Monitoring and Evaluation of Water Quality and Ecosystem in Lakes, Rivers and Coastal Zones in Japan

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1. Introduction

Water bodies such as rivers, lakes and coastal zones are widely used as water resources (coastal zones are not used directly as water resources but used as recreation site, transportation and fishery). They accept wastewater from the basin pollution sources and are constantly exposed to the risk of water pollution. Based on these facts, it is necessary to clarify whether the water quality meets a specific purpose of water use, to identify the causative substances and sources of water pollution, and to identify water quality issues and changes in water bodies, including the viewpoints to know the trend of chemical substance concentration and screening for deterioration of water quality.

Only by knowing the current situation can we determine the most suitable purpose for which the water resources in a particular water area can be used. In addition, the current cause of problems can be determined. Furthermore, if any countermeasure is taken, monitoring is necessary to confirm the effect.

It is wasteful for each concerned stakeholder to individually conduct surveys to grasp the current situation, and it is difficult to make comparisons in both time and space unless the surveys are unified. Such individual surveys may not be very useful. Basically, it is important for the person who manages the water area to monitor the water area, and to publish the results.

In Japan, the Environmental Standards are set in the water area for items related to the protection of human health (Health Items) and the items related to the preservation of the living environment (Living Environment Items), as shown in Tables 1 - 3. The value of the environmental standard of the health items is the same in any water area, but for the living environment items it differs depending on the designated type which varies depending on how the water area is used. Nitrogen and phosphorus are specified only for lakes and coastal zones, which are lentic areas. Such standards provide the basis for establishing whether a given water body meets the requirements for its intended use.

Table 1. Environmental Standards in Japan: Health Items

Item	Standard value	Item	Standard value
Cd	≦0.003	1,1,1-C2H３Cl３	≦1
CN (cyanide)	ND	1,1,2-C2H３Cl３	≦0.006
Pb (lead)	≦0.01	C2HCl３	≦0.01
Cr6＋	≦0.05	C2Cl４	≦0.01
As (arsenic)	≦0.01	1,3-C３H６Cl2	≦0.002
T- Hg （Mercury)	≦0.0005	Thiuram	≦0.006
Alkyl Hg	ND	Simazine	≦0.003
PCB	ND	Benthiocarb	≦0.02
CH2Cl2	≦0.02	Benzene	≦0.01
CCl4	≦0.002	Se	≦0.01
1, 2-C2H2Cl2	≦0.004	B	≦1
1, 1-C2H４Cl2	≦0.1	F	≦0.8
cis-1,2-C2H2Cl2	≦0.04	NO３ and NO2	≦10
		1,4-Dioxane	≦0.05

Table 2. Environmental Standards in the Water Area in Japan: Living Environment Items

Item	River	Lake	Coastal Zone
BOD	≦1～10mg/L	－	－
COD(Mn)	－	≦1～8mg/L	≦2～8mg/L
pH	6.0～8.5	6.0～8.5	7.0～8.3
SS	≦25～100mg/L	≦1～15mg/L	－
DO	2～7.5mg/L≦	2～7.5mg/L≦	2～7.5mg/L≦
DO at bottom	－	2.0～4.0mg/L≦	2.0～4.0mg/L≦
Total Coliform	≦50～5,000MPN/100mL	≦50～1,000MPN/100mL	≦1,000MPN/100mL
n-Hexane Extract	－	－	not detectided
Total Nitrogen	－	≦0.1～1mg/L	≦0.2～1mg/L
Total Phophorus	－	≦0.005～0.1mg/L	≦0.02～0.09mg/L
Total Zinc	≦0.03mg/L	≦0.03mg/L	≦0.01～0.02mg/L
Nonyl phenol	≦0.0006～0.002mg/L	≦0.0006～0.002mg/L	≦0.0007～0.001mg/L
LAS	≦0.02～0.05mg/L	≦0.02～0.05mg/L	≦0.006～0.01mg/L

Applied according to the defined category

Table 3. Environmental Standards in the Water Area in Japan:
Living Environment Items Applied to Rivers

