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Application of multi-channel multi-parameter intelligent water quality analyzer in industrial water testing

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ABSTRACT
This paper describes the application of a multi-channel multi-parameter water quality intelligent analyzer in industrial water testing. The instrument integrates a variety of water quality testing parameters, such as pH, conductivity, suspended solids, chemical oxygen demand (COD), ammonia nitrogen, total phosphorus, total nitrogen, etc., which can be quickly and accurately tested and analyzed. The application in water quality testing of Tianjin Petrochemical is demonstrated through example analysis. In addition, its potential for optimizing water treatment processes, improving efficiency and reducing costs is explored. The results show that the multi-channel multi-parameter intelligent water quality analyzer is an important tool for industrial water monitoring, which is of positive significance for environmental protection and sustainable development of industrial production.

KEYWORDS
Multi-Channel Multi-Parameter Analysis; Intelligent Water Quality Testing; Industrial Water; COD; Ammonia Nitrogen; Total Phosphorus; Total Nitrogen; Environmental Protection

1 Overview of intelligent water quality analysis

With the acceleration of industrialization, the amount of industrial wastewater discharge is increasing, causing serious pollution to the environment. Traditional water quality testing methods are often time-consuming and laborious, and are unable to monitor multiple parameters in real time and continuously, making it difficult to meet modern environmental protection needs. In this context, the Multi-Channel Multi-Parameter Intelligent Water Quality Analyzer was born, which integrates advanced optical detection technology, intelligent control and automated analysis, aiming to provide efficient and accurate water quality monitoring solutions(Balbuena, J. , et al, 2017).

The multi-channel design enables the instrument to simultaneously detect a variety of key water quality parameters, such as chemical oxygen demand (COD), ammonia nitrogen, total phosphorus, total nitrogen, etc., which greatly improves the detection efficiency. In addition, through the integration of a number of sensors, it can quickly and comprehensively respond to changes in water quality, providing an important basis for environmental protection and water treatment process optimization. At the policy level, China has issued a number of regulations to strengthen industrial water management, the application of multi-channel multi-parameter intelligent water quality analyzer helps enterprises to comply with the operation, reduce environmental risks, but also an important technical support for the realization of green and sustainable development.

Multi-channel and multi-parameter intelligent water quality analyzer is based on the integration and design of multi-channel sampling technology, water sample pre-treatment technology, highly sensitive optical detection technology, multi-scene monitoring technology, intelligent control technology(Wang, X. T. 2018). The core of the instrument is to set up multiple independent testing channels, integrate a number of water quality testing parameters, and adopt unique pre-processing technology to realize the intelligent management of equipment operation, remote operation and diagnosis and other functions. The analyzer is composed of sampling distribution module, analysis module, reagent unit, water circuit unit, central control module and other components.

The functional module layout of the multi-channel multi-parameter intelligent water quality analyzer is as follows:

Figure 1 Intelligent Water Quality Analyzer Layout and Appearance

Sampling distribution module, the use of three-dimensional robotic arm distribution of samples, and by grasping the pH, conductivity, turbidity, suspended solids and other electrodes on the sample measurement, after the detection of the electrode head with water for cleaning.

The analysis module, adopting the flow chemical analysis mode, realizes colorimetry through optical detection technology elements, and the detection indexes mainly include COD, ammonia nitrogen, total phosphorus, total nitrogen, nitrate and other chemical parameters. By determining the absorption of light at a specific wavelength or within a certain wavelength range of the substance under test, the substance is analyzed qualitatively and quantitatively. The analytical module adopts innovative optical detection technology, combined with advanced background deduction technology, effectively improving the sensitivity of the analytical module to meet the needs of more trace analysis.

The reagent unit is a storage place for the reaction reagents required by each testing equipment, and is equipped with temperature and liquid level monitoring sensors. The reagent design capacity is 1000ml, in order to ensure the activity of the reagent, the internal air conditioning for ambient temperature regulation.

The water unit, including water inlet piping, pure water box, sample discharge piping, circulation tank, etc., has set up a number of independent testing channels, each channel is specialized in one or several specific water quality parameters, such as pH, dissolved oxygen, conductivity, turbidity and ammonia nitrogen, and so on. Each channel contains highly sensitive sensors capable of capturing small changes in the water sample in real time.

