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.

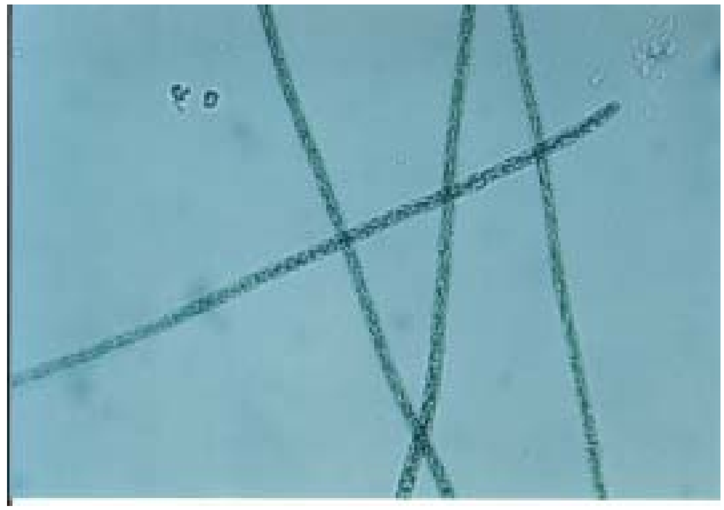

Photo 2-2-3 Micrograph of *Oscillatoria* sp.

(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).

