Water Quality Analyzers for Water and Sewage Treatment

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1. Introduction

Water is supplied to greater than 95% of Japan, and emphasis is changing to from quantity to quality. As water pollution increases with the advancing industrial age and changes in life-styles, a safer and higher quality supply of city water is desired. In the Special Measures Act and the Work Promotion Act enacted in 1994, the Ministry of Health and Welfare and the Environment Agency stressed the prevention of water source pollution in addition to the previous Water Pollution Control Law and Lakes and Marshes Act. In 1993, the water quality standards for city water were amended. The number of standard items was increased to 46 items. 26 items to be monitored and 13 desirable items were added to supply safer and better tasting water. New treatment systems such as membrane treatment and ozonization have been introduced, and greater importance has been given to water quality control, increasing the demand for new techniques.

Only approximately 54% of households in Japan are connected to a sewage system. The promotion of equipment to raise this rate is a major issue. To restore the rapidly deteriorating water environment, improvements in effluent quality related to water pollution control in public water areas is also an important theme. The effluent quality has been strictly controlled by strengthening effluent standards, total emission controls, and enactment of more stringent prefectural effluent standards. Advanced treatment systems for denitrification and phosphorus removal have had positive results when used in sewage disposal plants, and it has become more important to reliably demonstrate the performance of water quality control treatments.

Because of the increasing expectation of users regarding water and sewage treatment of the changing environment and the advance of water quality measuring technologies, new on-line water quality sensors, in addition to conventional sensors, have been developed and introduced with positive results. This paper describes the process flows of water and sewage treatments, all types of water quality sensors (from basic models to those based on new principles), and water quality control in water and sewage treatment processes.

2. Water Quality Sensors for City Water Treatment

The relationship between the process flow of city water treatments, water quality control, and sensors is shown in Fig. 1.

2.1 Intake water

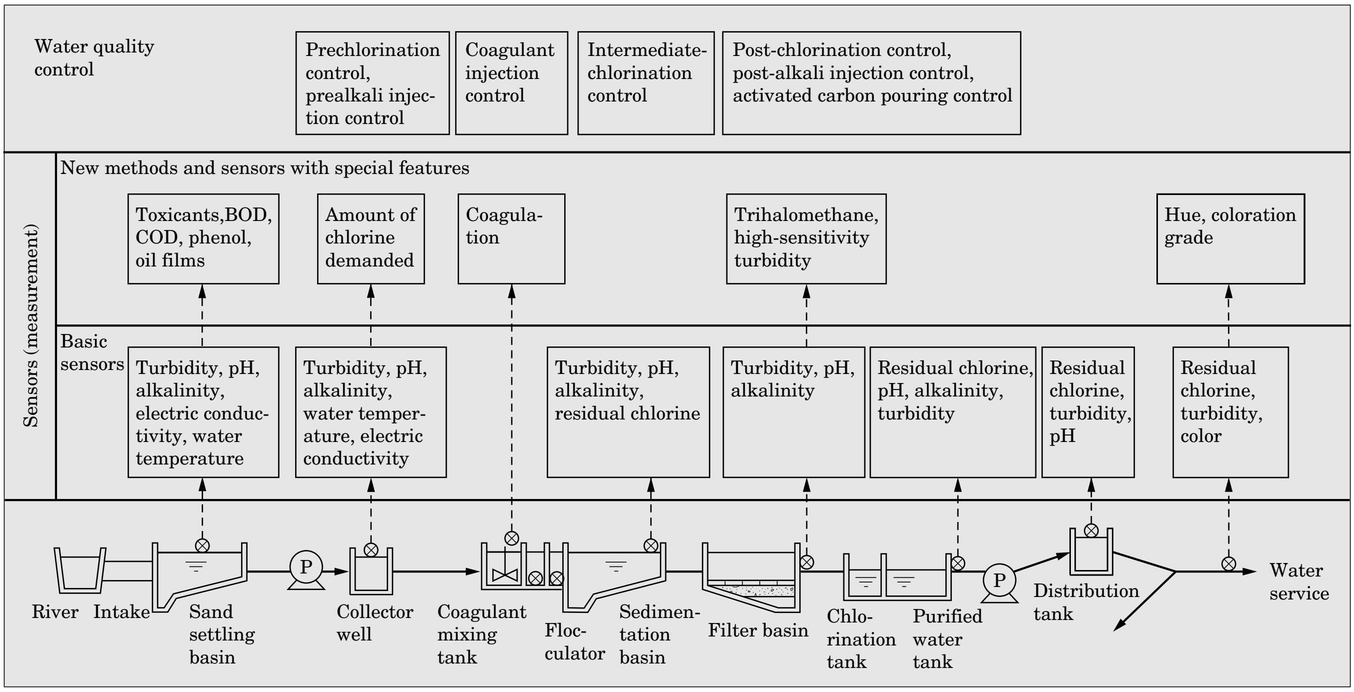
The safety and the general quality of source water are monitored for use as city water. Toxicants are the most important item to be monitored to verify the safety of source water quality. Until now, the general method used has been to visually monitor of fish behavior. As for sensors, cyanogen sensors are seldom used to monitor city water because their minimum detectable value is insufficient and reproducibility is poor. Recently, new technologies, a method of automatically judging abnormal fish behavior and a high-sensitivity toxicant sensor that utilizes a biosensor (Fuji Electric's product name: acute toxicant monitor), have been put to practical use. A remote monitoring application that includes both sensors and transmits video signal has also been implemented. Typical water quality items to be monitored include turbidity, pH, alkalinity, electric conductivity, and water temperature. Additional sensors for oil film, BOD (biochemical oxygen demand), COD (chemical oxygen demand), and phenol may be installed.

