0.01	1.0 (fishing 0.01)	1.0 (fishing 0.01)	1.0	1.0
total Zn[a)]	<	0.05	1.0 (fishing 0.1)	1.0 (fishing 0.1)	2.0	2.0
NO3-N (N conversion)	<	10	10	20	20	25
NO2-N (N conversion)	<	0.06	0.1	0.15	1.0	1.0
NH_3-N	<	0.02	0.02	0.02	0.2	0.2
Kerdale-N	<	0.5	0.5	1	2	2
T-P	<	0.02	0.1 (lake 0.025) (dam 0.025)	0.1 (lake 0.05) (dam 0.05)	0.2	0.2
permanganate index	<	2	4	6	8	10
dissolved oxygen	>	saturation 90%	6	5	3	2
COD_{Cr}	<	15	15	15	20	25
BOD_5	<	3	3	4	6	10
fluoride (F^- conversion)	<	1.0	1.0	1.0	1.5	1.5
Sl	<	0.01	0.01	0.01	0.02	0.02
total As	<	0.05	0.05	0.05	0.1	0.1
total Hg[b)]	<	0.00005	0.00005	0.0001	0.001	0.001
total Cd[c)]	<	0.001	0.005	0.005	0.005	0.01
Cr6+	<	0.01	0.05	0.05	0.05	0.1
total Pb[b)]	<	0.01	0.05	0.05	0.05	0.1
total cyanide	<	0.005	0.05 (fishing 0.005)	0.2 (fishing 0.005)	0.2	0.2
phenol[b)]	<	0.002	0.002	0.005	0.01	0.1
petroleum[b)]	<	0.05	0.05	0.05	0.5	1.0
anion surfactant	<	0.2	0.2	0.2	0.3	0.3
total E.coli[c)] (N/l)	<	-	-	10,000	-	-
benz (a) piren[c)] (μg/l)	<	0.0025	0.0025	0.0025	-	-

a)　adjusted by characteristics of background of each water area in local government

b)　not archeived the standard level by standard analysis method

c)　test pilot standard

Category 1; water resources, and national nature preserve. Category 2; the first grade intensive preservation areas of water resources for drinking water, the preservation areas for rare fish, spawning grounds for fish etc. Category 3; the second grade intensive preservation areas of water resources for drinking water, general preservation areas for fish, and swimming areas. Category 4; the areas for general industrial water and recreation areas having no contact with people. Category 5; agricultural water and general areas for sightseeing. In the case of having some functions in the same area, it is classified in the highest category, and if the function varies with the seasons, it is classified in adequate category according to the season.

The Drinking Water Quality Standards was published by the State environmental protection administration of China in August, 1985, and put it into force in October 1 in 1986. It was established to conserve the quality of drinking water, hygiene of water resources, to select water resources, and to meet hygiene demands. It has been applied to central and distributed water supply of domestic non-commercial water in cities and rural areas.

The Standards for Irrigation Water Quality was published in January, 1992, and put into force in October in the same year. This standard is based on the Environmental Preservation Law was established for the prevention of soil, water, and agricultural product pollution, the protection of human health, the conservation of ecological system, the promotion of economical development. The scope of application of the standard is surface water, ground water, treated wastewater, and agricultural irrigation water using industrial wastewater. Agricultural irrigation water using treated sewage coming from factories that produce biological or pharmaceutical products, chemical regents, agricultural chemicals, petrochemical products, and organic compounds stand outside the scope of the application. The standard is divided into 3 categories. Category 1: paddy field. For example, paddy rice, irrigation water 12000 m^3 / year / ha. Category 2: dry field such as wheat, field corn, and cotton. Irrigation water, 4500 m^3 / year / ha. Category 3: vegetables such as Chinese cabbage, green chive, onion. The amount of irrigation water varies according to the vegetable.

The Water Quality Standard for Fisheries was published on August 12, 1989, by the State environmental protection administration of China and put into force on March 1, 1990. This standard was established according to the Environmental Preservation Law, the Water Pollution Control Law, the Maritime Environment Protection Law, and Fisheries Law for the prevention of water pollution of fishery waters, the conservation of normal growth and breeding of fish, shrimp, shellfish, and seaweed, the maintenance of fish catches. This standard is applied to spawning and feeding grounds, wintering spots, migratory fish paths, aquaculturing waters, and freshwater fishery zones. Regulations for the preservation of water quality for fisheries are following: (a) Every industrial wastewater from companies and organizations, domestic wastewater, and hazardous waste must meet this standard. (b) Discharge of untreated industrial and domestic wastewater to spawning and feeding grounds, wintering spots, aquaculturing waters and others is strictly prohibited. (c) Discharge of wastewater containing pathogenic organism is strictly prohibited. When this kind of wastewater is discharged, it must be sanitized and treated properly.

The Seawater Quality Standard was published on April 6, 1982 and put into force on August 1 in the same year. This standard was established for the control and prevention of seawater pollution, the protection of human health, the preservation of sea life and resources, the conservation of ecological system, and the rational development and utilization of ocean. The scope of application is sea area being under the jurisdiction of China. There are 3 categories of seawater quality according to its purpose, and water quality demand. Category 1; for the preservation of sea life and resources, safe utilization. (Water for salt field, food processing, seawater desalination, fishery industry, and aquaculture etc.), and sea nature preserves. Category 2; for swimming beaches, sightseeing and recreation areas. Category 3; for general industrial water, waters of port entrance, and ocean development areas.

The Water Quality Standard for Recreation Area was published by the China State Bureau of Quality and Technical Supervision and the State environmental protection administration of China on March 18, 1991 and put into force on February 1, 1992. This standard is based the Water Pollution Control Law and the Maritime Environment Protection Law is for the improvement of scenery, the preservation of water quality for recreation, the recovery of water quality of natural ecosystem, the promotion of tourism. The scope of application is rivers, lakes, marshes and part of sea using sightseeing, recreation, and recuperation. This standard is categorized into 3. Category A; Natural bathhouses, and waters for sightseeing and recreation where people directly contact with water. Category B; National intensive sightseeing and recreation areas and waters for sightseeing and recreation where people don't contact with water. Category C; General waters for sightseeing and recreation.

In addition to those standards, many discharge standards, criteria of methodology and others have been established by contamination and industry. The collection system of pollutants emission cost, which is one of the environmental administrative management system in China defines the collection standards for wastewater, waste gas, and waste material.

9-2-3 Expected achievement

The main factor of the progress of water pollution in China is sulfur oxides (SOx) discharging from flues into the air as well as clay soil, notably the Yellow River. SOx discharging to the air dissolves in rainwater and then flows into rivers, lakes and marshes. PH decrease caused by SOx turns the lakes, marshes and rivers into acid lakes, marshes or rivers and has a great effect on ecological system. It was reported that 30% of acid rain falling in areas along the Sea of Japan comes from China. Therefore, Japan having advanced technology with abundant funding shouldn't ignore the miserable state of China. Transfer of technology from Japan is an essential factor.

Over 20 years, China has put considerable effort into environmental preservation projects and yielded great results in this difficult situation. Many countries have suffered economic depression though, industrialization and economic expansion have rapidly developed in China. Economic growth rate of China is 7% in 1991, 12.4% in 1992, 13.4% in 1993 and 11.8% in 1994, which shows significant growth. However, this significant growth produces serious environmental pollution issues arising from industrialization, which developed countries experienced before. The reinforcement of environmental policy and administration has been implemented, however, many problems still remain and economic loss caused by environmental pollution reaches 100 billion Yuan (about 1.5 trillion yen) every year. 22% of the world population is supported by only 0.7% of the cultivated acreage in China. 0.086 ha, which is average demesne for each person in China, is far smaller compared with the global average 0.3 ha. Although the population of China has increased by over a hundred million in recent decades, the cultivated acreage has decreased by an average of 0.3 million ha annually (run-off 31%, salination and turned into bog 18%, desertification 5%.) The current average cultivated acreage for each person has reduced by half the acreage of 50 years ago. Even land, which isn't cultivable, has been cultivated as the population increases and it causes many run-offs or flood disasters. In addition, the development of economy and industry has produced environmental issues such as acid rain and water pollution. Since the Earth Summit (UNCED) was hold in Brazil in June 1992, environmental issues have become international issues regardless of countries. Environmental issues of East Asia have significant meanings in terms of the global environment and regional environment from the international viewpoint. Therefore, the environmental issues of China having a population of 1.2 billion, which is the largest in the world, has come to international attention. The GNP (gross national product) of China was $ 370 per head (as of 1992) that is much less that that of developed countries like Japan. The area of cultivated land, grassland, and forests are 1000 m^2, 2860 $m^2$and 1200 m^2 respectively, which are only 27%, 38%, and 12% of the global averages. The amount of surface water for each person in China is 2700 m^3, which is 25% of the global average, on the other hand, the population has been increasing 17 million every year, which is almost same as the population of Australia. China has endured trials and tribulations such as the lack of funds, environmental technical capabilities, and labor under the pressure of a huge population. To support further development of the economy and the increase of population, environment conservation and measures are essential issues. It has been pointed out that the environment will deteriorate if only 0.5% of the GNP is invested in measures for environmental conservation, it will maintain the status quo if 1% of the GNP is invested, and it will improve if 1.5% is invested. There has been a growing interest in pollution control and water environmental preservation recently however, the investments in environment are still not enough. The environmental standards, which are effective measures to prevent environmental pollution, play an important role in promoting the environmental policy and environmental management. Thorough the implementation of environmental standards, environmental policy responding to Chinese circumstances, legal administration and certification will be further required in the future. Future development of environmental issues and policy in China must have great influence to global environment as well as Asian environment due to its potential amplitude of pollution source. Therefore, China is required to make greater efforts to improve its environmental policy and administration, and enhance environmental education and researches for solving the environmental problems as a member of .the developing countries. At the same time, as international cooperation is also essential, the cooperation of Japan in technology, funds, and experience, are expected. International cooperation needs mutual understanding about every environmental problem among countries. Economic support, and the international exchange and support of labor and techniques from developed countries are needed more than ever. The cooperation and leadership of the neighboring country Japan, an advanced country in pollution prevention is fundamental.

The current situation of the water environment in China is widespread organic pollution in main rivers and aggravated eutrophication in lakes and marshes. The quality of ground water has slightly improved or in stable condition in most part of China, however, the quality of ground water in some cities has deteriorated. The major part of Chang Jiang and northward suffered spring drought in 2000, and spring of 2001 that was the worst drought of the decade. The drought-affected regions were 22 provinces, autonomous regions and cities and the area reached 20.67

million ha in short term. More than 20 million people were short of drinking water. It demonstrated afresh that China has come under threat of water shortage. The amount of water resource in China is one of the 13 countries at the lowest level, and water resource for each person is a quarter of global average. China ranks number 121 in the world in terms of water possession. The imbalance of precipitation and the rainy season accelerates the water shortage. The water shortage has become a big threat against the ongoing China West Development and future economical development as the economy and life of the people have improved.

There is the danger that the deterioration of the water environment will worsen the water resource shortage. Future development of environmental issues and policy in China will have great influence on the global environment as well as Asian environment due to its potential amplitude of pollution source. Therefore, it is required that China should make greater efforts to improve its environmental policy and administration, and enhance environmental education and researches to solve the environmental problems as a developing country. In addition, international cooperation such as technology transfer related to environmental preservation from advanced countries is also required.

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9-3 Eutrophication strategies in the U.S.A.

9-3-1 Purpose of the strategies

To organize the social system to maintain a water environment, using water at a high degree, the plan must be made with consideration given to the major circulation cycle of water and the water-use cycle in urban and rural areas. River water is used for agriculture and industry, and moreover, for human lifestyles. After use, the polluted water is returned to the rivers again. Besides that water, livestock-related wastewater and polluted substances deriving from forests also flow into the rivers. The pollution of the rivers caused by these influences the ecological system, and also has a great influence on human health, because the downstream water may be used as drinking water. To minimize these influences, daily living-related drainage is released into the river through sewage-treatment plants, and factory-related drainage is recycled after treatment within the factory. Moreover, in office buildings in urban areas, suppression of the wastewater amount and reduction of the pollution load is made by the circulatory use of water. Since the river has natural purification (self-purification effect), making the best use of these actions is also effective for reducing the influence of pollution. However, it is necessary to make an integrated plan in which individual strategies are connected systematically, as the whole watershed is taken into consideration, and these strategies are not carried out separately. In this paper, the legal system of water-environment management in the U.S.A. is explained and the protection of the natural environment in the Everglades marshland basin is discussed along with the wide-range water environment or circulation recovery projects, which have been promoted by the Southern Florida Water Management Bureau, in Florida state.