Category	Water Use	Standard Values				
		pH	BOD	SS	DO	Coliforms
AA	Water Supply Class 1 Conservation of Natural Environment	6.5-8.5	≦1mg/L	≦25mg/L	7.5mg/L≦	≦50MPN/ 100mL
A	Water Supply Calss 2 Fiwhery Class1 Bathing	6.5-8.5	≦2mg/L	≦25mg/L	7.5mg/L≦	≦1,000MPN/ 100mL
B	Water supply Class 3 Fishery Class 2	6.5-8.5	≦3mg/L	≦25mg/L	5mg/L≦	≦5,000MPN/ 100mL
C	Fishery Class 3 Industrial Water Class 1	6.5-8.5	≦5mg/L	≦50mg/L	5mg/L≦	-
D	Industrial Water Class 2 Agriculture Water	6.0-8.5	≦8mg/L	≦100mg/L	2mg/L≦	-
E	Industrial Water Class 3 Conservation of Living Environment	6.0-8.5	≦10mg/L	No flowting garbage	2mg/L≦	-

In Japan, Article 15 of the Water Pollution Control Law stipulates that Prefectural Governors should constantly monitor public water bodies. Article 16 states that the Governor shall specify items, points and methods as a water quality measurement plan. Article 17 also stipulates publication of the monitoring results. Water area managers are stipulated by various laws, but the water quality measurement plan is to be formulated by the Governor in consultation with these various agencies and the results are to be published. This does not prevent the management of the water area or the water authority from conducting individual surveys. By complementing those surveys undertaken by the government, waste can be avoided.

The water quality measurement plan is formulated every year, but this survey is a continuous survey to confirm the achievement status of environmental standards set in line with the purpose of water use, and how the water quality has changed over time can be understood.

This paper introduces monitoring methods and evaluations using the case of water quality monitoring in public water bodies in the field of environmental administration in Japan. The

monitoring takes into account the chemical composition of dissolved and suspended substances as water quality and the biota (phytoplankton, zooplankton, etc.). Sediment is also a factor that affects water quality, and it is necessary to consider it, even if it is infrequent, as a monitoring target.

2. Categories of monitoring surveys

The water quality assessment process consists of different categories of surveys for collecting, evaluating, and publishing data. Depending on the objectives, the difference is in the frequency and period. For the purpose of this paper, the following classification of surveys is used:

- Monitoring: A survey to understand the current situation. If standards are set, it is confirmed whether the standards are achieved. It is a prerequisite to formulate countermeasures and includes a survey to understand effects of the countermeasure.
- Research: A survey to understand specific phenomena in research. The location, timing, period, etc. of the survey will depend on the purpose.
- Voluntary Monitoring: A survey by stakeholders such as the private sector or ordinary citizens. The purpose for such a survey includes knowing how to act or environmental awareness.

3. Procedure for investigation

Meybeck, 1992, in Chapman (1996) defined ten basic rules for successful water quality assessment:

a) Clear objectives, in line with the available resources;
b) A clear understanding of the water body, by preliminary surveys;
c) A choice of the appropriate media (water, sediment, biota);
d) A choice of parameters, stations and frequency, etc. in line with the objectives;
e) A choice of methods, instruments, laboratory facilities, etc. in line with the objectives;
f) A good reporting scheme;
g) Integration of water quality and hydrological monitoring;
h) A good Quality Assurance and Control (QA/QC) programme;
i) Clear recommendations to the decision makers; and
j) A regular evaluation of the monitoring programme.

The above rules describing the flow of monitoring are illustrated in Figure 1 and described below.