2.2 Raw water

To control the quality of raw water before the purification process, turbidity, pH, alkalinity, water temperature, and electric conductivity are measured as basic items. As a direct index for prechlorination, a chlorine demand sensor internally calculates values from the results of chlorination.

If a water source is a well, sometimes color is related to problems with the nature of the soil, and the water is monitored with a color sensor using a principle similar to that of the turbidity sensor.

Fig.1 Relationship between the process flow of city water treatment, water quality control, and sensors



2.3 Water mixed with coagulant

There are only a few examples of on-line water quality measurement in coagulant mixing tanks. Off-line jar tests are generally used to identify and confirm a coagulation state, a main water quality in coagulant mixing tanks. Other methods of testing for coagulation states are processing ITV pictures of flocculation states and an auto jar tester that automatically performs jar tests. Both of these methods judge results of floc coagulation and are incapable of real-time monitoring of the coagulation state. A new sensor which performs real-time measurement of floc diameters by analyzing the photodispersion of dual wavelength absorbance, and directly measures a flocculation state to give an index for coagulant injection control (Fuji Electric's product name: floc sensor) has been developed and implemented in practical applications.

2.4 Water under sedimentation

Turbidity, pH, alkalinity, and residual chlorine are measured to confirm results of coagulation, sedimentation, prechlorination and prealkali feeding, and to monitor water quality before intermediate-chlorination and filtration.

2.5 Filtered water

Filtered water undergoes turbidity control at the final stage of suspended solid removal and water quality control before post-chlorination and post-alkali pouring. In order to enact anti-cryptosporidium measures and to introduce membrane technologies into water purification, control that exceeds conventional measuring sensitivity is required, especially for the turbidity control. With regard to measuring technology, a sensor that utilizes particle counter and optical technology (Fuji Electric's product name: high sensitive turbidimeter) has been developed, and can measure up to levels of 0.001 mg/L. This sensor can also be used as a membrane rupture sensor for membrane treatment equipment. Trihalomethane, a carcinogen that has recently received a great deal of attention, is generated when a substance such as humic acid in raw water is disinfected by chlorine. Gas chromatography and mass spectrometry, official analytical methods for trihalomethane, are performed off-line with equipment that is difficult to use. A sensor, capable of on-line measurement of total trihalomethane concentration by measuring the fluorescent intensity of fluorescent substances produced by the Fujiwara reaction (Fuji Electric's product name: trihalomethane meter), has been developed. The measurement method of this sensor is highly correlated with the official analytical methods. The trihalomethane sensor is used as a sensor at water supply terminals to check for trihalomethane generation, in addition to verifying the condition of filtered water. Other water quality items for inspection are residual chlorine, pH, and alkalinity.