9-3-2 Outline of the strategies

Among the Acts concerning the protection and preservation of water areas in the U.S.A., the historical shift related to rivers and water areas is summarized as follows:

* Rivers and Harbors Act (1899): A federal Act enacted for management and the preservation of water areas to promote the first commercial activity in the U.S.A.
* Water Pollution Control Act (1948): An Act systemizing technical supports and grants for the preservation of water quality in States and local autonomous entities.
* Water Quality Act (1965): An Act imposing on States to set a standard of water quality, which is related to sailing among States.
* The Clean Water Act (CWA) (1972): Understanding biological, chemical and physical factors in water areas, it presents goals for the preservation and repair of water areas. Moreover, with the reinforcement of the standard of water quality, a huge revision was made in 1977. However, this Act is more important for basically preserving water quality in the U.S.A. In this Act, the drainage permission system and the promotion of constructing sewage-treatment plants are prescribed. Strictly speaking, this Act has taken effect as the "Clean Water Act" in the United Code Title 33 Navigation and Navigable Waters Chap.26 Water Pollution Prevention and Control.
* Clean Water Act Amendments (1977): In this amendment, the enforced management of toxic substances and the State's responsibility for the water quality preservation programs by the Federation are clearly described.
* Water Quality Act (1987): Revision of the CWA has been made in connection with this Act. Consequently, it has

been decided to promote strategies against the outflow of pollutants during rain, the establishment of financing grants for the construction of treatment plants, understanding of urban non-point pollution problems, the preservation programs of low-water areas and others, which are necessary to achieve the goals of water quality.

* Safe Drinking Water Act Amendment (1996): The U.S.A. Safe Drinking Water Act enacted in 1974 was greatly revised. In this amendment, new approaches and efforts for the preservation and protection of water sources are prescribed. These approaches and efforts will be carried out in an integrated manner with the prevention of the pollution of water quality and the Clean Water Program in CWA.

Table 9-3-1 Achievement of purification of water quality 25 years after CWA enactment

Items	1972	Present
Basins suitable for fishing and swimming	1/3	2/3
Reduction rate of marshland area (areas / year)	460,000	70,000-90,000
Corrosion rate of soil (10 n / year)	2.25 billion	1.25 billion
Population using sewerage (10,000 persons)	8,500	17,300

Next, the outline of the Clean Water Action Plan is summarized below. The Clean Water Action Plan is an action plan that was proposed by the Vice president in 1997, 25 years after the enactment of the Federal Clean Water Act (CWA) in 1972. Its main purpose is to achieve water areas where all nations can enjoy fishing and swimming, as an original goal of the CWA, and important proposals have been made about the extraction of subjects, reinforced strategies of the water-resource purification plan and the overall strategic framework. Table 9-3-1 summarizes the achievement of 25 year's of water purification, comparing the current situation with that when the CWA was enacted.

The main points in the Clean Water Action Plan are arranged around the following four items: (1) management based on watersheds, (2) strategies and management which are aware of the ecological system and the protection of natural resources, (3) strategies of pollution sources according to a strict standard of water quality and (4) providing appropriate information. Especially, for (1) management based on watersheds, this is based on the idea that clean water can be ensured in a watershed where sound management is conducted. It is also considered that the subject of a watershed should be an area or a border where the most cost-effective strategies against pollution are studied for achieving the goal of water purification. That is, in order to consider the expenditure of contaminated substances moving with water as well as the expenditure of water, the watershed unit must be applied hydrologically. Although the necessity for management of this watershed unit was pointed out previously, its proposal as a federal action plan is very significant. However, the condition of this watershed management cannot be said to have been established completely as it is in Japan. In the U.S.A., in such a stream, the management is actually going to be established. In 1996, one year prior to the proposal of this action plan, the EPA presented the Watershed Approach Framework. To break through the current situation in which the improvement of water quality in the country has stopped according to the proposal, an integrated cooperation among different departments and fields is necessary. Thus, regardless of whether it is a public or private enterprise, the building up of a cooperative system with each community and each watershed is emphasized. This idea has resulted from the development of an idea of the Watershed Protection Approach by the HPA's Office of Water in 1991, and was presented as the EPA's Watershed Approach in 1998. Moreover, in 2000, the Unified Federal Policy for a Watershed Approach to Federal Land and Resource Management was announced as an integrated federal policy assigned as a common recognition of the necessity of watershed management in the framework of cooperation among the EPA, and the Departments of Agriculture, Commerce, Defense, Energy and Interior. As for (5), providing appropriate information, the necessity for cooperation between regional inhabitants and administrative organs is indicative. Because the information about a watershed must be shared to achieve cooperation, new programs for disclosing information have been developed. When the regional inhabitants provide information and the administrative organs cooperate with each other and make decisions about a watershed, it is expected that a management method with high quality will be executed. Inhabitants' participation, which becomes possible by providing information, appropriately results in cooperation among persons interested in a watershed and moreover, the driving power of an action plan with community involvement.

The restriction of drainage in the U.S.A. is conducted for the purpose of human health and protection of the water environment as it is in Japan. As is prescribed in CWA, for sources excreting contaminated substances, it is their assigned duty to obtain approval for the discharge according to the National Pollutant Discharge Elimination System (NPDES) program. Pipe conduits such as sewer systems and water canals are treated as pollution sources. However, no approval is necessary for home-polluted water connected to urban sewage treatment systems. This approval system functions as a method for reducing water pollution, as the wastewater standards are set in Japan. However, it has been recognized that this restriction only of wastewater cannot achieve the CWA goal of making watersheds fishable and swimmable, namely the meeting of the environmental standard. That is, it is necessary to shift from the water management of the restriction of wastewater as a pollutant to the management which focuses on an environmental standard of water quality reflecting a desirable water environment and usage. Originally, in Article 303(d) of the CWA enacted in 1972, the State government was requested to make a basin list where the water quality was disturbed and the environmental standard of water quality was not met. When the State government has executed strategies against point pollution sources (point source), but the standard has not been met, the government can decide a priority order of disturbed basins and meet the standard of basins at the same time. Or, the setting of the allowable Total Maximum Daily Loads (TMDL) is determined. At that time, non-point source loads as well as specific pollution sources are usually taken into consideration. The basic concept of this idea is the same as that of pollution loads and analyses in an integrated plan of the arrangement of sewage systems. When the EPA judges that the list and TMDL made by the State government is insufficient, the EPA shall set a new list and TMDL. Thus, the Acts promoting the management of water quality based on an environmental standard of water quality have already been arranged previously. However, the regulations are not actually in effect, and the EPA thus set a regulation for revising TMDL programs in 1985, actually revising a part in 1992. Moreover, it began to work for its further revision in 1996 and submitted the final draft of an active time schedule in July 2000. The contents include the necessity for actively promoting strategies against non-point sources clearly, as well as strategies against point-pollution sources such as sewage treatment plants. In relation to strategies against non-point sources, it is interesting that the policy to apply this approval system to flow-out water during rain was set forth in the CWA's revision in 1987 and the Act was enacted in 1990. Polluted water in urban basins during rain contains overflow water (CSO) from combined sewer systems, which is also a subject. As such, it is recognized that the reduction of loads deriving from non-point pollution sources from urban basins as well as point pollution sources must be executed legally. This approval system is also applied to the discharge of pollutants from livestock feedlot, and strives to prevent the nutrient salt pollution of surface water and underground water accompanying inappropriate management and the pollution of supply water sources. In addition, in relation to strategies such as those against CSO, the EPA's CSO Control Policy was presented in 1994.

Recently, in Japan, the importance of water management with watershed units has begun to be re-recognized. In the U.S.A., water management with watershed units is actively progressed, which is the first in the world. A map showing each watershed across the entire U.S.A., which made use of GIS, has already been arranged. Water management and nature protection according to natural borderlines are tackled progressively at each administration level of Federal and State governments and regional self-governing bodies. For example, they execute environmental protection strategies of a whole watershed including lakes, marshes and bays, as well as rivers, such as strategies against non-specific pollution sources and natural restoration of straight rivers as re-naturalization.

The Watershed Protection Center striving to protect urban area watersheds appeals against the pollution of surface water, which has become a serious problem in relatively small urban area watersheds, and their strategies. The river network with a firm achievement in the protection of the river environment appeals for the necessity of protecting the watershed scale and unit and its effects. Although cooperation among ministries and government offices is essential for executing a sound water management in each watershed, agricultural fields are greatly involved in water management such as collecting water for irrigation and the problems of non-specific pollution with agrochemicals and chemical fertilizers. The Ministry of Agriculture promotes protection of the watershed in the agricultural field, such as the "Small Watershed Program," promoting and supporting the joint works of farmers who intend to protect small scale watersheds of 100,000 ha or less. The Department of Fish and Wild Organisms of the Ministry of Internal Affairs is a governmental organ executing protection policies all over the U.S.A., including the checking of developmental projects. Here, policies and legal systems for the protection and recovery of aqueous animals and plants have been arranged, including the "Act for Species at Risk of Extermination," which has the strongest restriction among the Acts for the protection of wild animals and plants in the U.S.A. For example, in the Chesapeake Bay, which has the highest level of brackish water in the world, the environment worsened temporarily due to agriculture and the development of residential land. However, the ecological system of the bay has recovered more than was expected by means of "critical area programs" setting various developmental regulations for areas situated at 1,000 feet from rivers and long-term efforts to arrange and promote protection strategies against rivers flowing into the bay by state governments and NGOs. To protect and recover nature in Florida, the State government investigated the residual situation of nature in each area of Florida, collected data in each habitat area annually and made a map. The Florida Natural Regional List Association has established a utilization method of the GIS data, which is essential for the procedures and for making maps to elucidate ecologically important areas requiring protection. Under the 2000 Water-resource Developmental Act, the integrated Everglades Restoration Plan (CERP) will be carried out with a total budget of about 150 billion yen (under negotiation with the Federal government). The Ministry of Environmental Protection boldly tackles the protection of habitat areas of wild animals, such as the "Program for Florida Forever" through the purchase of natural land on a large scale. In Florida, endeavors are being made to protect nature all over the state using gap analyses and analyses of the appropriateness of individual numbers, in which important habitat areas are extracted with wild animals, such as species at risk of extermination, as an index. The State Ministry of Fish, Birds and Animals promotes the tackling of advanced natural environmental protection such as the purchase of lands based on these analyses' results. Moreover, in Florida, the whole state has been divided into five watershed units and water management has been executed with each governmental management department. In the Southern Florida Water Management Department, to which the Everglades, a great marshland area occupying an area about 40% of the size of the whole land mass of Japan belongs, the river routes which were made straight once in the past, were filled in, the floodgate was broken and natural restoration projects were conducted to recover the natural weave of the Kissimmee.

9-3-3 Effects expecting strategies

As for water problems or problems of a basin's natural environmental protection, the contents and areas are set to expand and are becoming increasingly serious in Japan. Resolving such problems with a view toward the next era cannot be avoided. The strongly motivated systematic efforts for recovery of the natural environment of the Everglades marshland area as a central subject by the Southern Florida Water Management Department and related whole communities provide some indication of the direction in which protective policies of the water environment and regional plans in Japan should go. Such policies and systems are characterized below. In Florida State, there are five water management departments, which are divided according to the jurisdiction areas of each watershed, regardless of the administrative division such as district and city. Each management department integratively manages all fields related to water resources and environment, including flood prevention in the area, the water supply to agricultural and urban areas, the protection of water quality, the protection and maintenance of a basin's habitat environment and organism resources and the preservation and creation of a recreation basin. As such, one-dimensional management of various fields related to the water environment in each basin unit of a watershed has a very important significance for the purpose of reasonable and efficient strategies. Various subjects related to the protection of the water environment are not treated individually, but subjects such as river improvement, water utilization, protection and the maintenance of wild animals and their habitat environment, and the recovery of the recreational environment for citizens are understood to be in mutual relation mainly with the recovery of natural water circulation and environment, and strategies aiming at multiple effects have been set. In relation to this, although it is important to have the perspective of understanding problems widely when the protection of the water environment is considered, here, subjects are understood as the "Satellite's Eye," and an integrated thinking takes the ecological system into consideration from the view of field works. The satellite picture showing the area 500 km south and north of the Everglades watershed in the southern area of the Florida peninsula is displayed on the wall of the meeting room for the governing board, as if it is inspiring attendants to promote diverse ideas. To elucidate causes and the mechanism of occurrence of water environmental problems, a joint team consisting of many research institutions of related fields, researchers and technicians was formed, and multi-faceted and efficient investigation and researches are carried out. The results obtained are analyzed and studied intergratively to understand the core for resolution of the problems. In the Southern Florida Water Management Department, there is a Governing Board as the highest decision organ to decide strategies and projects for the management of the water environment in the jurisdiction area, which has higher authority in this field than the state congress. The nine members are appointed after the state governor has taken certain areas and fields into consideration. They are not interest representatives and receive no pay during the four years of the service term. All discussion is conducted publicly and residents and private organizations can present documents with rationales and state opinions directly. Only the Southern Florida Water Management Department has this Governing Board system among the five water management departments. In the Water Management Department, the entire process is proceeded publicly including drafting, deciding and executing projects, and evaluating the projects and results, planning basic investigation and research, and studying the achievement with the participation of residents as a prerequisite. Moreover, to help residents understand problems, public hearings and issues for public announcement with sufficiently specialized contents are conducted frequently. Obtaining information through the Internet and attending meetings with the members of the governing board or staff of the department is guaranteed for residents. When a critique or opinions by specialist groups independent of natural protection groups and governmental bodies seems to be rational, strategies for management of the water environment may be changed, a new administrative organ or research institution may be set and an Act may be revised or a new Act enacted when necessary. Such external power has been more than a little involved in the new establishment of the Environment and Ecology Department, the enactment of the "Sunshine Act" for transparent administration and the "Everglades Forever Act" for restoration of the marshland environment of the Everglades.