The central control module, which is responsible for the power supply, data processing (saving, remote transmission) and communication of the whole testing system, is the control center of the intelligent analytical instrument, receiving and processing the signals from each sensor, carrying out data calculations and corrections to ensure the accuracy and stability of the measurements. At the same time, it can automatically adjust the working conditions according to the preset program, such as temperature compensation, to eliminate the influence of environmental factors.

The multi-channel, multi-parameter intelligent water quality analyzer, designed to enhance the efficiency and accuracy of industrial water testing, can realize the simultaneous measurement of multiple parameters, greatly reducing the sampling and analysis time. Secondly, the equipment adopts modularized design, which can be flexibly configured and upgraded to detect items according to different water quality monitoring needs, with strong adaptability to application scenarios. Furthermore, the built-in high-precision sensors and advanced signal processing technology ensure the accuracy and stability of the data. Finally, the device is also equipped with real-time data transmission function, the test results can be quickly uploaded to the cloud or local management system, to facilitate remote monitoring and data analysis. These features make the multi-channel multi-parameter intelligent water quality analyzer become an important tool for modern industrial water monitoring.

2 Optical detection technology

Optical detection technology plays a crucial role in water quality analysis, especially in the multi-channel multi-parameter intelligent water quality analyzer, its innovation is reflected in the simultaneous determination of a variety of pollutants and high sensitivity detection. While traditional optical detection often relies on basic principles such as light absorption, fluorescence or scattering, modern technologies enable more sophisticated and accurate measurements by integrating spectroscopy, fiber optic sensing and microfluidics(El-Sayed, M. K. , & Mansour, R. S. 2017).

The optical detection unit of the intelligent water quality analyzer is mainly composed of light source system, monochromator system, sample chamber and detection system, as shown in the figure. The composite light from the light source is decomposed into monochromatic light through the monochromator, when the monochromatic light passes through the sample chamber, a part of it is absorbed by the sample, and the rest of the unabsorbed light arrives at the detector, which is transformed into an electrical signal, and after amplification and data processing by the electronic circuit, it gives the measurement result through the display system.

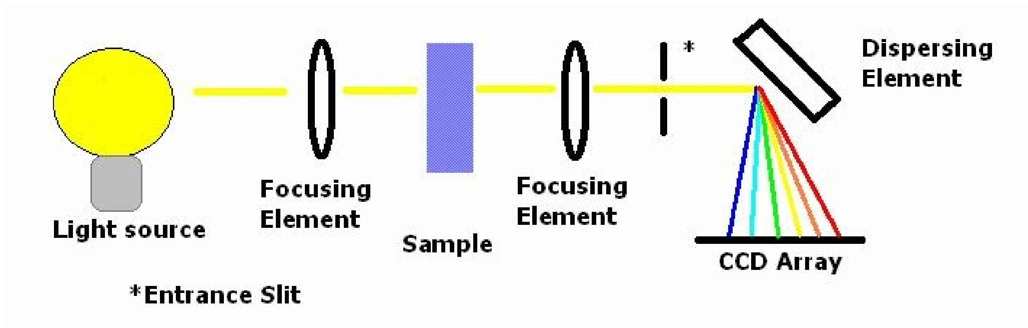

Figure 2 Spectrophotometer structure

In the structural design, the intelligent water quality analyzer adopts “Z” type long optical range colorimetric device, the optical range can reach 15cm, effectively improve the sensitivity of the analysis module, support the trace analysis of water samples; in the optical fiber detection structure, the use of fiber optic isolation mode, effectively blocking the impact of electromagnetic interference, to ensure the stable transmission of signals, improve the system's anti-interference ability, the sensor detects changes in physical quantities by measuring changes in wavelength, to ensure the accuracy of the test results. The sensor detects changes in physical quantities by measuring changes in wavelength to ensure the accuracy of the detection results.