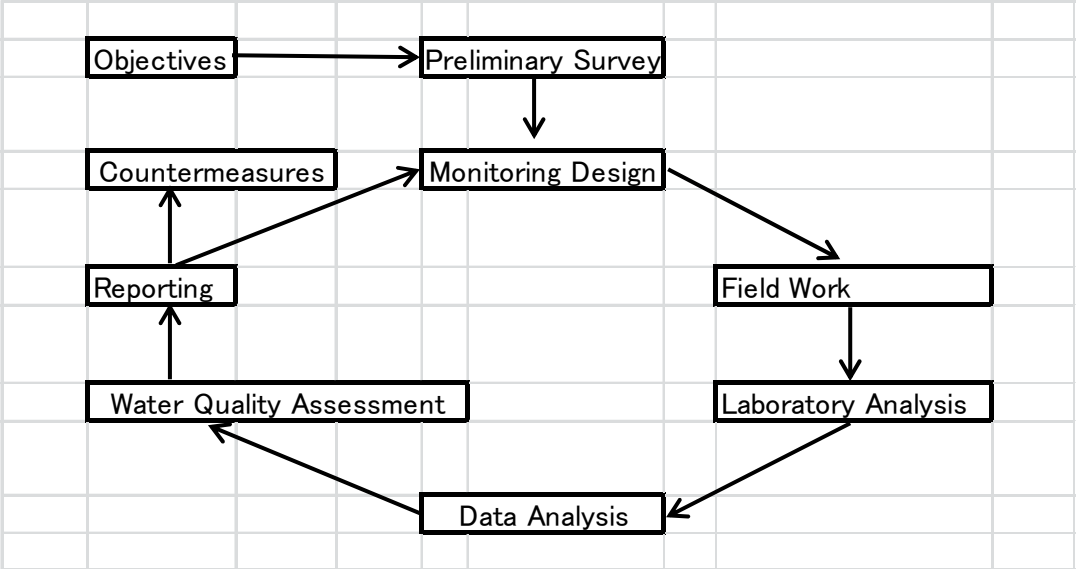

Figure 1. Outline of PDAC Cycle of Monitoring

1) Clarification of objectives

Clarify what is to be known from the survey, and how to use the results.

2) Preliminary survey

Understand the information and characteristics of the water area to be surveyed. In addition to grasping the important factors that affect the target survey item, confirm the existence of equipment necessary for the measurement of the target survey item.

3) Formulation of survey plan

Formulate a study plan to achieve the objectives. Determine survey points, items, frequency, surveyors and analysts. The location (including depth) and frequency of the survey will vary depending on how the concentration of the surveyed item is expected to fluctuate. (In addition, confirm that the accuracy required for analysis can be obtained.)

4) Field work

Sampling will be conducted on site. At the same time, measure items that need to be measured on site. For materials to be transported for indoor analysis, consider the material of the container (polyethylene, glass, etc.) in consideration of the analysis contents. In addition, pre-processing is performed as needed, and the sample is kept cool and transported. Also, obtain information on hydrology and weather necessary for analysis of the results.

5) Laboratory analysis

Perform chemical and biological analysis on the samples transported.

6) Data analysis

After confirming the obtained data for outliers and mutual inconsistency, perform necessary analysis such as creating graphs and tests.

7) Evaluation of water area and analysis of causes

Based on the obtained data, evaluate the water area in comparison with the reference value, etc., evaluate and analyze the results for the target survey items, and estimate the cause/reasons for the obtained results.

8) Proposal for water area management

Announce the results and make proposals for management that can be derived from the results obtained. This includes revisions to the survey plan. The content differs depending on the relationship between the survey entity and the administrator.

4. Monitoring plan

4.1 Objectives

Determine the purpose of the monitoring survey. If the purpose is not clarified, the subsequent survey plan will not be necessarily sufficient, and there is concern that necessary analysis of results may not be performed. Water quality surveys place a heavy burden on costs, manpower, survey equipment, etc. in field surveys and indoor analysis, etc. Therefore the necessity of survey items (including analysis methods), survey points, survey frequency, etc. should be decided according to the purpose. At the same time, the survey needs to be carefully examined so that it does not become too large.

4.2 Preliminary survey

In order to determine the survey point, it is necessary to collect various information on the water area in advance. These include the following:

- River: Cross-section of major points, annual flow characteristics, water use status
- Lakes: Water depth maps, water level fluctuations, lake flow conditions, water use conditions
- Coastal zone: Water depth map, tide fluctuation, tidal current, coastal usage

- Watershed: Land use, population, rainfall, major pollution sources

Estimate the factors that cause the items to be surveyed to change.

4.3 Formulation of survey plan

Points to be considered when formulating a monitoring survey plan are described by taking the case of grasping the current state of the basin as an example.

4.3.1 Sampling point

a) River

The sampling point is selected in consideration of the following points.

- Irrigation point
- Points where the main polluted water mixes well after flowing into the river and points before it flows
- Points where the tributaries mix well after merging and points on the main or tributaries before merging
- Diversion point of running water
- Other points to be set as necessary

In addition, each sampling point is in principle at the center of the river. However, when polluted water drifts remarkably or the river width is wide, depending on the situation, the right bank and left bank are set as separate sampling points. The sampling depth shall be approximately 20% of the water depth from the water surface in principle.

b) Lakes

The following points should be selected in order to comprehensively grasp the pollution situation of lakes.