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9-4 Strategies of eutrophication in Europe

9-4-1 Purpose of strategies

Nitrogen and phosphorus are listed as nutritional salts for promoting eutrophication in watersheds. As their treatment method, the underground penetration method is conducted. However, this method may contaminate the underground water resource by nitrogen and phosphorus. Because sunlight does not reach the underground water, the internal production by photosynthesis activity of plant plankton (organic pollution) does not occur. However, phosphorus is absorbed by soil and nitrogen is accumulated in the underground water. Especially, the concentration of nitric acid becomes high. When the underground water containing a high level of nitric acid is taken orally, it may induce methemoglobinemia causing cyanosis symptoms in infants, and there is also a risk of producing nitrosoamines, a carcinogen. It is already reported that nitrate nitrogen may be reduced to nitrite nitrogen and cause the formation of nitrosoamines. Thus, nitrate nitrogen is very dangerous as a potential precursor of methemoglobin and carcinogen. As such, the nitrate pollution of underground water is an important problem because it affects the human body. There are two forms of supply sources of nitrate nitrogen to underground water: point source deriving from the treatment of soil penetration such as living or factory wastewater, and non-point source deriving from the eluviation of fertilizer

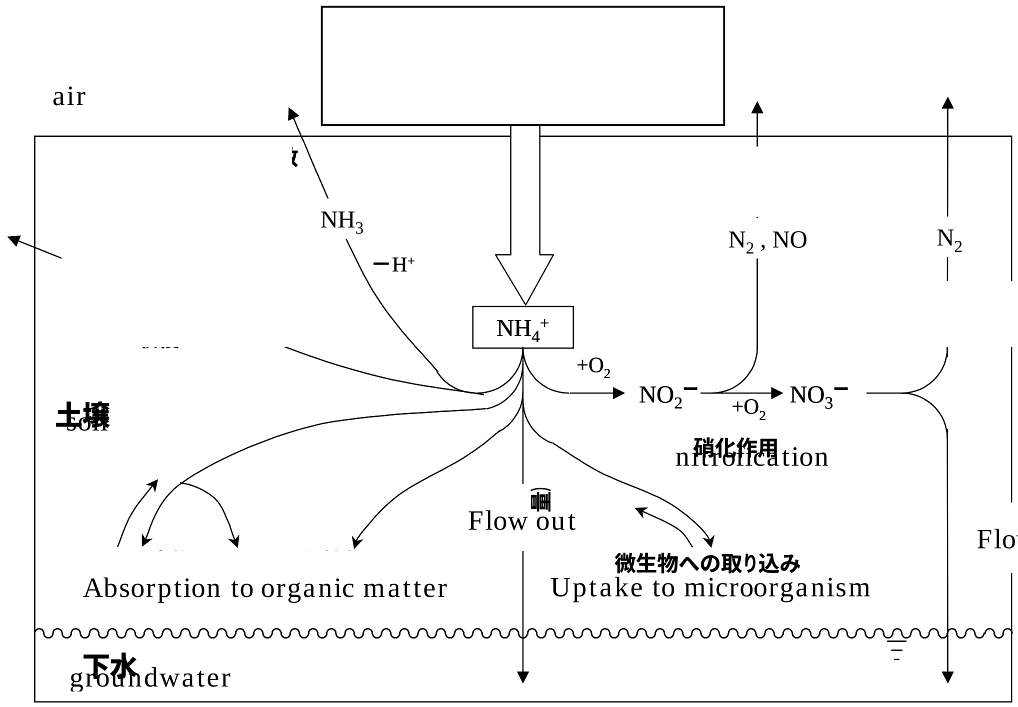

Fig. 9-4-1 Form change of soil nitrogen

components used for agricultural ground. As for living or factory wastewater, countermeasures by elimination strategies of TN: 10 mg/1 are necessary so as not to exceed the 10 mg/1 or less in the guideline of water quality for drinking and the 10 mg/1 of the health item of the environmental standard. Because the supply source of the pollutant giving fertilizer to an agricultural land expands two-dimensionally, it is necessary to optimize the amount of fertilizer used. The elimination strategy of the nitrate pollutant of underground water by bioremedation is necessary as a direct purification strategy. Fig. 9-4-1 shows the morphologic changes of soil nitrogen supplied from ammonium nitrogen. Here, the legal systems of the management of the water environment in European countries are explained and the strategies of underground water, in which the management of the watershed is taken into consideration, are also described.

9-4-2 Outline of strategies

The legal arrangement in Europe can be divided into three steps: (1) the legal arrangement of water relations during the period from the 1970's to 1980's, (2) the legal amendment for strategies of nutritional salts and (3) the Water Framework Directive for new water strategies. As the history of the EU direction is cited, the pollution of water and the shift of its strategies in Europe are arranged. The reasons why European water policy is discussed within the EU framework are because efficient management is impossible in a European country unit and the necessity for a constant standard and strategies in the whole of the EU is reflected, as there is a limitation in the environmental management of water quality at the state unit in the U.S.A. The history up to the Water Framework Directive, which is a new water strategy mentioned above in (3), is described by the chronological table method below.

First generation

1967: Directive on Dangerous Substances (Introduction of management of dangerous and toxic substances)

1975: Surface Water Directive (Water quality of rivers, lakes and marshes related to collecting drinking water)

1976: Bathing Water Quality Directive (Setting of goal of water quality for bathing)

1978: Fish Water Directive (Setting of goal of water quality for fish)

1979: Shellfish Water Directive (Setting of goal of water quality for shellfish)

1980: Drinking Water Directive (Setting of goal of water quality for drinking)

Second generation

1988: Summit about water in Frankfurt

1991: Urban Waster Water Treatment Directive (Necessity of biological treatment and application of high-level treatment)

1991: Nitrate Directive (Strategy of nitrogen pollution from agricultural area)

1996: Directive for Integrated Pollution and Prevention Control (IPPC) (Strategy against pollution from a large-scale industrial area)

1998: New Drinking Water Directive (Reconsideration of standard items of drinking-water quality, and reinforcement of standard level)

From 1995, as the water strategies were reconsidered, the necessity for a global-scale approach to water management was pointed out in meetings of the environmental committee of the European Parliament and with environmental ministers. In May 1996, the Water Conference, in which there was a wide range of attendants, as well as various governmental attendants, was held. Although great efforts for the resolution of individual pollution problems of water quality were made through such negotiation processes, it was conceded that there was no mutual cooperation in current policies, which was a problem. That is, although action policies in the EU such as the Drinking Water Directive and the Urban Waster Water Directive have been presented, the necessity for conducting constant procedures in water strategies and management has to be emphasized at the same time. Consequently, it is now at the stage of changing to new EU water strategies in the framework. As the first work for that, the European Commission (EU) structured a new European Water Policy draft and proceeded to a negotiation process with related organizations. The EU has proposed the Water Framework Directive. Formally, negotiations were conducted with the environmental committee of the European Parliament and environmental ministers, and then adjustment work was proceeded through taking opinions from related organizations, regional and district governmental departments, water users and NGOs. Then, after 25 year's of arranging the legal systems, the EU restructured water policies and adopted the Water Framework Directive in the summer of 2000.

As such, the Water Framework Directive proposed by the EU was finally approved as an effective regulation after being arbitrated by the two legal enactment bodies of the European parliament and council. In Europe, the request for purer water (rivers, lakes and marshes, underground water and coastal areas) has increased from the following three perspectives: (1) as drinking water, (2) for water bathing and (3) for precious regional property in the natural environment. Compared with the perspective of the CWA (Clean Water Act) in the U.S.A., the differences are listed in the points for clearly treating underground water as a part of the watershed and presenting the need for awareness on the cleaning of the watershed as a water source for drinking, which is related to the former. In addition to the "watershed enabling the enjoyment of bathing" presented as a goal in the CWA, it is interesting that a watershed is regarded clearly as a property in the natural environment. The purposes of this water policy are presented below:

(1) Returning polluted or contaminated watersheds to a clearer condition.

(2) Protecting the current clear watershed and preserving it.

To achieve these purposes, it was recognized that conventional strategies of individual pollution sources are insufficient and it was judged that rationalization of the legal systems should be considered. In addition, it was confirmed that the roles of residents and residential bodies are essential from the perspective of watershed management. Consequently, this direction has the following purpose and characteristics.

(1) A unified watershed management accompanying harmonized strategy programs.

(2) All watersheds including surface water and underground water are subjects and the protection of the quality, quantity and ecological system is aimed at.

(3) Strategies against pollution by methods connecting excretion regulations and the standards of water quality

(4) Increase of pricing (policy of market price)

(5) Reinforcement of the participation of residents

Some of the above points are similar to those of the Clean Water Action Plan in the U.S.A. The most important point is to have set forth integrated strategies that are aware of the watershed management as is being done in the U.S.A. In other words, it was recognized that the effects of the direction introduced since the 1980's were limited because of the non-integrated individual strategies against pollution. This new direction is placed as a central pole of the integrated watershed policies for making the existing EU water legal system more perfect. The Nitrate Directive and Urban Waste Water Directive, which are conventional directions individually corresponding will continue to exist through combining with the new directions. However, within the framework of watershed management, some directions have been abolished or unified to maintain this consistency.

It is desirable to conduct management with the watershed base, which is a natural unit both geographically and hydrologically, but not management with an administrative or political borderline. In some countries, management with the watershed base has already progressed and a River Basin Management Plan has been formulated. This plan requires renewal every six years. The situation necessary for cooperative adjustment (cooperative relationship) will become clear. Specifically, watershed management projects of international rivers (Maas, Schelde, Rhine rivers), which are progressed by the related countries, are a good example. Important purposes for preserving clean basins and recovering basins with polluted conditions are the protection of the basin ecological system, protection of the habitat of precious species, protection of the tap water source and protection of the bathing area. As for the latter three, although specific basins are subjects, the management of the basins must be conducted from an integrated perspective. On the other hand, for protection of the basin ecological system, all basins are related and protection of the environment is requested, which should be protected in a complete form by the agreement of the protection of organisms. It seems that the environmental preservation of water quality is not discussed in individual items, and there seems to be room for the water quality environment to be discussed from the perspective of preservation of the ecological system.

Preservation of the quality of underground water including watershed management in EU countries is described below.

(1) Preservation of the quality of underground water in Germany

In 1953, technical directions for preserving tap water sources were first presented in Germany after modern laws were arranged. Then, the laws were revised and now the "German Federal Water Balanced Act" is in effect at present. In this Act, it is prescribed that a landownership is not applied to the utilization of water and the expansion of surface water, which need permission or approval by laws or State Acts. When water is protected from unprofitable influence for public supply at present or in the future, underground water is cultivated or an outflow of falling water is prevented, the zones to be preserved can be set. The preserved zone is furthermore divided according to the two indices of reach time and distance, and various activities are prohibited or restricted in each preserved zone of underground water. In the preserved zone, it is prescribed that landowners and users have certain duties for examinations of water quality and soil. The first zone is the most important zone for protecting underground water from any pollutants, and the range is within a 10-m radius from a water source. Usually, the water source is surrounded by a fence and only authorized persons are allowed to enter it. The second zone aims at preventing the pollution of underground water by pathogenic microorganisms and the zone is prescribed with a range in which it takes 50 days for underground water to reach a pumping well. The number of 50 days was determined empirically as the mean number of days until pathogenic microorganisms die in underground water. The third A zone was set within 2 km from a pumping well, and aims mainly at the pollution of underground water by industrial activities. In this zone, land utilization related to the use or storage of non-easily degradable substances is restricted. The whole zone of cultivating a water source external to the third A zone is the subject zone of the third B zone, which is protected from water sources with non-degradable substances and radioactive substances.