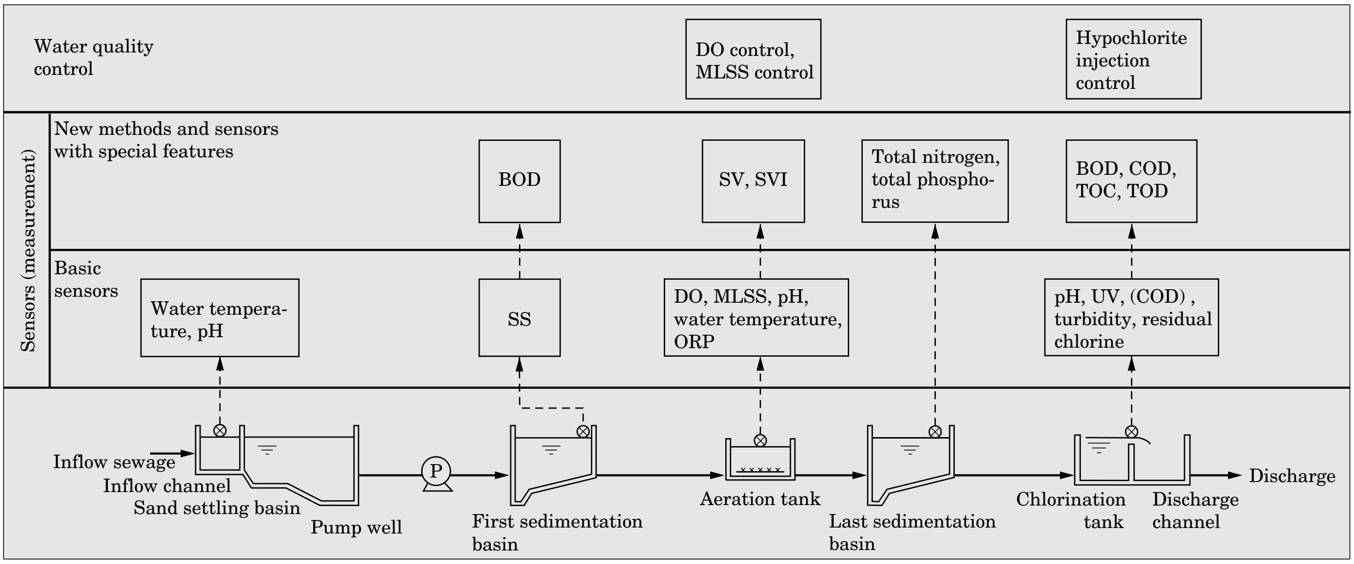
2.6 Water purification, conveyance, and distribution

Water quality is controlled after purification, after conveyance from purification plants, and before distribution. Major items for control are residual chlorine, turbidity, pH, and alkalinity.

2.7 Water service points

Water quality is controlled at the piping network

Fig.2 Relationship between the process flow of sewage treatment, water quality control, and sensors



ends positioned near consumers. Major water quality items measured on-line are turbidity, color, and residual chlorine. Color and turbidity, required to be inspected daily as stipulated in the Water Service Act, are evaluated by visual inspection. Colorimetry with conventional sensors was utilized as a substitute method, but has insufficient color sensitivity. Recently, a new optical sensor (Fuji Electric's product name: Service water quality monitor) to measure hues and coloration grades with the same sensitivity as visual inspection has been developed and put to practical use. This sensor can be used as a multisensor, with optional functions capable of measuring water pressure, water temperature, pH, and electric conductivity. With a built-in transmission unit, this sensor is designed for use as a centralized service water monitor over a wide area.

2.8 Advanced treatment

To remove offensive smells and tastes characteristic of degraded raw water quality and to reduce the potential of trihalomethane formation, advanced treatment facilities using ozone and ultraviolet rays have recently been introduced. It is important for ozone treatment equipment to have a dissolved ozone sensor to monitor the concentration of dissolved ozone in water.