- Center of the lake
- Irrigation point
- The point where the polluted water mixes well after flowing into the lake
- A point where the river mixes well after flowing into the lake
- Lake water discharge point

Water is collected from the surface layer during the circulation period. During the stratified period, multi-layer sampling will be performed for each depth. The standard depth is every 5-10m.

c) Coastal Zone

The sampling points will be selected in such a way as to give a comprehensive understanding of water pollution, taking into account the topography of the water area, ocean tides, coastal

usage, the location of major pollution sources, and inflow of river water. Water is collected from the surface layer and middle layer in principle. The surface layer is 0.5m below sea level, and the middle layer is 2m below sea level. At depths less than 5m, water is collected only from the surface. However, if the water depth exceeds 10m, water will be collected from the lower layer (10m below sea level) as necessary.

4.3.2 Survey items and frequency

Regarding the survey items, environmental standards should be covered. At the same time, other items that are deemed necessary in view of the status of water pollution, the status of effluent contamination, etc., will be implemented as appropriate, including biota surveys. The items naturally vary depending on the purpose of the survey.

As for the survey frequency, items that are expected to fluctuate yearly, such as living environment items, should be conducted at least once a month. For items that are not detected, such as health items, or that have low concentrations and do not fluctuate much, once in a month is the basis, but it is appropriate to reduce the frequency according to the detection status. In addition, if there is a seasonal variation in the pollutant load generation situation, the survey shall be conducted intensively at a time when the variation is considered. (In biological survey, consider annual variation or daily variation)

4.4 Field survey

For rivers and lakes, record the date and time of water sampling, water surface width, distance from the right or left bank of the sampling point, water depth, flow rate, flow direction, rainfall conditions, topography and water use near the sampling point, major pollution sources, etc. In addition, water temperature, air temperature, hue, turbidity, odor, biota, etc. shall be measured or observed on site in principle.

In the coastal zone, date and time of sampling, location of sampling point, water depth, time and tide of ebb, tidal current, rainfall situation, wind direction, wind speed or wind force, water use situation near sampling point, major pollution sources, etc. are recorded.

As the survey items in the field, the items that can be measured by portable sensors at present are increasing, and it is desired to make effective use of these items. Items that can be measured by portable devices include water temperature, DO, pH, ORP, EC, turbidity, and salinity. In addition, measure and record items that can only be measured on site, i.e. temperature, clarity, underwater illuminance, hue, odor, flow conditions.

4.5 Indoor analysis

a) Physical and Chemical Survey

The analysis method is based on the official method such as the Standard Method. However, if it is necessary to increase the accuracy in order to achieve the purpose, it is possible to use a new analysis method using a more accurate device. If you cannot use the equipment specified in the official method for analysis, you can use the simplified analysis method, but you need to confirm that the required accuracy can be ensured. When using an analytical method other than the official method, it is necessary to take into consideration the accuracy of the method.

b) Biological research

Of water bodies, especially in lakes and coastal waters, which are stable waters, the first significant phenomenon caused by eutrophication is the growth of phytoplankton. The growth of phytoplankton affects the growth of secondary and tertiary producers which use it as food, and changes the water quality environment induce change in species, so by investigating this, the type of eutrophication and the effects of the measures can be comprehensively determined.

The measurement of organisms includes identification of species and measurement of biomass. Biomass can be measured by the number of organisms, volume, dry weight, etc., and phytoplankton can be measured as chlorophyll a. When the amount of plankton is small, microscopic examination and identification can be performed using a sample concentrated by sampling using a plankton net.

For quantitative measurement, it is appropriate to take 1 ml of the test sample collected in the same way as the chemical investigation, put it on a plankton counting plate, and identify and count it under a biological microscope. However, it is not be suitable for large zooplankton or species with low population density.

4.6 Example of Lake Biwa Monitoring Plan

This section introduces the case of Lake Biwa and its inflowing rivers as an example of a specific water quality survey plan. Lake Biwa is managed by Shiga Prefecture and some of the inflowing rivers (downstream of Yasu River) and outflowing Seta River are under the direct control of the national government, while for the rivers that flow in Otsu City management has been delegated to the municipal government. For this reason, each manager is responsible for conducting river water quality surveys. In addition, for surveys within the water body of Lake Biwa, although the responsibility is delegated to Shiga Prefecture, the

National Government (including the Japan Water Resources Agency) is also responsible since the government has been involved over time. The survey points are shared, but the survey items and survey frequency are standardized. Regarding the survey method, the water quality survey method (including bottom sediment survey) for constant monitoring published by the Ministry of the Environment stipulates, in principle, survey points and survey frequency. As for disclosure of results, Shiga Prefecture has compiled data from all concerned research entities, analyzed, evaluated and published the results.