(2) Preservation of the quality of underground water in France

In France, the original form of strategies for preserving the quality of underground water was arranged by the "Public Sanitation Act," and the strategies were determined by a governmental ordinance as follows. First, in the first type (direct) protection areas where all economic developments are prohibited and fencing off is required, a tap-water operating company must purchase the land as a principle. For example, in Paris, 1,850 ha of land including the areas surrounding regions for collecting spring water and the area along aqueducts has been purchased. The reasons why the land along aqueducts is protected are because the aqueducts are a natural flow-down type made of plate stones and weak to external shock, and the internal water pressure lowers without a full-water condition. In the second type (adjacent) protection areas (100 m to several km from a well), the following activities are prohibited or restricted: digging wells / quarrying stone materials at open places / digging holes or landfill; accumulation of human waste and duct from homes, radioactive substances and other substances influencing water quality; excavating canals / storage and the accumulation of liquid and gas carbohydrates, and all chemicals and waste water; construction of ground and underground structures; spraying composts, organic chemical fertilizers, all soil modifiers and dusting powders; raising animals; and all activities which are harmful directly and indirectly to water quality. In the third type (distance) protection areas, which are set when it is insufficient to apply only the first and second types, the same activities as those in the second protection areas are prohibited or restricted. Although excavating a canal and the storage and accumulation of liquid and gas carbohydrates, radioactive substances, all chemicals and wastewater may be restricted, for the third type areas, almost none have been actually determined. In France, the setting for the first and second protection areas are regarded as a matter of importance; in both cases, the hydraulic, geological relationship between places to collect surface water and underground penetrating layers must be considered. In the second protection areas, landowners are forced to undertake considerable duties, and whether or not security money has to be paid is determined in each case.

(3) Preservation of the quality of underground water in Holland

In Holland, wells for homes hardly exist and tap water is used in almost all homes. These tap waters are supplied from 240 wells by about 100 operating companies. The main aquifers are structured mainly by sea and river sediments non-coagulated. Because the underground water level is high, 0-2 m under the ground surface, the underground water is contaminated very easily. The initial preservation system of underground water quality in Holland referred to the German system. However, because the hydrogeological conditions differ from Germany’s, it was likely to be argued that the scientific rationale was weak in setting regional divisions. Ensuring safe drinking water caused conflicts with other interests in many cases and it was difficult to restrict land utilization. Therefore, an original standard was set after Holland's special hydrogeological conditions, social conditions and natural purification ability were taken into consideration.

(4) Preservation of the underground water quality in Switzerland

In Switzerland, about 80% of the industrial water and tap water depends on underground water. Although these underground waters were good quality, because the pollution of underground water has advanced recently, the setting of zones for the preservation of underground water quality was first considered in 1966. Moreover, in 1972, a Federal act was put into effect, in which states were assigned the duty of setting zones for preserving the quality of spring water and pumping water, and tap-water operating companies were also assigned the duty of submitting related documents after conducting hydrogeological investigations for setting zones. On the other hand, in 1971, the study committee consisting of specialists in the fields of microbiology, chemistry, hydraulics, hydrogeology, sanitary science and law was organized and a guideline for setting preservation zones based on reports by the committee was presented in 1977. At the time point, 1990, the preservation zones were set in about 50% of the whole water-source areas. The first zone is a preservation zone for preventing the pollution of underground water by bacteria and chemicals, and is set in regions surrounding water source and spring water wells. In areas without a water supply or with limestone, the zone is set even in areas connecting directly to water sources such as holes for aspiring water. Basically, land utilization of the entire range within a 5-20-m radius of a well is prohibited. The second zone is set to prevent the pollution of underground water by pathogenic microorganisms and non-easily degradable chemicals. In addition to the restriction of scattering livestock's raw sewage, the storage of harmful liquid and reclamation, the discard and sewage from waste, and the construction of roads and railways are prohibited. This zone is prescribed as a range such that the distance from a point collecting water is 100 m or more and pollutants stagnate in aquifers for at least 10 days or more before they reach the point collecting water. In areas where the corrosion of limestone advances, and splits and hollows are developed, the second zone may cover an entire cultivated area. Thus, in areas with limestone, detailed hydrogeological investigations are carried out as a prerequisite and a trial zone is set according to its actual situation. A similar size of an area to that of the second zone is designated as the third zone for the purpose of providing a buffer zone to preserve the quality of underground water in the second zone. Although agriculture and construction are possible in the third zone, special restrictions such as those for sewage facilities and the storage of harmful chemicals are set. However, in areas with limestone, there have been cases where a range double the size of the second zone was set as the third zone. In any case, the remaining cultivated area is designated as the zone called sector A.

In addition, besides these countries, there are some countries where preservation areas are set, based on an original standard. For example, in England, an area with a radius of 500 m from a water source is set for the protection of the water source, and purchased.

9-4-3 Expected effects of strategies

As explained previously, nitrate pollution of underground water has a very serious influence on the human body. If the strategies in European countries described above function effectively, the pollution of underground water can be prevented. However, even if a sense of security is felt, 100% safety can still not be guaranteed. Thus, in the future, reinforcement of its monitoring systems and development of a treatment method for preventing penetration underground will be required. In the EU, there are international long rivers flowing down among multiple countries such as the Rhine River and the Donnau River, and regional problems between the upstream and downstream occur at the level of countries. While strategies against problem sources are being strengthened, the concept of not flowing down water polluted beyond national boundary frontiers is important. Especially, for nitrogen and phosphorus, if they are not treated at the original sites, lakes and bays existing at the terminal points may be damaged, and the pollution of water quality advances beyond the national boundary frontier. That is, to prevent the progress of environmental pollution on a global scale, strategies that are aware of the environment of distant areas beyond national boundary frontiers as well as domestic watershed management are essential.

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10. Methods for Studying Lakes and Points to Note

For the recovery of a lake, research on biota and various analyses, evaluations and assessments of those results are necessary to provide fundamental data. This chapter briefly explains those methods.

10-1 Methods of Biological Study and Points to Note

10-1-1 Purposes

Certain types of microbes inhabit clean lakes, rivers and sea areas because they prefer a clean environment. On the other hand, if water becomes polluted, microbes with a preference for a polluted environment start to emerge. Species of inhabitants depend on the degree of water pollution. The relation between inhabitants and water pollution has been studied by many researchers, and concluded in the scheme of saprobic organisms that contain microbes. According to this scheme, water areas are classified into the following four saprobic levels: polysaprobic, α-mesosaprobic, β-mesosaprobic and oligosaprobic (saprobity). Also, each species of plankton has a suitable trophic level (trophity). Previous studies have found that trophic levels are linked to the frequency of plankton, and the levels are classified into eutrophic, mesotrophic and oligotrophic. A saprobic level defines the decomposition intensity of organic matter including dead organisms. A trophic level defines the intensity of the primary production of organic substances. Saprobity has been applied to the methods for assessing water pollution caused by human activities. Trophity has been used to analyze inland water in wildernesses that are free of human influences. However, considering the above definitions, both saprobity and trophity can be applied to every water area. Saprobity and trophity are symbolized as follows: os: oligosaprobic and oligotrophic, β-ms: β-mesosaprobic and mesotrophic, α-ms: α-mesosaprobic and mesotrophic, ps: polysaprobic and eutrophic. Because every species of organism including plankton requires a certain suitable water quality to grow, the study on biota is able to determine the saprobity and trophity in a water area. This approach has a great significance in helping people to understand water pollution as a current social problem, because pollution can be recognized not by difficult chemical analyses, but by friendly biological observations. Table 10-1-1 shows the types of bio-indicators.

Table 10-1-1 Characteristics of bioassey

(1) **ecological index：the one that conforms to the waste water biotic index system**

（for the overall evaluation such as water environment/the water quality）

- a) On the basis of biotic characteristics, species composition, individual numbers
- b) On the basis of characteristics of dominant species
- c) On the basis of diversity of community
- d) On the basis of the substance metabolism, nutrition characteristics, oxygen demand, etc. in one system

(2) **physio-biochemical index：the one that conforms to growth, activity, etc.**

（for the evaluation of materials in the water environment）

- a) On the basis of the oxygen demand quantity of an individual creature or mixture community
- b) On the basis of the reaction of the cell / organization of an individual creature
- c) On the basis of the growth condition of a specific creature
- d) On the basis of the change of specific bio-materials / life substance

10-1-2 Methods

Water quality analyses including biological studies usually proceed in the following steps: (1) confirming the objectives of the study, (2) brainstorming (discussion), (3) making a research plan, (4) doing preliminary research, (5) doing full research, (6) brainstorming (discussion), (7) concluding the results and (8) making reports. Researchers have to clearly understand what their goals are, and what and how far they will research. It is desirable to make a work schedule in advance.

Generally, the distribution of organisms is affected by the water flow and abiotic environment of a lake. Particularly, a horizontal distribution is easily affected by water flow, which is largely related to the shape of a lake basin, locations of inlets and outlets and the water amount. Therefore, in advance of any research, the following tasks are necessary: (1) organizing and checking the information of a targeted lake, (2) sorting out the traits of targeted biotic communities, (3) confirming study locations and study objectives and (4) observing the lake altogether and correcting the research schedule in advance. Timing for sampling depends on the objectives of the research and the targeted biotic communities. If the research is being conducted to record secular changes of a lake, sampling can be done once a year. But in that case, the sampling must be made within a specific period of a year. A season such as spring, summer, autumn and winter would typically be used to show a sampling period. However, in Japan located in the Temperate Zone, dominant species, biomass and biological activity can change drastically during a three-month period. The sampling period should be specified at least as a certain period of a month, such as the beginning, middle or end of the month. In other words, a research schedule has to be planned according to the study objectives and the life history of organisms. The average doubling time of phytoplankton in natural lakes is about 7 days. For a detailed research on annual changes relating to phytoplankton, sampling should be made every seven to ten days. For further research in a reproductive period, sampling should be made every two to three days. The sampling period and sampling interval of the biological research should not be determined automatically. For example, in research on a creature in a certain period such as a reproductive period, a hatching period and an eclosion period, the sampling period and interval should be determined by the targeted creature's biological activity. If the targeted creature has the possibility of daily rhythmic activity, the sampling time should be carefully chosen, and it is desirable to be fixed at a specific time in the day. In the research of a bacterium whose cells divide into new cells extremely rapidly compared to other organisms, sampling may have to be made every few hours and special treatments for samples are needed. In short, the sampling timing and interval are important for meeting the study objectives.

The sizes of plankton are diverse, ranging from a few microns to more than 1 mm. In other words, larger species are several thousand times the size of smaller species. In addition, a smaller species has a larger population. Therefore, there is no satisfying sampling method for capturing all these diverse sizes of plankton at once, other than the methods that collect plankton divided by their sizes. Surface water can be scooped up by a container. For sampling water at each vertical depth, conventional water samplers (Heyroth type water sampler, Kitahara type advanced water sampler, Van Dorn water sampler, Ekman water sampler, water column sampler, suction water sampler etc.) can be used. If those water samplers are not available, researchers themselves should design a sampler. Surface water is often collected by a bucket, a plastic beaker or a sampling bottle directly. However, if the vertical temperature distribution in a surface layer is large, or a large number of phytoplankton gathers in the surface layer, direct sampling should be avoided. If the density of plankton is small, filtering by a quantitative plankton net is necessary. As for quantitative sampling, the Hensen type net, which consists of a filtering cloth with meshes measuring some 0.06-mm in diameter, is suitable. This sampling net meets the international standard No. 25 or the Japanese standard XX17. For sampling by a net at a targeted depth, the speed for pulling up the net should be about 1 m/s. At a higher speed than 1 m/s, the sample cannot be filtered sufficiently. If the speed is lower than 1 m/s, some zooplankton can escape from the net. The net can be pulled up from 1 to 2 m in eutrophic water at the maximum, and 5-10 m or more in oligotrophic water. However, different nets can become clogged in different conditions; therefore, sampling should be completed within those limits. A filtered volume of water can be calculated by multiplying the area of the net mouth by the length that the net was pulled up. Figure 10-1-1 and Figure 10-1-2 show sampling instruments.