3. Water Quality Sensors for Sewage Treatment

The relation between the process flow of sewage treatment, water quality control, and sensors is shown in Fig. 2.

3.1 Inflow sewage

To control inflow sewage conditions, water temperature and pH are generally measured. There are also instances of first flush pollution control employed at trunk inflow points.

3.2 First sedimentation tank outlet (after primary treatment)

Generally, there are no on-line measurements and SS (suspended solids) are rarely monitored. Recently, in some places, BOD loading measured with a BOD biosensor is utilized to automatically control the amounts of activated sludge and air.

3.3 Aeration tank

Aeration is the most important process in a treatment system that uses the standard activated sludge method. As a required water quality measurement, DO (dissolved oxygen), is used to control the amount of air blown into the tank.

Other general measurement items are MLSS (mixed liquor suspended solids), pH, and temperature. MLSS is especially used to control the amount of stored sludge and estimate the total volume of sludge in the system. In some cases, SVI (sludge volume index) is measured as an index for sludge in the tank. When an advanced biological treatment process using activated sludge for the purpose of denitrification and phosphorus removal is employed as a measure against eutrophication, it is necessary to control the nitrification or denitrification of activated sludge and the absorption or release of phosphorus. Anaerobic and aerobic control has been introduced using an ORP (oxidation reduction potential) sensor as an index to estimate activated sludge conditions.

3.4 Last sedimentation tank outlet (after secondary treatment)

To confirm results of advanced treatment processes for denitrification and phosphorus removal, the total

Table 1 Specifications of basic water quality sensors

Item \ Sensor	Turbidimeter	pH meter	Alkalinity meter	Residual chlorine meter with reagent	Free chlorine meter without reagent
Method of measurement	Surface scattering method	Glass electrode method	Neutralization titration with sulfuric acid	Polarography with a fixed rotating electrode	Polarography with a fixed rotating electrode
Measuring range, etc.	Range 1, 2 and 3, min. range 0 to 2mg/L, max. range 0 to 1,000mg/L	0 to 8, 0 to 14, 2 to 12, 4 to 10	0 to 50, 0 to 100 (mg/L)	0 to 1, 0 to 3, 0 to 5, 0 to 6 (mg/L)	0 to 1, 0 to 2, 0 to 3 (mg/L)
Accuracy of measurement	±2% FS (reproducibility)	±0.1 pH	±2% FS (reproducibility)	±2% FS (repeatability with checking fluid)	±2% FS (repeatability with checking fluid)
Response time, etc.	Continuous	Continuous	Approx. 10 to 99 min (setting)	Approx. 6 min (90% response)	Approx. 2 min (90% response)

Item \ Sensor	Electric conductivity meter	DO meter	ORP meter	MLSS meter	Other specifications
Method of measurement	Directly immersed 2-pole AC electrode method	Diaphragm galvanic electrode method	Glass electrode method	Scattering light comparator	Power supply: 100V ±10% AC Output signal: 4 to 20mA DC (isolated), partial optical signal output possible (optional) Ambient temperature: −5 to +45°C Ambient humidity: 90% RH or less
Measuring range, etc.	0 to 200, 0 to 500, 0 to 1,000 (μs/cm)	0 to 10, 0 to 15, 0 to 20 (mg/L)	0 to 600, 0 to 1,000, −700 to +700, 300 to 1,000, −200 to +500 (mV)	0 to 5,000, 0 to 10,000, 0 to 20,000 (mg/L)	
Accuracy of measurement	±1% FS (reproducibility)	±1.5% FS (reproducibility)	±1% FS (reproducibility)	±2% FS (reproducibility)	
Response time, etc.	Continuous	Approx. 1 min (90% response)	Continuous	Approx. 1 or 3 min (90% response)	