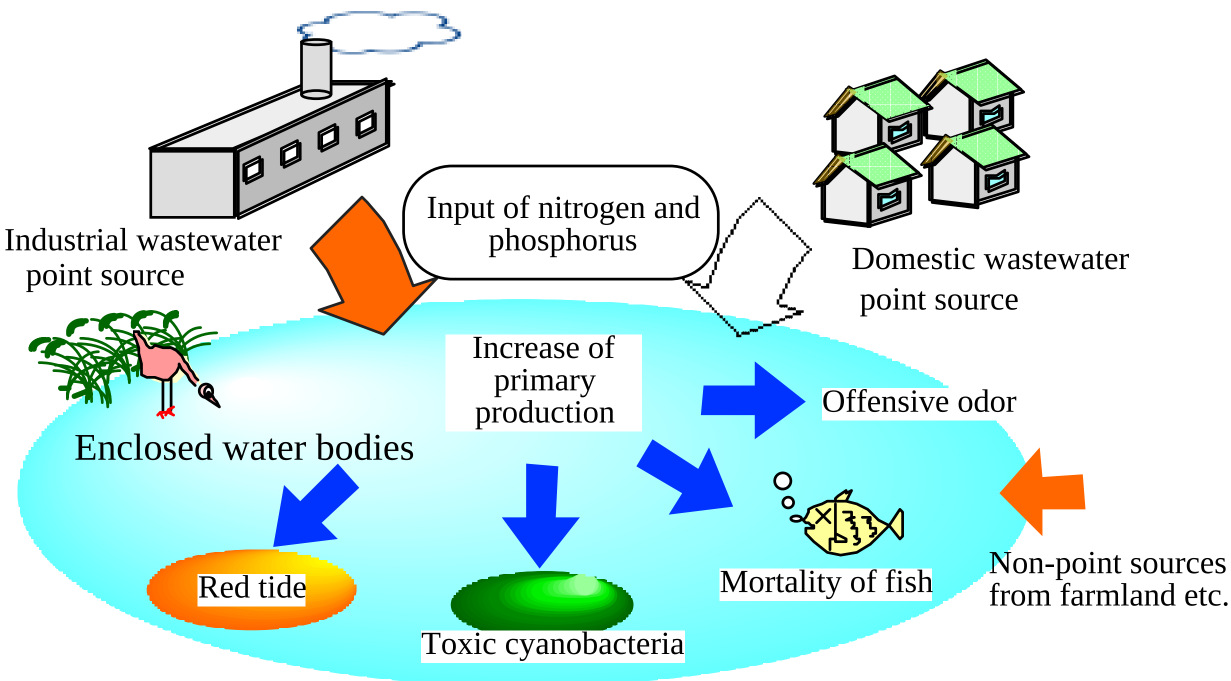

Fig. 2-3-1 Eutrophication prosesses

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

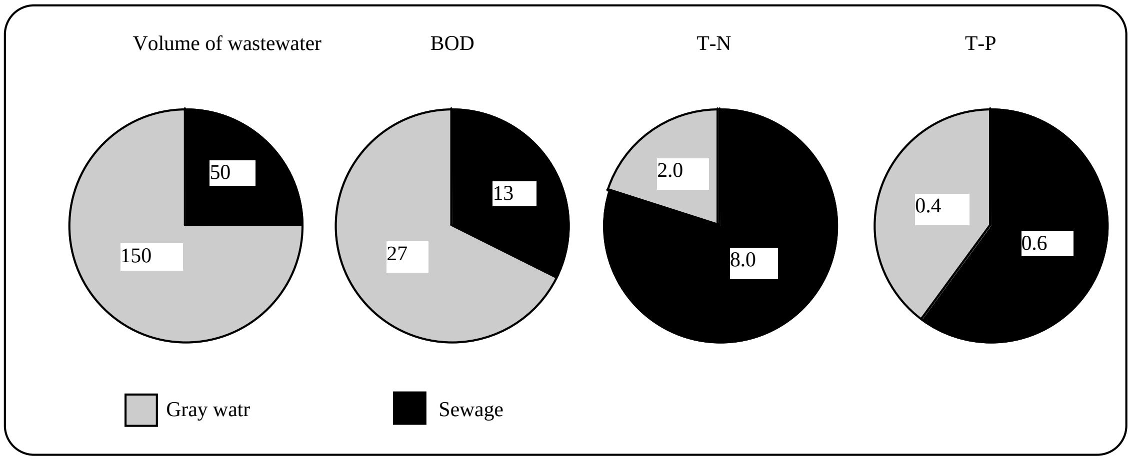

Fig. 2-4-1 Pollution sources from domestic water use
unit: Volume of wastewater(L・person^{-1}・day^{-1}) Others (g・person^{-1}・day^{-1})

treatment tanks imposes such a heavy point-source load. 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*.