The identification of phytoplankton and zooplankton is made by microscopic observation at a magnification from 100 to 800 times, except for the observation of the distribution pattern of striation on the cell wall of diatoms. The number of plankton can be counted by using an eyeglass with a magnification from 10 to 20 times and an object glass with a magnification from 10 to 40 times. Phytoplankton and zooplankton are counted at a magnification from 400 to 800 times and from 100 to 200 times, respectively. In addition, graduated slide glasses, cover glasses and graduated pipettes are necessary for the observation. The slide glass should be graduated every 0.5 mm. The cover glass should measure 24 mm by 36 mm, because the pipetting volume of the sample is 0.1 ml. The pipette should be accurate enough to measure 0.1 ml and should have a bore of 2 mm or more to capture larger zooplankton. Plankton counting trays are also commercialized for easy quantitative sampling. Because the amount of phytoplankton is usually shown

Fig. 10-1-1 Plankton net

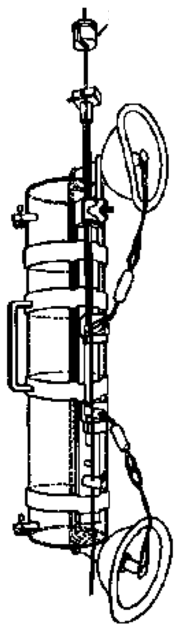

Fig. 10-1-2 Vandorn Water Sampler

by the number of cells, it should be counted by microscopic observation. In the case of phytoplankton (algae) that forms colonies, after calculating the average number of cells in a colony, the whole number of cells can be calculated by multiplying the number of colonies by the average number of cells. The amount of zooplankton is shown by the population. After counting, the amount of plankton should be converted to a population density in natural water. The population
density in natural water is calculated with the degree of the concentration of the sample and the volume of the observed sample. The amounts of phytoplankton and zooplankton are conventionally shown by the number of cells in 1 ml and the number of the population in 1 l, respectively. Figure 10-1-3 and Figure 10-1-4 show microscopes.

Fig. 10-1-3 Optical microscope

Fig. 10-1-4 Stereomicroscope

10-1-3 Points to Note

The classification and identification of plankton by microscopic observation are sometimes difficult, because they depend on morphological knowledge. Automatic identification by illustrations or photos of organisms should be avoided. It is important to first determine whether an object is a living organism or a nonliving object. Fibers of plants can be confused with fungi or cyanobacteria. Daily practices of microscopic observation from 1 to 2 hours are required to get accustomed to microorganisms and to obtain accurate results. Because there are quite various species of plankton, it is desirable to keep picture books and specialized books at hand. The identification of species is a fundamental task for both qualitative and quantitative analyses. Some species of zooplankton that move actively are particularly difficult to identify. Because the fixation of plankton causes the destruction or contraction of cells, physical controlling agents or anesthetics are usually used. 1% gum arabic solution or 10% methyl cellulose solution can be used as a physical controlling agent. These agents can significantly lower the swimming ability of plankton. However, it should be remembered that these agents also largely contort and change the shapes of plankton from their original swimming shapes in water. The moment just before water on a slide glass dries up is the best time for the observation of plankton in a natural condition. The more water on the slide glass is evaporated, the less actively plankton moves, and accurate observation of the plankton becomes possible. Photographs can capture every cell organ clearly in such conditions. However, plankton is destructed when the water dries up completely.

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10-2 Analysis Method of Nitrogen and Phosphorus, and Points to Note

10-2-1 Purposes

Nitrogen and phosphorus are essential for microbes to propagate. On the other hand, these substances are related to the eutrophication of an enclosed water area and the biological treatment of wastewater. And those substances have significant effects on water organic pollution and the biological decomposition of organic matter. In a water area where there is a habitation of plants, which photosynthesize with photosynthetic pigments, i.e. aquatic plants and phytoplankton, the condition can be classified into eutrophic, mesotrophic or oligotrophic according to the concentrations of nitrogen and phosphorus. In ordinal lakes containing abundant minerals, the amount of nitrogen and phosphorus is usually insufficient and the propagation of aquatic plants and phytoplankton is restricted. Therefore, the concentrations of nitrogen and phosphorus compounds are usually used to classify the nutrient condition of a lake. Although a lot of classification methods are suggested, conditions are generally distinguished by the following criteria: for the concentration of total nitrogen (T-N), 0.2 mg/l or more is classified as eutrophic, 0.03 to 0.2 mg/l as mesotrophic and 0.03 mg/l or less as oligotrophic, and for the concentration of total phosphorus (T-P), 0.02 mg/l or more is classified as eutrophic, 0.003 to 0.02 mg/l as mesotrophic and 0.003 mg/l or less as oligotrophic. These nutrient conditions affect the propagation of phytoplankton, and consequently, change the water quality. Therefore, the color, transparency and pH of water, the concentration of dissolved oxygen, chlorophyll a, total nitrogen and total phosphorus are usually used as criteria to determine the nutrient level of a lake.

10-2-2 Methods

The industrial wastewater testing method JIS K0102 specifies the following analytical methods. Regarding the analyses of total nitrogen (T-N), (1) the aggregate method, (2) ultraviolet spectroscopy, (3) the hydrazinium sulfate reduction method, (4) the copper-cadmium column reduction method and (5) the thermal decomposition method are available. For the ammonium ion (NH_4-N), (1) indophenol blue spectroscopy, (2) the neutralization titration method, (3) the ion electrode method and (4) ion chromatography are used. Regarding the nitrite ion (NO_2-N), (1) naphthylethylenediamine spectroscopy and (2) ion chromatography are employed. For the nitrate ion (NO_3-N), (1) reducing distillation-indophenol blue spectroscopy, (2) the reducing distillation-neutralization titration method, (3) copper-cadmium column reduction-naphthylethylenediamine spectroscopy, (4) brucine spectroscopy and (5) ion chromatography are available. For organic nitrogen, (1) indophenol blue spectroscopy and (2) the neutralization titration method are available. To determine total phosphorus (T-P), (1) the potassium peroxodisulfate decomposition method, (2) the nitric acid-perchloric acid decomposition method and (3) the nitric acid-sulfuric acid decomposition method are used. For the phosphate ion (PO_4-P), (1) molybdenum blue (ascorbic acid reduction) spectroscopy and (2) molybdenum blue (tin (II) chloride reduction) spectroscopy are used. And the JIS K0102 also specifies the determination of hydrolysable phosphorus. Although auto analyzers are not included in the official methods, these are widely used because their analyses are highly consistent with those of the official methods. The auto analyzers are effective for analyzing many samples simultaneously and for minimizing measuring errors by analysts. Figure 10-2-1 shows an auto analyzer.

The following describes manual analyses of nutritive salts. These methods are helpful for a laboratory in which auto analyzers are not available, or which has been temporarily built near a field.

Fig. 10-2-1 NP Auto Analyser

・Measurement of Total Nitrogen

This section describes ultraviolet spectrometry as a colorimetric analysis of total nitrogen. First, an alkaline solution of potassium peroxodisulfate is added to the sample and heated at ca. 120℃. In the sample, nitrogen compounds change to nitrate ions, and organic substances are decomposed. After the pH of the sample is adjusted to 2-3, the absorbance is measured at 220 nm that is absorbed by the nitrate ions. This method is applied to samples with small volume, those containing decomposable organic substances or those that do not contain enough bromide ions or chromium to affect the measurement. 5 to 50 μg of nitrogen is measurable. The repeatability is 3 to 10% (the coefficient of variation).

〔Reagents〕 (1) distilled water, (2) hydrochloric acid (1+16), (3) hydrochloric acid (1+500), (4) a mixed solution of sodium hydrate and potassium peroxodisulfate, (5) nitrogen standard solutions (0.1 mgN/ml, 20 μgN/ml)

〔Procedures〕 (1) 50 ml of the sample is separated into an analysis bottle. (2) After 10 ml of the sodium hydrate and potassium peroxodisulfate solution is added to the sample, the sample is immediately sealed and mixed. (3) The sample is heated at about 120℃ for 30 min in an autoclave. (4) The bottle is pulled out from the autoclave and cooled at room temperature. (5) 25 ml of the supernatant of the sample is separated into a 50-ml beaker. (6) The pH of the supernatant is adjusted to 2-3 by adding 5 ml of hydrochloric acid (1+16). (7) The supernatant is separated into an absorption cell and the absorbance is measured at 220 nm. (8) For a blank test, 50 ml of water is prepared in an analysis bottle, and its absorbance is measured in the same way. This absorbance is used to correct the absorbance of the sample. (9) The concentration of total nitrogen (mgN/l) in the sample is calculated with a calibration curve.

・Measurement of Ammonium Ion

Ammonia contained in the sample water is easily affected by microbes, and often changes, while the water is stored. Therefore, samples should be tested as soon as possible after sampling, or should be treated for frozen storage. It should also be remembered that in many cases, the atmosphere in a laboratory contains ammonia vapor and the sample can be contaminated by it. Analytical methods for ammonia in lake water are the Nessler Method, the pyridine-pyrazolone method, the oxidizing method to nitrous acid, the indophenol method, etc. The Nessler Method is easy to operate, but its sensitivity is low. The pyridine-pyrazolone method is complicated, and not suitable for routine testing. On the other hand, both the oxidizing method to nitrous acid and the indophenol method are highly sensitive and accurate. This section explains the generally used indophenol method. 5 to 100 μg of ammonium ion is measurable. The repeatability is 2 to 10% (the coefficient of variation).

〔Reagents〕 (1) distilled water, (2) a solution of sodium hydrate (200 g/l), (3) a solution of sodium phenoxide, (4) a solution of sodium hypochlorite (10 g/l of available chlorine), (5) ammonium-ion standard solutions (1 mgNH^{4+}/ml, 10 μgNH^{4+}/ml)

〔Procedure〕 (1) An appropriate volume of the sample (containing 5 to 100 μg of ammonium ion) is separated into a 50-ml graduated cylinder with a stopper. The total volume of the sample is adjusted to 25 ml by adding water. (2) After 10 ml of the solution of sodium phenoxide is added to the sample, the sample is sealed and shaken. (3) After 5 ml of the sodium hypochlorite solution is added to the sample, water is also poured into the cylinder until the surface of the sample reaches the marked line of 50 ml. Then, the cylinder is sealed and shaken. (4) The sample is permitted to stand at 20 to 25℃ for some 30 min. (5) A portion of the sample is separated into an absorption cell and the absorbance is measured at around 630 nm. (6) For a blank test, 25 ml of water is prepared, and its absorbance is measured in the same way. This absorbance is used to correct the absorbance of the sample. (7) The amount of ammonium ion is derived from the calibration curve and then the concentration of ammonium ion in the sample (mgNH_4^+/l) is calculated.

・Measurement of Nitrite Ion

This section explains naphthylethylenediamine spectroscopy, which is generally used as a colorimetric analysis of nitrous acid. This method calculates the concentration of the nitrite ion from the absorbance of red azo compounds that are produced in the following steps. After the sulfanilamide (4-aminobenzenesulfonamide) is added to the sample, the diazotization of sulfanilamide occurs by the nitrite ion contained in the sample. And, by adding N-1-naphthylethylenediamine (N-1-naphthylethylenediammonium dichloride), the azo compound is produced in the sample. 0.6 to 6 μg of nitrite ion is measurable. The repeatability is 3 to 10% (the coefficient of variation).

[Reagents] (1) distilled water，(2) a solution of 4-aminobenzenesulfonamide，(3) N-1-naphthylethylenediammonium dichloride，(4) nitrite-ion standard solutions （20 μmgNO_2^-/ml， 2 μgNO_2^-/ml）

[Procedure] (1) An appropriate volume of the sample (containing 0.6 to 6 μg of nitrite ion) is separated into a 10-ml graduated cylinder with a stopper. Then, the total volume of the sample in the cylinder is adjusted to 10 ml by adding water. (2) 1 ml of the solution of 4-aminobenzenesulfonamide is added to the sample. After the sample is shaken, it is permitted to stand for about 5 min. Then, 1 ml of the solution of N-1-naphthylethylenediammonium dichloride is added to the sample. After the sample is shaken, the sample is allowed to stand for some 20 min at room temperature. (3) A part of the sample is separated into an absorption cell, and then absorbance is measured at around 540 nm. (4) For a blank test, 10 ml of water is prepared, and its absorbance is measured in the same way. The absorbance of the sample is corrected by the absorbance of the blank test. (5) The amount of nitrite ion is derived from the calibration curve and then its concentration of nitrite ion in the sample (mgNO_2^-/l） is calculated.

・Measurement of Nitrate Ion

This section describes brucine spectroscopy as a colorimetric analysis of nitrate ion. The amount of nitrate ion is determined by the absorbance of yellow compounds, considered as oxidation products, which are produced by the reaction of nitrate ions and brucine in a strong acidic condition with sulfuric acid. Nitrite ion in a sample causes the positive error of measurements. To avoid the interference, 4-amino benzene sulfonate （sulfanilic acid） is added to a solution of the color-producing brucine solution to decompose nitrite ion. 5 to 10 μg of nitrate ion is measurable. The repeatability is 3 to 10％ (the coefficient of variation).