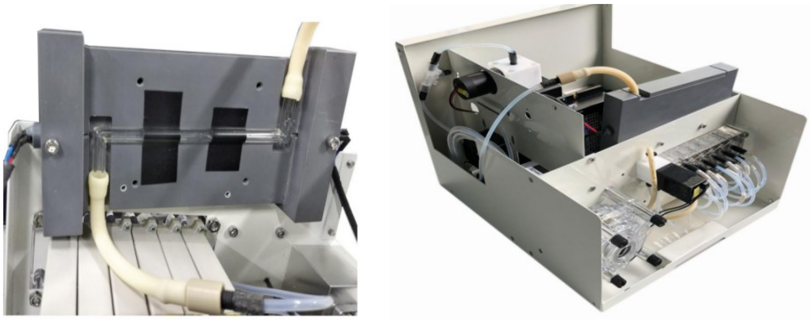

Figure 3 Intelligent water quality analysis optical monitoring module

In optical detection, Smart Water Analyzer also adopts the background deduction technique, which aims to isolate the true contribution of the target substance from the measurement signal and eliminate non-specific signals caused by environmental interference, matrix effect or the instrument's own noise. This technique calculates and subtracts the difference between the sample signal and the signal of a blank sample (a sample without the target substance) by comparing the two to improve the accuracy and sensitivity of the detection. Specifically, background deduction usually involves the following steps: first, obtain the spectral data of the sample to be tested; then, collect the spectra of a blank sample under the same conditions as a background reference; next, compare the sample spectra with the blank spectra and calculate the difference spectra; finally, analyze the difference spectra to obtain the pure signal after deduction of the background, so as to more accurately identify and quantify the concentration of pollutants in water.

When encountering complex water quality, water samples exist interference ions, analytical instruments also need to use the joint masking technology, such as high concentration of chloride ions on the COD measurement has an impact, by adding mercury sulfate to reduce the interference of chloride ions. Multi-link masking technology to effectively improve the applicability of chemical methods, salinity, calcium, magnesium and other ions can be minimized interference.

Intelligent water quality analyzer, through the use of innovative optical detection methods not only improves the speed and accuracy of water quality analysis, but also expands the range of detectable parameters, providing strong technical support for industrial wastewater testing. In the selection of analytical methods, according to the field water samples, focusing on the study of buffer system, catalytic system, redox system, color development system, to ensure that the method system is in the best state.

3 Industrial testing practice

Tianjin Petrochemical circulating water, chemical water, sewage and boiler water and other systems of water quality analysis frequency is far below the requirements of the standard specification, of which the circulating water analysis frequency of the highest rate of deficiency, reaching 64.47%. In order to meet the needs of water quality process control, Tianjin Petrochemical in accordance with the headquarters of the "water quality analysis machine instead of people" work requirements, in the field configuration of multi-channel multi-parameter intelligent water quality analyzer. The intelligent water quality analyzer realizes automatic intelligent analysis of water quality parameters, and the analysis data is automatically uploaded to the LIMS system and can be instantly synchronized on the mobile terminal and the PC terminal, solving the problems of fewer water quality analysts and the frequency of analysis that does not meet the standard requirements.

At present, TPDC has realized fully automatic intelligent analysis of 13 sets of circulating water with 10 indicators and 517 items/day, 4 sets of boiler water with 6 indicators and 144 items/day, 2 sets of chemical water with 6 analytical parameters, and 4 sets of sewage with 10 indicators. The frequency and items of water quality analysis meet the requirements of water quality analysis frequency in the standard specification, and the average annual analysis cost is 73.6% and 75.2% lower than that of manual analysis and traditional on-line water quality analysis instrument respectively.