5. Public participated monitoring

There are many stakeholders related to water use and utilization in rivers, lakes and coastal waters, and it is important to actively involve residents as stakeholders in water quality survey activities from the viewpoint of deepening their involvement. Since such a survey is not conducted by an expert, there are limitations on the methods that can be carried out, and the survey is conducted in a limited manner depending on the purpose.

5.1 Simultaneous survey

Surveys are conducted at a certain time with a large number of organizations participating and sharing many points over a wide area. For example, the “Nationwide Simultaneous Survey of Familiar Water Environments” in Japan was started in 2004. In 2018 the focus was on June 5th, the Environmental Day at 6,920 locations with the participation of 730 organizations. A survey was conducted in the two months before and after the day and the results were compiled and published.

5.2 Fixed point survey

Various organizations set fixed points on the waterfront close to them and conduct continuous surveys. In these surveys, it is difficult to carry out analysis by official methods because there is no specialized analysis facility, nor is it a survey by a specialized organization. Therefore, several simple analysis methods are used.

a) Pack test

This is a technique in which a test sample is suction-injected into a polyethylene tube previously filled with chemicals required for analysis, reacted with a reagent, and the color of the reaction with a target substance is measured by visual colorimetry. The reagent used for the reaction is often the same as the official method, but since heat is not applied, a reagent

different from the official method is used for those requiring a heating reaction. Since accuracy cannot be ensured by visual colorimetry, it is possible to measure the reacted water sample with a simple colorimeter depending on the item.

b) Transparency

This method measures the turbidity in water visually. When conducting surveys on the boat in lakes, coastal zone, etc. where water flow is minimal, measurements are taken with a transparency secchi disc. For rivers with flowing water, measurements are taken with a transparency tube after sampling. The principle is the same as that of the turbidity measurement by sensors, and the depth at which the double cross on the bottom surface becomes invisible by water detection in a cylinder is visually measured. It is suitable for turbid water management of agricultural runoff.

6. Sediment survey

The sediments that have been removed from water and which settle at the bottom of a water body contain substances dissolved substances transferred from the water by adsorption. In addition, due to decomposition and oxidation-reduction reactions in the sediment, transfer of substances into water also occurs. Thus, bottom sediment reflects the past water quality history and still has a certain impact on water quality. For this reason, it is important to pay attention to sediment in water quality surveys, and it is desirable to conduct sediment surveys as necessary. Since the rate of change in sediment is low, it is sufficient that the survey frequency is generally low such once in several years. In the laboratory analysis, it is necessary to pay due attention to the possible interference from the test reagents as specified official method.

6.1 Sampling point

In addition to the vicinity of major pollution sources and estuaries, select locations where there is much sedimentary mud due to topography and tidal currents, and there is a possibility that the sediment will deteriorate. In addition, a site that seems to have little sediment will be selected as a reference site. If the distribution of sedimentary mud is unknown, the sampling points should be evenly distributed. In places where the distribution of sedimentary mud tends to change, such as river mouths, it is necessary to make the points appropriately dense.

6.2 Method of collecting sediment

In principle, sediment samples should be taken at the same location and changed little by little. Columnar sediment shall be collected at points deemed necessary.

6.3 Matters to be implemented when collecting sediment

Record the date and time of sampling, sampling point, topographical geology near the sampling point, flow velocity, current direction, sampling method (model of sediment collector used), sediment condition (sand, mud etc.). In addition to the records, the sediment temperature, color, odor, appearance (especially the presence and thickness of an oxide film on the bottom sediment surface), large organisms, and PH (using a PH meter) and Eh (redox potential using an Eh meter) are immediately observed and measured. Analyze the sample as soon as possible. If it takes a long time to perform the analysis, keep the temperature low.

6.4 Measurement items

In addition to health items, PH, Eh COD, ignition loss, sulfide content nitrogen and phosphorus and water content should be measured. In principle, the measured value is expressed in mg/g of dry weight and wet weight of the sample, but may also be expressed in mg/kg.