[Reagents] (1) distilled water，(2) sulfuric acid（20＋3），(3) a solution of brucine and 4-amino benzene sulfonate，④ nitrate-ion standard solutions 1 mgNO_3^-/ml， 0.1 mgNO_3^-/ml）

・Measurement of Total Phosphorus

This section describes the procedure of the potassium peroxodisulfate decomposition method combined with molybdenum blue spectroscopy as a colorimetric analysis of total phosphorus. Potassium peroxodisulfate is added to the sample. The sample is heated at about 120℃ and organic substances in the sample are decomposed. The concentration of total phosphorus is calculated by the quantity of phosphate ion in the sample determined by molybdenum blue spectroscopy of the solution. 1.25 to 25 μg of phosphorus is measurable. The repeatability is 2 to 10% (the coefficient of variation).

[Reagents] (1) distilled water，(2) a solution of ascorbic acid，(3) a solution of potassium peroxodisulfate，(4) a solution of ammonium molybdate, (5) a mixed solution of ammonium molybdate and ascorbic acid, (6) phosphate-ion standard solutions (50 μgP/ml, 5 μgP/ml)

[Procedure]

(1) 50 ml of the sample is separated into an analysis bottle. (2) After 10 ml of the potassium peroxodisulfate solution (40 g/l) is added to the sample, the bottle is sealed and mixed. (3) The sample is heated at about 120℃ for 30 min in an autoclave for thermal decomposition. (4) The sample is pulled out from the autoclave and is cooled at room temperature. (5) 25 ml of the supernatant is separated into a test tube with a stopper. (6) After 2 ml of the mixed solution of ammonium molybdate and ascorbic acid is added to the supernatant and shaken, the mixture is allowed to stand for about 15 min at a temperature from 20 to 40℃. (7) A portion of the solution is separated into an absorption cell, and its absorbance is measured at 880 nm. (8) For a blank test, 25 ml of water is prepared in an analysis bottle, and its absorbance is measured as above. The absorbance of the sample is corrected by the absorbance of the blank test. (9) The concentration of total phosphorus (mgP/l) is calculated with a calibration curve.

• **Measurement of Phosphate Ion**

This section explains molybdenum blue spectroscopy as a colorimetric analysis of phosphate ion. 7-ammonium 6-molybdate and tartrate antimonate (III) potassium are added to the sample. In the sample, the phosphate ion reacts with these reagents and produces heteropoly compounds. The heteropoly compounds are reduced by L (+)-ascorbic acid, and produce molybdenum blue. The quantity of phosphate ion is determined with an absorbance of the molybdenum blue. 2.5 to 75 μg of the phosphate ion is measurable. The repeatability is 2 to10% (the coefficient of variation).

[Reagents] (1) distilled water, (2) a solution of ascorbic acid (72 g/l), (3) a solution of ammonium molybdate, (4) a mixed solution of ammonium molybdate and ascorbic acid, (5) phosphate-ion standard solutions (0.1 mg PO_4^{3-}/ml, 5 μg PO_4^{3-}/ml)

[Procedure] (1) An appropriate volume of the sample containing 2.5 to 75 μg of phosphate ion is separated into a 25-ml graduated cylinder with a stopper. Then, the total volume of the sample in the cylinder is adjusted to 25 ml by adding water. (2) 2 ml of the mixed solution of ammonium molybdate and ascorbic acid is added into the cylinder. After the sample is shaken, it is permitted to stand at a temperature from 20 to 40℃ for about 15 min. (3) A portion of the sample is separated into an absorption cell, and its absorbance is measured at 880 nm. (4) For a blank test, 25 ml of water is prepared, and its absorbance is measured in the same way. The absorbance of the sample is corrected by the absorbance of the blank test. (5) The concentration of phosphate ion in the sample (mg P/l) is calculated with a calibration curve.

10-2-3 Points to Note

Organic nitrogen compounds in water are decomposed to ammonium ion (NH_4-N). It also changes to nitrite ion (NO_2-N) by nitrifying bacteria such as Nitrosomonas and Nitrobactor, then becomes nitrate ion (NO_3-N). Generally, nitrogen compounds including ammonium ion are unstable and vulnerable to microbes. Therefore, analyses of nitrogen compounds should be made as soon as possible after sampling. If samples have to be stored for quantitative analyses, the pH of the sample is adjusted from 2 to 3 by adding 1 ml of the reagent. If the sample is stored to determine nitrite ion, the reagent is chloroform. In other cases, the reagent is hydrochloric acid or sulfuric acid. Then, the sample is stored from 0 to 10℃ in the dark. For a few days' storage, the sample can be stored without any treatment from 0 to 10℃ in the dark.

Phosphorus compounds in water exist in the forms of phosphate（inorganic phosphate）, various forms of polyphosphoric acid and phospholipid. These forms always change by the effects of microbes in water. Because these phosphorus compounds are difficult to measure separately, those compounds are divided into groups according to their characteristics and measured to evaluate the water quality. A standard method also divides these compounds into three groups such as phosphate ion（PO_4-P）, hydrolyzable phosphorus and total phosphorus（T-P）, and determines each concentration. An analysis of the filtered sample determines the dissolved phosphorus, which can be distinguished from the concentration of suspended phosphorus compounds.

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10-3 AGP Method and Points to Note

10-3-1 Purposes

The effects of toxic substances and nutritive salts in water can be evaluated by the observation of microbe propagation inoculated into the water. This evaluation is called bioassay, which includes cultural tests of microorganisms or algae. The cultural test of algae examines the nutrient level by the maximal amount of inoculated algae in the sample water, which is cultivated in the best *in vitro* condition. This method is based on Liebig's law of the minimum（Figure 10-3-1）. According to the law, if more than one essential nutrient exists, the least amount of an essential nutrient restricts organisms' propagation. For details, firstly, algae

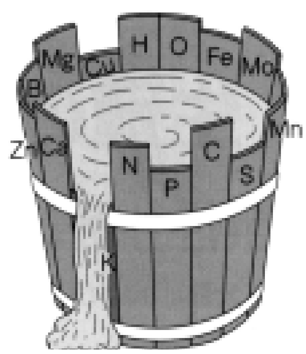

Fig.10-3-1 Concept of Liebig's minimum-law

are cultured until the propagation reaches a stable state at a certain illumination and temperature. Next, the dry weight of the algae is measured. The measurement shows the Algal Growth Potential (AGP). This method is usually called the AGP method. In this method, a culture solution is made of lake water, river water or wastewater that flows into a targeted lake. And algae are cultivated in the culture solution. The algae's propagating characteristics are used to evaluate the AGP of the sample water from various aspects. Therefore, this method is used not only for understanding the degree of eutrophication but also to predict and control the water quality. Typical applications of this method are: (1) the assessment of the degree of eutrophication, (2) the estimation of restricting nutritive salts, (3) the evaluation of the efficiency of water treatments such as denitrification and dephosphorylation, (4) the assessment of the effect of waste water on eutrophication, (5) the estimation of available nutritive salts for algae and (6) the detection of the restricting substances of algae's propagation.

10-3-2 Methods

A conical flask or L-shape culture tube of a volume from 300 to 1000 ml is used for the culture container. A certain species of algae is inoculated into 100 to 500 ml of the sample water in the container, and cultivated until its propagation reaches maximum at a stable temperature (20 or 25℃) and a stabile illumination. The period for reaching maximum propagation is usually 1 to 3 weeks, though it depends on species and cultural conditions. The illumination is 1,000 lx for cyanobacteria, 4,000 lx for other species. Shaken culture and stationary culture are prepared for the fresh water sample and sea water sample, respectively. For the stationary culture, the culture solution should be stirred once a day because algae tend to stick and propagate on the wall of a container. Inoculated algae are usually a dominant species in the targeted water area, such as *Selenastrum capricornutum*, *Microcystis aeruginosa*, *Acenedesmus quadricauda* and *Chlorella vulgaris* in fresh water; *Skeletonema costatum*, *Thalassiosira pseudonana* and *Dunaliella tertiolecta* in sea water. These species are generally inoculated because they are easily separated and grow stably, and the culture, measurement and comparison with other water areas are not difficult. *Selenastrum capricornutum* is used as a standard worldwide because: (1) it grows in various nutrient levels form oligotrophic to eutrophic, (2) its shape is relatively stable in various environments, (3) it is not prone to condensing and (4) its culture is easy and allows stable propagation.

The population of algae is counted by microscopic observation or the absorbance at 750 nm to confirm whether the propagation of algae reaches the maximum. Afterward, the culture solution is filtered by a membrane filter, and the dry weight of the algae in the solution is measured. Using a Coulter counter is the easiest way, because it can calculate the dry weight from an average cell volume and the number of particles. If such an instrument is not available, the dry weight can be calculated from the number of cells counted by microscopic observation. Alternatively, AGP can be calculated from the amount of chlorophyll and TOC, or total organic carbon. This method also detects propagation restricting substances. According to Liebig's law of the minimum, among all the nutritive substances that algae need, algae's propagation is restricted by one in the least amount in a system. When a propagation restricting substance is added to the system and cultured, the algae continues to grow until the amount of the added substance or other existing nutritive substances becomes a restricting factor for its propagation. In other words, if the propagation is stimulated by adding a nutritive substance, the very substance can be determined as the propagation restricting factor. The substances to add are usually 0.05 to 0.1 mg/l of phosphorus (K_2HPO_4), 1.0 to 2.0 mg/l of nitrogen ($NaNO_3$), 1.0 to 2.0 mg/l of iron ($FeCl_3$) and 1.0 to 2.0 mg/l of chelate compound ($Na_2EDTA \cdot 2H_2O$).

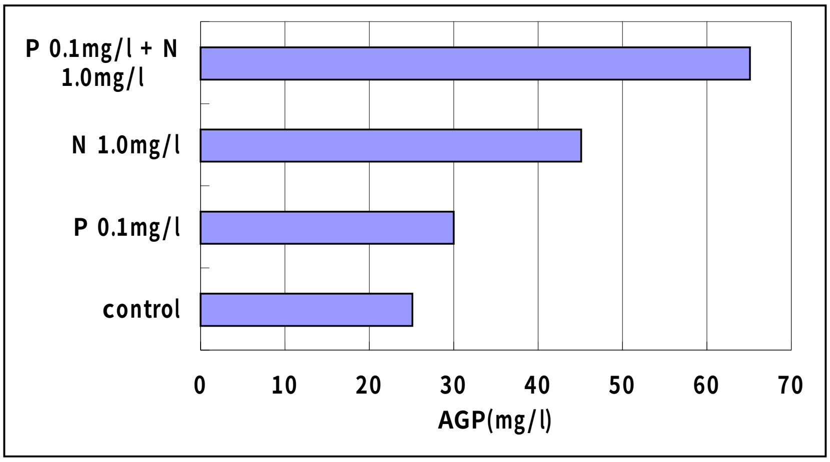

Fig. 10-3-2 Determination on limiting nutrient salt of *Selenastrum capricornutum* by AGP test

Various vitamins can also be added. To evaluate the effect of wastewater, 1 to 20% of wastewater is added. Figure 10-3-2 shows one example of an AGP test. In this test, to detect nutritive salts that restrict algal propagation, *Selenastrum capricornutum* was inoculated into sample water collected from Lake Kasumigaura. The water had already been treated for the thermal decomposition of contents. The results show that the propagation of *Selenastrum capricornutum* in Lake Kasumigaura is restricted by the shortage of nutritive salts, mainly nitrogen. This research indicates that inflow loads into Lake Kasumigaura have to be reduced, because *Selenastrum capricornutum* increases with the concentration of nitrogen.

10-3-3 Points to Note

AGP is usually 1 mg/l or less, 1 to 10 mg/l and 20 to 30 mg/l or more in oligotrophic, mesotrophic and extremely eutrophic water, respectively. Of course, AGP varies depending on the species of inoculated algae, some of which do not grow in particular water. Therefore, it is also important to evaluate the water quality by the ease of propagation for a certain species. Sometimes, rather than AGP, the adaptability of various algal species should be studied by cultural tests.

As for pretreatment of the samples, samples are usually filtered or thermally decomposed, though both pretreatments are not appropriate. Because filtering removes all of the nutritive substances contained in the solid state, and nutritive substances do not elute sufficiently by the thermal decomposition. And the degree of elution is different between samples. Although the further improvement of pretreatment has been required, no better method has been developed yet. Therefore, it is desirable to test both samples, the filtered sample and the thermally decomposed sample, and to make a comparative study. As for seawater, because thermal decomposition often inhibits algae's growth, filtering is the only alternative. Regarding another pretreatment, preliminary examinations show that aerobic decomposition (aerobic treatment in the dark) from 1 to 2 months has high repeatability and a high elution rate. Although it takes a long time, this pretreatment might be suitable for the evaluation of restricting factors. Algal cultural tests are also used for the assessment of toxic substances in a sample. In this assessment, the specific growth rate of algae is measured. The cultural period is 2 to 4 days. The effect of a toxic substance is evaluated by EC50（Median Effective

Concentration） as well as the evaluation using microzoon. In either case, the same cultural test should be made three times for one sample. To obtain statistical data, it should be made five or more times.