The intelligent water quality analysis system adopts the national standard analysis method for automatic analysis, which is consistent with the manual analysis method in the laboratory. Tianjin Petrochemical Laboratory Measurement Department analyzed the data of the system for three consecutive months of manual analysis comparison, the system testing accuracy to meet the requirements, can replace the manual analysis. Taking boiler water manual comparison data as an example, the deviation between analyzing instrument and manual assay is within the permissible range, as shown in the table:

Table 1 pH, silica, phosphate, conductivity comparison results

Date	pH			Silicon dioxide (mg/L)			Phosphates (mg/L)			Conductivity(μS/cm)		
	instrumentation	labor	Tolerance ±0.03	instrumentation	labor	Tolerance ±0.04	instrumentation	labor	Tolerance ±0.4	instrumentation	labor	Tolerance ±3
2021.2.1	9.58	9.7	-0.12	0.11	0.1	0.01	1.4	1.3	0.1	26.54	27	-0.46
2021.2.2	9.37	9.5	-0.13	0.08	0.07	0.01	0.96	0.9	0.06	21.93	23	-1.07
2021.2.3	8.99	9.1	-0.11	0.1	0.09	0.01	1.2	1.06	0.14	19.12	19	0.12
2021.2.4	9.2	9.4	-0.2	0.07	0.07	0	1.11	0.96	0.15	17.52	18	-048
2021.2.5	9.46	9.6	-0.14	0.07	0.06	0.01	1.22	1.32	-0.1	22.9	24	-1.1
2021.2.6	9.27	9.3	-0.03	0.09	0.07	0.02	0.63	0.53	0.1	24.59	25	-0.41
2021.2.7	9.17	9.3	-0.13	0.07	0.08	-0.01	0.71	0.54	0.17	22.46	22	0.46

In Tianjin Petrochemical, multi-channel multi-parameter intelligent water quality analyzer shows significant advantages, with a high degree of automation, system expandability, stability and reliability, low one-time investment, low operation and maintenance costs, etc., a single set of equipment can replace multiple sets of traditional water quality online analysis instrumentation. Specifically manifested in. First, the investment and operation and maintenance costs are lower, a single set of systems can achieve 20 points of access to the analysis, the same conditions need to configure dozens of traditional water quality online analysis instrumentation, the investment cost of about 30% -50% of the traditional water quality online analysis instrumentation, while the system consumes less reagents, operation and maintenance of the workload is small, the operating cost can also be reduced by 70% -80%. Second, the integration of a variety of sample pretreatment

Table 2 Comparative results of saturated silica, saturated sodium, superheated silica, superheated sodium

Date	Saturated silicon(μg/kg)			Saturated sodium (μg/kg)			Superheated silicon (μg/kg)			Superheated sodium(μg/kg)		
	instrumentation	labor	Tolerance ±1	instrumentation	labor	Tolerance ±1	instrumentation	labor	Tolerance ±1	instrumentation	labor	Tolerance ±1
2021.2.1	1.07	1.9	-0.83	1.05	1.5	-0.45	1.18	2	-0.82	1.16	1.4	-0.24
2021.2.2	0.49	1.3	-0.81	1.16	2	-0.94	0.76	1.7	-0.94	1.13	1.6	-0.47
2021.2.3	0.32	1.1	-0.78	1.09	1.5	-0.41	0.6	1.5	-0.9	1.21	1.4	-0.19
2021.2.4	0.04	1	-0.96	1.18	2.1	-0.92	0.18	0.9	-0.72	1.49	2	-0.51
2021.2.5	0.58	1.4	-0.82	1.66	1.9	-0.24	0.5	1	-0.5	1.89	2.3	-0.41
2021.2.6	0.75	1.7	-0.95	1.79	2.4	-0.61	0.6	1.4	-0.8	2.19	2.6	-0.41
2021.2.7	1.81	1.7	0.11	1.68	1.8	-0.12	0.09	1	-0.91	1.96	2.1	-0.14

technology, with filtration, ultrasonic emulsification mixing and multi-stage online cleaning and other functions, can effectively reduce the interference of complex water quality analysis, compared with the traditional water quality online analysis instrument has outstanding advantages. Third, the intelligent control is powerful. The system has intelligent functions such as operation status monitoring and feedback, independent diagnosis, reagent and waste liquid monitoring and early warning, and on-site production equipment interlocking control; the traditional water quality online analyzer is only an on-site analysis terminal, and most of the intelligent functions are missing. Fourth, the analysis project is complete, compared with the traditional water quality online analysis instrument, the system has calcium hardness, ammonia, sulfide, sulfate, nitrate, nitrite and other indicators of the analysis function. In addition, when abnormal data is detected, the analyzer will immediately trigger an alarm and automatically transmit the information to the central control system, so that the operation and maintenance personnel can view and take appropriate measures through the PC. Through long-term operation, the intelligent water quality analyzer has achieved significant results in reducing operating costs, improving processing efficiency and ensuring compliance with environmental regulations.