Table 2 Specifications of new water quality sensors

Item \ Sensor	Acute toxicant monitor	Floc sensor	High-sensitive turbidimeter	Trihalomethane meter	Service water quality monitor	BOD biosensor
Measuring method, range, accuracy, response time, etc.	◦ Biochemical sensor (detects acute toxicants, measures microbe respiration activity) ◦ Detection of abnormal water quality by measuring relative output values of respiration activity. ◦ Response time approx. 20 min	◦ NIR and UV absorbance dispersion analysis (measures floc diameters and absorbance) ◦ 2 to 500 (floc dia.) 0 to 2.5 (absorbance) (optional) ◦ Reproducibility C.V. value 10% or less ◦ Continuous measurement	◦ Forward scattering particle counter (converts density of particles into turbidity) ◦ 0 to 1mg/L (0.001mg/L measurable), density of 1 to 105 particles/mL, Turbidity or particle count can be selected. ◦ 0.5μm (countable particle dia.) ◦ Continuous measurement	◦ Measurement of fluorescence due to reaction of nicotinamide and trihalomethane ◦ 0 to 200μg/L (equivalent to chloroform) ◦ Reproducibility C.V. value 5% or less (at 50μg/L chloroform) ◦ Approx. 30 min per measurement	◦ Water quality measurement of multiple items. ◦ Color: transmission spectrophotometry, 0 to 10 deg. (range), ±5% FS (accuracy) ◦ Coloration grade: transmitted light RGB photometry analysis, 0 to 100% (range), ±5% FS (accuracy) ◦ Hue: transmitted light RGB photometry analysis, colorless, black, white, red, yellow, and other ◦ Turbidity: transmission spectrophotometry, 0 to 5 deg. (range), ±2% FS (accuracy) ◦ Residual chlorine: polarography, 0 to 2mg/L (range), ±5% FS (accuracy), ◦ 15 min interval between measurements ◦ Other: pH, water temperature, water pressure, electric conductivity (optional)	◦ Microbe sensor (in accordance with JIS K 3602-1990) ◦ 0 to 30, 0 to 60mg/L ◦ Reproducibility C.V. value 5% or less (11mg/L standard method), 3% or less (55mg/L standard method) ◦ Approx. 40min per measurement
Power supply	100V ±10% AC					
Output	4 to 20mA DC and alarm output	RS-232C, 4 to 20mA DC (optional)	4 to 20mA DC	RS-232C, 4 to 20mA DC	RS-232C, 4 to 20mA DC (optional)	4 to 20mA DC
Ambient temperature	5 to 35°C	−10 to +45°C	0 to 40°C	15 to 35°C	−10 to +45°C	5 to 30°C
Ambient humidity	85% RH or less	90% RH or less	95% RH or less	85% RH or less	90% RH or less	85% RH or less

nitrogen and total phosphorus in the water are measured.

3.5 Discharged water

Water discharged from a treatment plant into rivers, lakes, or the ocean is regulated under the effluent standards of the Water Pollution Control Law (which includes more stringent prefectural effluent standards) and the total emission regulations for water quality. Standard water quality items that can be measured on-line include pH, UV (ultraviolet), BOD, COD, TOC (total organic carbon), turbidity, and residual carbon. With the official analytical method, BOD requires five days for measurement. However, a sensor that utilizes a biosensor for quick, continuous measurement (Fuji Electric's product name: BOD biosensor) has been implemented in practical applications.

3.6 Rainwater

Measures against rainwater have recently become an important topic. When a storm water reservoir for flood control is installed to equalize loads and provide extra draining capacity, turbidity measurement is utilized to control quality of the rainwater inflow.

4. Basic Water Quality Sensors

Specifications of basic water quality sensors mainly based on physical and chemical technologies are shown in Table 1.

5. New Water Quality Sensors

Specifications of unique water quality sensors utilizing biotechnology, information processing technology, and new measuring principles are shown in Table 2.

6. Conclusion

To manage the operation and maintenance of waterworks and sewerage, water quality control will become increasingly important. Currently used on-line water quality sensors are still limited in type and also require more maintenance than conventional sensors. Fuji Electric will develop new water quality sensors to simplify maintenance, and will also improve conventional water quality sensors by prolonging maintenance intervals so they are easier to use.