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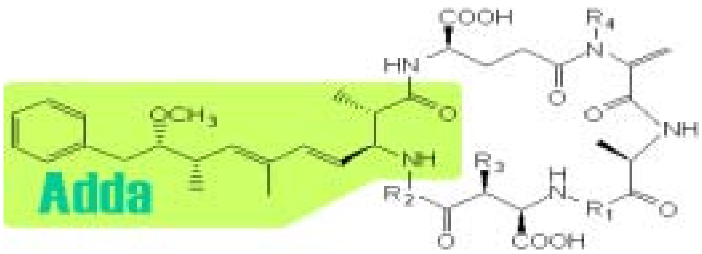
10-4 Analyses of Microcystin and Other Minor Chemicals, and Points to Note

10-4-1 Purposes

The algal-bloom phenomenon, which is an abnormal upsurge of cyanobacteria, is caused by the eutrophication of lakes that relates to the nitrogen and phosphorus in industrial, domestic and agricultural wastewater. Twelve genera of cyanobacteria have been found to produce toxins. However, the chemical structures and mechanisms for producing toxins have been found for only 8 of these genera such as *Anabaena*, *Aphanizomenon*, *Cylindrospermopsis*, *Microcystis*, *Nodularia*, *Nostoc*, *Oscillatoria* and *Umezokia*. Figure 10-4-1 shows the chemical structure of microcystin, and Table 10-4-1 shows its toxicological characteristics. Fresh-water lakes are used for water supplies and the water is drunk by livestock and wild animals, and is also used for fish culture. Therefore, the pollution of lakes by cyanobacteria toxins causes not only damage to the health of people and animals, but also economic losses. A toxin produced by cyanobacteria is a hepatotoxin or a neurotoxin. Microcystin, nodularin and cylindrospermopsin belong to the former, and anatoxin-a, anatoxin-as and aphantoxin belong to the latter. Among these toxic compounds, microcystin that exists worldwide attracts much attention due to its carcinogenicity and liver toxicity that is stronger than potassium cyanide. For instance, at a hospital in Brazil, a few dozens patients died from a treatment that used water containing microcystin. In view of these facts, the World Health Organization (WHO) set the standard for the concentration of microcystin in water at 0.1 μg/ml. In line with that decision, Japan also established the standard in 1999. Consequently, research on minute chemicals such as microcystin is essential for evaluating the safety of water.

Table 10-4-1 The toxicological characteristics of microcystin

	Compound	LD_{50} (μg/kg, mouse, i.p.)
L-Amino Acids (R_1, R_2)	Microcystin LR / LA	＜100
	Microcystin YR	＜100
	Microcystin RR	400～800



化合物	R1	R2	R3	R4	分子量
Microcystin LA	Leu	Ala	CH_3	CH_3	909
Microcystin LR	Leu	Arg	CH_3	CH_3	994
Microcystin YR	Tyr	Arg	CH_3	CH_3	1,044
Microcystin RR	Arg	Arg	CH_3	CH_3	1,037
3-Desmethylmicrocystin LR	Leu	Arg	H	CH_3	980
7-Desmethylmicrocystin LR	Leu	Arg	CH_3	H	980
3,7-Didesmethylmicrocystin LR	Leu	Arg	H	H	966

Fig 10-4-1 Chemical structure of microcystin

10-4-2 Methods

Because microcystin is a strong hepatotoxin, tests using mice have been conducted mainly to evaluate its toxicity. However, chemical analyses with accurate separation and reliable detection have always been required because microcystin has as many as 50 components and their toxicity is not exactly the same. Generally, analyses of organic compounds need steps such as extraction, cleaning, separation and determination. The combination of these steps should be made after each step is optimized.

The method using a high-speed liquid chromatography (HPLC, shown in Figure 10-4-2) combined with an ultraviolet detector and the bioassay using mice are established as the determination methods for microcystin. Also, extraction and refining methods for microcystin have been established. N-butanol is commonly used to extract microcystin. In some cases, 50% hydrous methanol and 5% aqueous solution of acetic acid are also used. An extracted microcystin in a solution is concentrated and dried. And the microcystin is dissolved into 5% acetic acid aqueous solution, and then absorbed by an ODS cartridge. The cartridge is cleaned by 20% methanol, and 80% methanol is used to elute the fraction of microcystin.

The fraction of microcystin is analyzed by HPLC using an ODS column or DEAE column. For the mobile phase of an ODS column, 50 mM phosphate buffer (pH3.0） / methanol （capacity ratio: 4/6) or 20 mM ammonium acetate / acetonitrile（capacity ratio: 25/75）is used. For the mobile phase of a DEAE column, 20 mM phosphate buffer（pH7.0） containing 0.3 M ammonium acetate is used. Microcystin is detected by the absorbance at 239 nm, which is absorbed by the conjugated diene in Adda (3-Amino-9-methoxy-2,6,8-trimethyl- 10-phenyldeca-4,6-dienoic Acid). In the cases of reversed phase chromatography, an elusion order of homologs of microcystin depends on the pH of the mobile phase. This is because the separation is affected by the reversed phase as well as by the cation exchange at silanol groups that remain in the silica of the ODS support. When the pH of a mobile phase is neutral, the elusion order is microcystin-LA，-LR，-YR and -RR, though the separation of microcystin-LR and -YR is quite difficult. In the case of an acid mobile phase, retention times of all of the microcystin homologs except -RR are longer than other pH conditions.

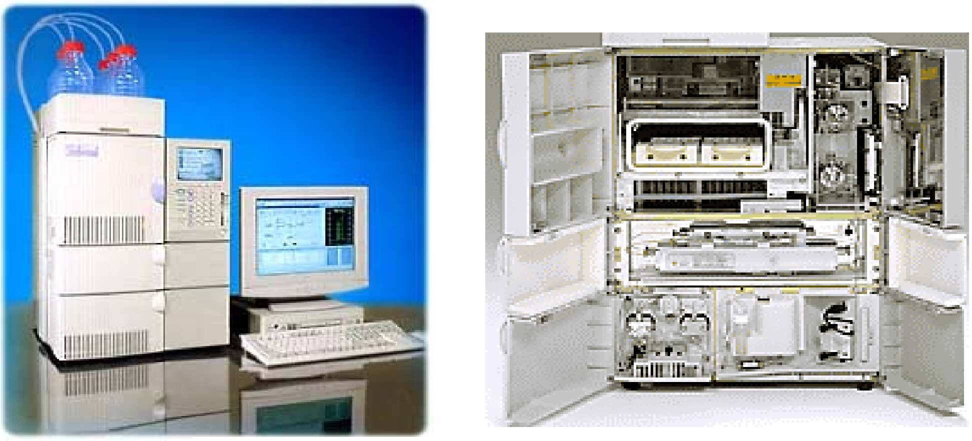


Fig. 10-4-2 High-speed liquid chromatography

Usually, microcystin is detected by UV absorption. However, because the molecular absorption coefficient of microcystin is only log4.4 at 239 nm, which shows the maximal absorption, further improvement has been required to realize a more sensitive analysis method. The HPLC/FABMS method provides high sensitivity. Also, there are some ongoing studies to develop other high-sensitive methods using the HPLC/fluorescence detector, or GC/MS. In these methods, the Adda group of microcystin is cut at the diene position by the oxidization caused by potassium permanganate/sodium periodate. Then, MMPB（2-methyl-3-methoxy-4-phenylbutylic acid） is produced. And the methyl ester of the MMPB is measured by GC/MS, or the MMPB labeled with the fluorescent pigment is measured by HPLC. Although this method is not able to detect the homologs of microcystin, it is able to determine a whole amount of microcystin in water and *Nodularia* toxins that also contain Adda. Because MPB and MMPB-d3 have been commercialized, a quantitative method using SIM（Selected Ion Monitor）with MMPB-d3 as an internal standard has been developed.

Regarding immunochemical analyses, there is ELISA (Enzyme-Linked Immuno Sorbent Assay) that uses the polyclonal antibodies and monoclonal antibodies of microcystin. Because microcystin itself does not have antigenicity due to its small molecular size, an artificial antigen has to be made. The antigen is microcystin-LR that is combined with a protein carrier such as BSA (bovine serum albumin) by using water-soluble carbodiimide. It is measured by Radio Immuno Assay (RIA), direct ELISA and indirect ELISA. For RIA, microcystin-LR labeled with tritium is reacted with antibodies. And after unreacted microcystin and microcystin-antibody compounds are separated by ammonium sulfate precipitation, the radioactivity of the supernatant or precipitated matter is measured by a scintillation counter to determine the microcystin that is combined with antibodies. By combining the microcystin with radioactive labels and the sample, it is possible to recognize the amount of microcystin in the sample.

Direct ELISA uses a plate coated with antibodies, and the microcystin labeled with horseradish peroxidase（HRP）and the sample are reacted with the antibodies on the plate. The microcystin in the sample is determined by the absorption at 490 nm that is caused by an enzyme reaction, whose substrate is o-phenylenediamine. When microcystin exists in a sample, it causes a decrease in the amount of the HRP labeled microcystin combined with the antibodies on the plate. Therefore, microcystin in a sample is determined by the reduction of the absorbance.

Indirect ELISA uses a plate coated with the microcystin-LR combined with poly-L-lysine. Antibodies are reacted with the microcystin-LR on the plate. And the amount of the combined antibodies is determined with HPR labeled rabbit immune globulin. Analytical kits for ELISA are also commercialized. The detection limits of RIA, direct ELISA and indirect ELISA are 1.15 ng/ assay, 20 pg/ assay and 2.85 pg/ assay, respectively. Indirect ELISA is the most practical among these methods due to its simple procedure. The detection limit of commercial ELISA analytical kits is 50 pg/ml. Because these kits do not require complicated operation, many samples can be analyzed in a short time with high sensitivity. The monoclonal antibody used in these kits detects the structure of Adda that causes the toxicity of microcystin. Therefore, these kits can detect all of the toxic microcystin at once.

10-4-3 Points to Note

Sampling for the analyses of microcystin concentration should be done at some growing phases of algae, such as the period when the algae begin to emerge, one when they flourish and one after they have vanished. Although microcystin is a toxin contained by cells, it is excreted from cells as the cell bodies are decomposed. Therefore, microcystin sometimes remains in lake water after algae have vanished. Microcystin decreases after being photodegraded by sunlight, and the amount is lowered to below the detection limit within 1 to 2 weeks. Also, it is strongly biodegradable and is decomposed by bacteria and the metabolic products of microbes in water. Therefore, samples should be analyzed as soon as possible after sampling. It should also be remembered that microcystin reference standards for instrumental analyses and the reagents of commercial ELISA kits have an expiration date. They should be purchased while considering when the examination and analyses are to be made.

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10-5 Handy analyses and Points to Note

10-5-1 Purposes

There are various easy methods for analyzing water quality. Among them, described in this section is the pack test （shown in Figure 10-5-1） that is often used in environmental education classes and by nongovernmental organizations.

10-5-2 Methods

A color-producing reagent is decompressed and sealed in a small plastic tube. The air in the tube is pushed out through a hole made by a pin, and the tube is immersed into the sample water. Then, a certain volume of the sample, which is imbibed into the tube, reacts with reagents and develops color. The degree of the color development is compared to a standard method (printed), which usually comprises 5 to 6 degrees of color development. The concentration is determined by the color of the standard method most similar to the color of the sample. Although this method provides fewer measurable objects and low sensitivity, it is helpful for field analyses to estimate approximate values, because of its simple and short time procedures that require almost no instruments. As mentioned above, this method is also suitable for the analyses of water quality by the general public who do not belong to research laboratories. The measurable objects are pH, NH_4-N, NO_2-N, NO_3-N, PO_4-P, COD, Cl^-, DO and others, though they depend on the makers. Test-paper typed analyses of the similar objects are also commercialized, and they are simpler than the pack test. Other types of commercialized handy kits, not in the form of the pack test, are available for the tests of viable cell count and coliform bacteria count. It is reported that these tests have a similar accuracy to the official methods.