4 Benefits and Challenges

In practical applications, machines instead of people can avoid errors caused by human factors, such as fatigue, negligence or inconsistencies in subjective judgment, and ensure the reliability and consistency of data. For example, an automated analysis system can perform measurement tasks precisely in accordance with preset procedures, independent of the environment or personal status, ensuring the accuracy of measurement results(Youn, I. H. , Park, D. J. , & Yim, J. B. 2018). The centralized deployment and centralized assay mode reduces labor costs and response time, enabling unattended remote monitoring. For example, in the Petrochemical Park, a multi-channel, multi-parameter intelligent water quality analyzer enables real-time monitoring of all discharge outlets in the park, triggering an alarm and locating the source of the problem as soon as water quality abnormalities are detected, providing the possibility of a rapid response to and treatment of pollution problems.

Intelligent water quality analyzing equipment can respond quickly to changes and warn of potential problems in a timely manner(Gao, K. C. M. 2019). When water quality parameters exceed preset thresholds, the system immediately triggers an alarm and automatically records abnormal information, providing an important basis for subsequent troubleshooting and treatment. In some large industrial facilities, this immediate response capability is critical to preventing environmental accidents and minimizing economic losses. In addition, centralized deployment enables big data analysis. By mining large amounts of water quality data, regular changes in industrial water quality can be identified, providing decision support for process optimization and pollution prevention and control. For example, through the analysis of water quality parameters, enterprises can be guided to adjust the production process, improve the effect of water treatment, reduce the over-addition of pharmaceuticals, and realize green production. As shown in the figure:

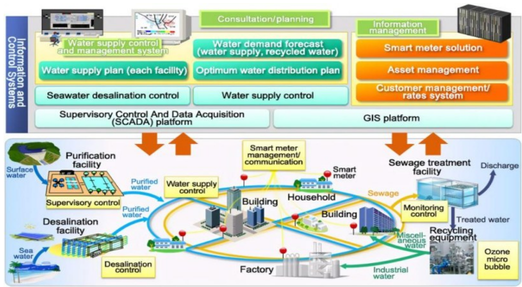

Figure 4 Intelligent water quality analysis and dosing system linkage

However, the application of multi-channel and multi-parameter intelligent water quality analyzer in water quality monitoring also brings some challenges. On the one hand, the maintenance and calibration of intelligent analyzers require professional technical knowledge and high requirements for operators, which to a certain extent limits the speed of their popularization. On the other hand, despite the high sensitivity of optical detection technology, it is susceptible to the influence of suspended solids and color in water quality, and the background deduction algorithm needs to be continuously optimized to improve measurement accuracy. In addition, data security and privacy protection are also issues of concern, especially during centralized data management and remote transmission. Therefore, continuous technology development and optimization is the key to ensure the effective functioning of the machine generation.

References

[1] Balbuena, J. , Quiroz, D. , Song, R. , Bucknall, R. , & Cuellar, F. . (2017). Design and Implementation of an USV for Large Bodies of Fresh Waters at the Highlands of Peru. Oceans (Conference).

[2] El-Sayed, M. K. , & Mansour, R. S. . (2017). Water scarcity as a non-traditional threat to security in the middle east. India Quarterly: A Journal of International Affairs.

[3] Gao, K. C. M. . (2019). An intelligent iot-based control and traceability system to forecast and maintain water quality in freshwater fish farms. Computers and Electronics in Agriculture, 166.

[4] Wang, X. T. . (2018). Design of multi-parameter portable water quality detector based on wireless network. Wireless personal communications: An Internaional Journal, 102(2).

[5] Youn, I. H. , Park, D. J. , & Yim, J. B. . (2018). Analysis of lookout activity in a simulated environment to investigate maritime accidents caused by human error. Applied Sciences, 9(1).