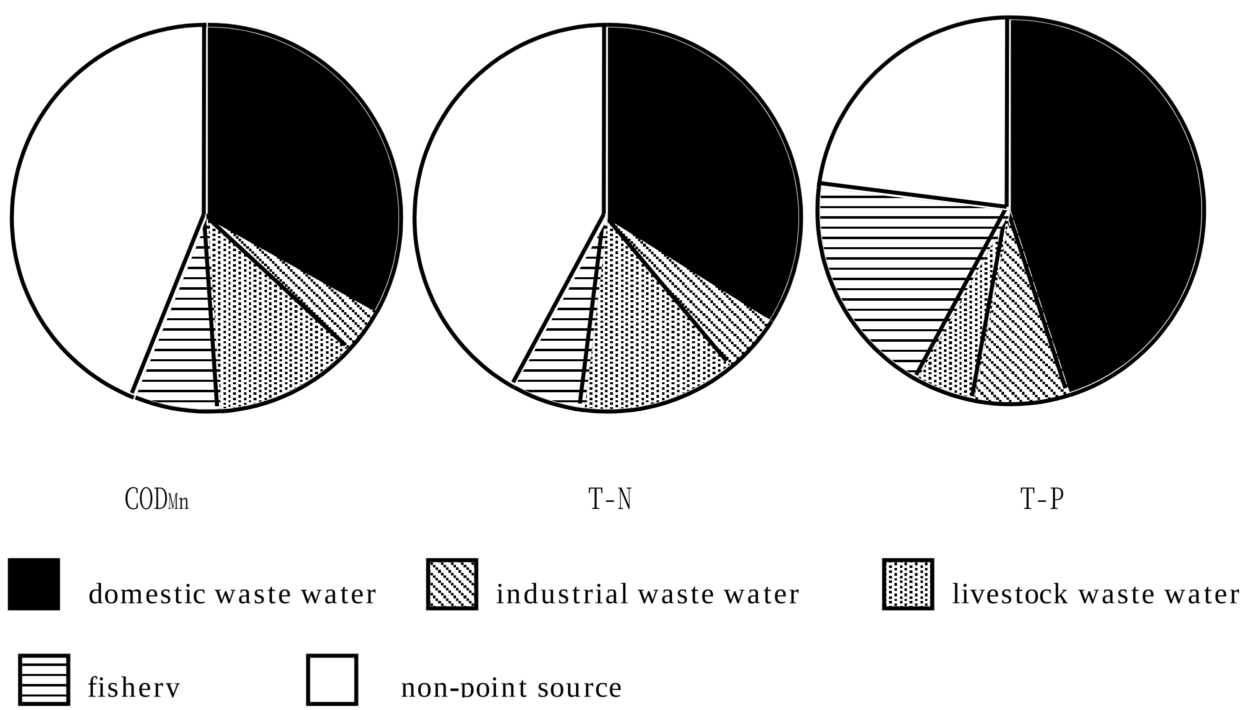

Fig. 2-4-2 Pollution source of Lake Kasumigaura

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

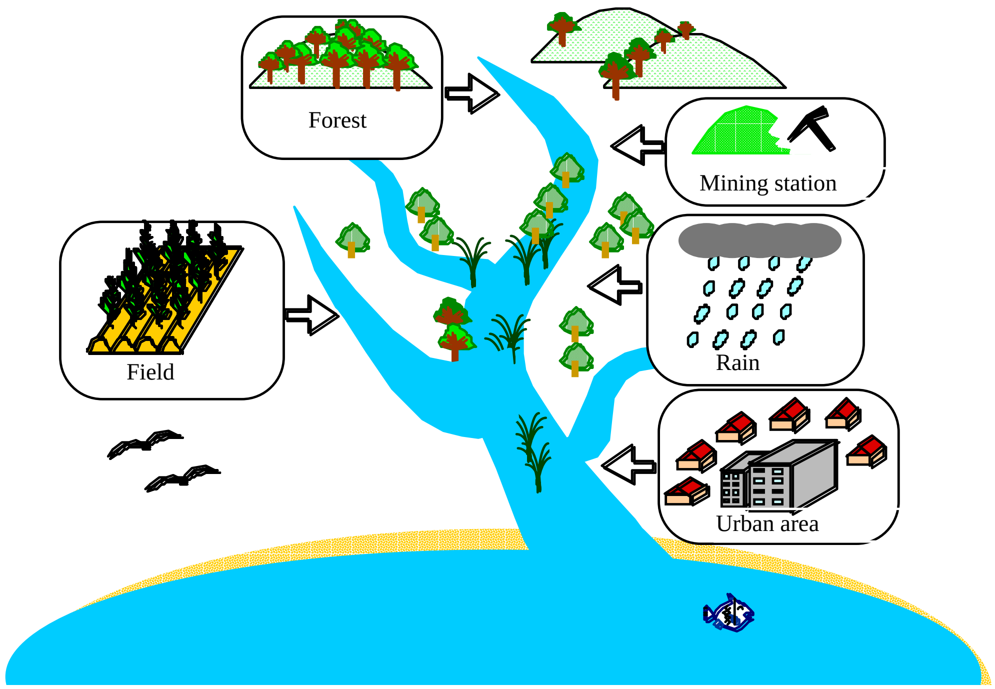

Fig. 2-4-3 Non-point sources

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.

<Reference>

1) SUDOH, Ryuichi, ed., *Microbiology for Environmental Decontamination (Kankyo Joka no tameno biseibutsugaku)* (Kodansha Scientific, 1983).

2) WATANABE, Mariyo, HARADA, Ken-ichi, FUJIKI, Hirota, ed., *Algae Bloom – their Eruption and Toxin – (Aoko – sono Syutsugen to Dokuso–)* (University of Tokyo Press, 1994).

3) SUDOH, Ryuichi, INAMORI, Yuhei, *Graphic Diagnosis of Treatment Capacity through the Biota (Zusetsu Seibutsusoh kara mita Shori Kinoh no Shindan)* (Industrial Water Institute (*Sangyo Yohsui Chosakai*), 1983).

4) TAKAMURA, Noriko, "State of Ecological Study on Water Bloom by Blue-Green Algae Represented by the Microcystis Genus (*Ranso niyoru Mizu no Hana, Tokuni Microcystis Zoku no Seitaigakuteki Kenkyu no Genjo*)" *Algae (Sohrui)* vol. 36, pp. 65-79 (1988).

5) FUJIMOTO, Naoshi, FUKUSHIMA, Takehiko, INAMORI, Yuhei, SUDOH, Ryuichi, “Analytical Evaluation of the Relationship between the Dominance of Cyanobacteria and Aquatic Environmental Factors in Japanese Lakes”, *Journal of Japan Society on Water Environment*, vol. 18, pp. 901-908 (1995).
6) SUDOH, Ryuichi, KONUMA, Kazuhiro, “Water Quality of Lake Kasumigaura and its Non-Point-Source Pollutants (*Kasumigaura no Suishitsu to Mengenfuka*)” *Environmental Conservation Engineering*, vol. 29, pp. 509-515 (2000).