Fig. 10-5-1Handy Analytical Kit (pack test)

10-5-3 Points to Note

It is necessary to check the degree of agreement between the handy tests and official tests such as the JIS method, by analyzing some sample water using both the handy and official methods at the same time. In this case, the distilled water containing only the objects to be measured is not sufficient as the sample water, but the target water containing the objects and other substances should be tested as well. As for the pack test, coexistent substances in the sample might affect the results. When special care for water sampling and analytical procedures is required as in the case of the analyses of minute toxins, the water sample, obtained from the same place and at the same time, should be analyzed by more than one person and the results of the analyses should be cross-checked. And, each analyst needs to present detailed records concerning the water sampling method, the storage conditions of reagents and chemicals and analytical procedure. Such presentation makes it possible to explain the differences found in the cross-checked results.

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10-6 Evaluation of Results and Points to Note

10-6-1 Purposes

Although the existing problems of water environment have not been sufficiently studied, various new problems continue to emerge. Consequently, further studies are necessary to promote this. Researchers should fully examine the results of field research and *in vitro* experiments, and should precisely understand what these results indicate.

Methods for evaluating ecosystem conditions in lakes are broadly divided into (1) chemical analyses such as water quality tests and (2) biological analyses including one using bio-indicators. Chemical analyses have less interpersonal errors, but the evaluation might be transient and lopsided at a specific time. On the other hand, although biological analyses require some experience, long-term environmental changes or the environmental history can be comprehensively evaluated. Chemical analyses can be quantitative, while biological analyses tend to be qualitative. There are various evaluation and analytical methods available. Statistics management methods, for instance, demand various analytical methods depending on purposes. Researchers have to choose proper evaluation methods considering their purposes. Improper methods yield only meaningless results. Researchers should evaluate their results keeping in mind what they want to study, and should not reach subjective conclusions on purpose.

10-6-2 Methods

To assess the nutrient level of a lake precisely, one ideal method is to measure as many factors as possible, and examine the many parameters that are determined by these factors. However, measuring many factors requires much effort, and the methods of compiling data also have many problems. Meanwhile, the evaluation using a single parameter might bring contradictory results. For instance, one factor indicates eutrophic and another indicates oligotrophic. The ideal indicators for evaluating nutrient levels require both the accuracy that is achieved by a composite parameter and the simplicity of single parameter. These requirements are met when a certain relation between parameters exists, and such a relation allows the creation of indicators with a single parameter. TSI（Carlson index）is a typical example of this. This index is also called the trophic state index, and can be calculated from 3 independent parameters, such as the concentration of chlorophyll a, the concentration of total phosphorus and transparency. The most appropriate index can be chosen according to the study objectives. And when all of the 3 parameters are used in measurements, it is easy to make a comparison between parameters by calculating each index. Thus, TSI facilitates the understanding of the characteristics of a lake. At the same time, it is possible to describe the state of eutrophication of a lake in detail because nutrient levels are shown by the sequent numbers from 0 to 100.

The N/P ratio is also used to evaluate a lake’s condition. The N/P ratio refers to the ratio between T-N (mg/l) and T-P (mg/l) in the sample water. An N/P ratio of around 10 is unusually considered well-balanced. However, some reports show that algae are likely to grow at an N/P ratio of about 13.5, and the ratio of somatic cell composition of sea algae is 7.2 （Redfield ratio). Therefore, a well-balanced N/P ratio might be wider than the above-mentioned figure. In ecosystems in lakes, nitrogen fixing cyanobacteria increase when the N/P ratio is low. If the N/P ratio is high, cyanobacteria and pico-plankton propagate. There has been some previous research in which cultivation was effected in lake water, where animals were removed and nitrogen and phosphorus were added, under the condition of an N/P ratio from 5 to 45. In the conditions of low N/P ratios, diatoms such as the genus *Nitzschia* and *Synedra*， and green algae such as the genus *Scenedesmus* grew dominantly, and in the conditions of high N/P ratios, cyanobacteria such as the genus *Synechococcus*, which is one species of pico-plankton, became dominant. It is also reported that a dominant species changed from nitrogen fixing *Cyanobacteria Anabaena* to the genus *Synechococcus* as the N/P ratio was artificially increased. There is also an assumption regarding Lake Kasumigaura that the increase of the N/P ratio from less than 10 to more than 20 caused the change of a dominant species from *Cyanobacteria Microcystis* to *Oscillatoria agardhii* from summer to autumn. Thus, the change of the N/P ratio causes the change of a dominant species of phytoplankton. Consequently, when an environmental condition is evaluated, it is essential to pay attention to the N/P ratio as well as the concentrations of nitrogen and phosphorus.

This section describes the evaluation of river environments from the perspective of biotic communities. Emphasis has been put on the effects of water pollution, and the environmental factors that have an effect on organisms have been evaluated by the species compositions of biotic communities. However, recently, the conservation and recovery of peculiar biotic communities and biodiversity including natural waterfronts and diverse flow paths are being considered more important than ever. Under these circumstances, the conventional methods are becoming insufficient for analyzing and evaluating river environments. And new methods are required to deal with various factors that have an effect on biotic communities. The evaluation of species diversity uses some indexes including the Shannon diversity index.

While conserving diverse species is a goal of environmental conservation and recovery, species diversity is also considered to show the degree of environmental stress on a biotic community. When the stress is large, the diversity becomes smaller, and a place with smaller diversity is regarded to have a problematic environment. However, there are some opinions that the species diversity index is not appropriate for environmental evaluation suggesting that it is vague that the index is meaningful. Concerning organisms in rivers, studies have been made since long ago about the change of species composition with water pollution. And many indexes showing water pollution were originated such as the Bech index. In these methods, species are divided into 2 to 5 groups according to their resistance to water pollution. Evaluation points of water quality are given to each group, and the number of species and the population of each group are counted, and then the water pollution index is calculated in an equation. Because those indexes are specialized in the evaluation of water quality, they have high correlation with various measured values of water quality. However, these indexes can only be used on limited occasions.

Multivariate analyses are expected to deal with various environmental factors and unlimited organisms. Multivariate analyses are a generic name for the methods of compiling data that are composed of many variables, aiming to extract patterns or structures behind the data. These methods are generally used in questionnaire research, marketing research, client management and epidemiological survey. Multivariate analyses can also be applied to the data of species composition that contains many species, in other words, variables. And studies using these analytical methods have been promoted in such fields as vegetation science and synecology. There are two types of multivariate analyses: (1) classifying multivariate analyses and (2) grading multivariate analyses.

10-6-3 Points to Note

Water ecosystems in lakes and seas are composed of algae working as producers, bacteria as decomposers and animals as predators. A normal system is maintained and functioned by the harmonious coexistence of these creatures. However, water ecosystems have been destructed by the inflow of polluting substances produced by human activities. Therefore, it is necessary to maintain sound water ecosystems and coexist with them, from the perspective of the water ecosystem as well as that of the users of the system. For that purpose, the adverse effects on water ecosystems must be prevented including the increase of nitrogen concentration and the N/P ratio. And new energy-cost-effective technologies are required to remove nitrogen and phosphorus at the same time in the process of wastewater treatment.

People usually think that visually clear water is good. And the amounts of nitrogen and phosphorus are used to determine water quality that is related to the value of the Biological Oxygen Demand (BOD) and eutrophication. However, from the perspective of maintaining the lives of all living creatures in the environment including mankind, studies to examine the cytotoxicity and carcinogenicity of minute chemicals, and the endocrine disrupting chemicals in water are extremely important. These dangers cannot be estimated by visual cleanness or the BOD value; therefore, the simplistic determination of water quality is very risky. It is important to understand from which perspective the water quality evaluation is being made.

It is usually considered that unacceptable abnormal measurements are caused by mistakes. But these measurements might show the possibility of abnormal environmental conditions. Even if the abnormality cannot be explained at the time of the measurement, the explanation might become possible in future. Therefore, abnormal measurements should be recorded with notes, and should not be deleted from the record. When the mean value is calculated, it depends on the assay whether abnormal measurements are included or deleted. However, because it is not clear whether the applied assay is suitable for the tested environmental condition, both calculations including the abnormal measurements and excluding the abnormal measurements should be made, or some measurements can be selected by researchers.

Fantasy is to imagine causal relations without logic. Hypothesis is one of those causal relations that provide logic. The hypothesis for explaining a fact is not always one. A hypothesis that seems to support the results of a study might not be right. When only one hypothesis among various hypotheses is able to support the results, is the very hypothesis proved to be close to the truth.

Water ecosystems are places of recreation and relaxation for people. However, it is also humans who cause the pollution of the environment by discharging nitrogen, phosphorus and other polluting loads. This fact has to be recognized and tackled with the tasks for preserving and improving the water quality.

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11. Tasks and Perspective

It is said that the twenty-first century is the Century of Water; the total securing of safe and healthy water resources, beginning with drinking water, is an important task. However, in developing countries in Asia and the Pacific area, water pollution has been accelerating progressively with the increasing human and industrial activities; and it has now reached a critical state. Particularly in recent years, in lakes and marshes, there has been the growing presence of toxic water-blooms that produce microcystins, a designated poisonous substance in the WHO's (World Health Organization) guidelines on the qualities of drinking water. Thus, the problem of securing safe water resources has become an issue of extreme concern. This microcystin is more poisonous than potassium cyanide and has killed a large number of livestock all over the world. In Brazil, it has been confirmed that microcystins have killed human beings. Therefore, worldwide investigation on the actual state of affairs caused by this substance is urgently required. Furthermore, if toxic water-blooms proliferate abnormally, taking in nutritive salts such as nitrogen and phosphorous, they absorb the inorganic nitrogen in lakes and transform it into organic nitrogen, which is found in the cells of algae. That is, they are produced internally, and consequently they become the organisms that are responsible for the COD increase. For this reason, the toxic water-blooms have been indicated internationally as a toxic-substance producing algae as well as the organisms responsible for the COD increase in lakes. In such circumstances, it has also been pointed out, as a technological response to the remediation of water environments and as a measure for treating residential wastewater that occupies 50% to 80% of the overall pollutant loads to a water area, it is essential to implement an energy- and cost-saving, low maintenance-cost, dispersive-type purification system that is not targeted at only one point or purpose. This system also has to be capable of returning onsite, highly-treated water for nourishment, removing nitrogen, phosphorous and so forth, and meeting the conditions of each country.

Therefore, an important positioning is given to the development of bioecoengineering, a hybrid engineering that combines bioengineering as bioremediation engineering and ecoengineering as the engineering of ecology, and to the building of responsive technology that is based on the conditions of each country and the particularities of each area, and that can be widely used and diffused. In other words, effective measures for solving the international water-related problems of the twenty-first century are: to investigate the actual situation relating to the generation of toxic water-blooms in lakes and marshes across the world under different climatic conditions, ranging from the temperate and tropical to subtropical and sub-frigid zones; to develop technology to utilize remediation microorganisms such as microanimals that eat toxic water-blooms; to grasp the properties of discharged wastewater at pollution sources of dispersive, residential wastewater in a basin that is principally responsible for eutrophication; to develop technology for advanced, simple wastewater treatment that includes, among other things, dispersive wastewater treatment septic tanks and soil purification systems as a measure against pollution sources; to develop bioengineering technology to utilize aquaculture, artificial wetlands and large-size water plants such as reeds and cattails; and through all such technology, to create bioecoengineering aimed at energy- and cost-saving, recycle-oriented, easy-to-maintain-and-control water environment remediation technology that is compatible with the reality of each country in Asia and the Pacific area, and to build healthy water environments.

In other words, water environment remediation measures in developing countries of Asia and the Pacific area are the problems and tasks of scientific and technological policies that are based on the national and social needs of each country; and such problems and tasks are common to every country now that it has rivers, lakes and marshes in the areas surrounding cities heavily polluted by untreated residential and industrial wastewater. Thus, for the remediation of such water environment pollution, the introduction of water treatment technology is indispensable. Although some aspects relating to water environment remediation measures and water treatment technology are not common between developed and developing countries, it is essential that for solving these water pollution-related environmental problems, the internationalization of water environment remediation measures be more thoroughly promoted through joint international study for the development and diffusion of measures suitable for each country. In promoting such internationalization of water environment remediation measures, the tasks will be: (1) the cultivation of experts in water environment remediation technology, (2) the cultivation of talented staff in developing countries, (3) the building of a tripartite system among industry, government and academia, (4) the building of an international network and (5) financial aid through ODA, JICA and so forth. The philosophy behind the Basic Environment Law is, "Promotion of global environmental conservation through international cooperation." Thus, internationalization is gaining an increasingly important position; reinforcing and promoting international joint study will further advance the development of technology aimed at energy- and cost-saving, and low maintenance-cost systems suitable for developing countries, and will make it possible to build a sustainable, recycle-based and coexistent system that has less load on the environment. It will also be very important in the future to positively provide international technological assistance and cooperative study to developing countries suffering from worsening water environment pollution, and endeavor to promote water environment remediation measures from a global, borderless environmental perspective.