Application Analysis of Conductivity in Drinking Water Quality Analysis

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Abstract. Water is the source of life, people take food as the sky, and food takes water first. With the discharge of industrial waste water, urban and rural domestic sewage and the increasing consumption of pesticides and fertilizers, many drinking water sources have been polluted, and the pollutant content in water has seriously exceeded the standard, which makes it difficult to guarantee the drinking water quality and hygiene of urban and rural residents who directly drink surface water and shallow groundwater. Classical wet chemical analysis method can only use different methods to determine parameters individually, and it has low sensitivity, many interferences and lengthy steps. According to the calculation method of conductivity in water quality analysis, this paper introduces the coincidence degree between measured conductivity and calculated conductivity, and the principle and practical application of taking the correlation between conductivity and total ion as quality control method.

Keywords: Conductivity; Drinking water; water quality analysis

1. Introduction
With the acceleration of social industrialization, environmental pollution, especially water quality safety, has gradually attracted people's attention, and the demand of related enterprises and institutions for online water quality detection system is also increasing. Many small water supply points are distributed in remote areas, so it is difficult to collect information and the investment is large [1]. The wireless network system consist of user acquisition terminal equipment and local exchange can well solve that problem of scattered water supply points and long distance. Conductivity in aqueous solution is not only a common index to measure water quality, but also can reflect the amount of ionizable substances in water [2]. Because of its simple test, it has been widely used in earthquake monitoring and water quality analysis.

With the progress of science and technology, various modern means have been applied in water quality monitoring and analysis. Among them, electrochemical analysis is an analytical method to determine the content of substance components according to the electrical and electrochemical properties of substances in solution, such as potential, charge, current, resistance and other electrical signals and their changes; Conductivity method has been widely used in water quality analysis [3-4]. The conductivity of water is a very important index to measure water quality, which can reflect the degree of dielectric in water. When the water contains inorganic acid, alkali or salt, the conductivity is increased. Ion concentration is equivalent to conductivity through a certain mathematical relationship,
and water quality is formed by adding up, that is, near-pure water degree is intuitive, simple and convenient. Through quantitative analysis of drinking water in Huaibei City, the results are satisfactory.

2. Calculation of conductivity

The water contains ions, and the charged ions migrate under the action of an external electric field, so that the conductivity value of the water body and the water paste capacity can be quantified by the specific conductivity of the water body, and the number of ion charges is increasing. In recent years, people have developed some purification technologies for polluted water, which can be roughly divided into oxidation method, adsorption method, biological method, membrane method, etc. The purpose is to ensure the quality of drinking water [5]. The purpose of drinking water treatment is to improve the quality of water, remove colloidal substances, suspended particles and toxic components in water, and reach the drinking standard. At present, the commonly used drinking water treatment processes include sedimentation, coagulation, clarification, filtration, oxidation and disinfection. It is conducive to comprehensively, scientifically and truly reflecting the measured water quality, and timely and accurately grasping the water quality status and dynamic change trend.

List the results of water quality analysis, including the concentration of various main ions and the measured conductivity. The formula for calculating the ionic strength \( I \) is [6]:

\[
I = \frac{1}{2} \sum_{i=1}^{n} C_i Z_i^2 \quad (1)
\]

In the formula, \( C_i \) is the concentration of the \( i \)th ion; \( Z_i \) is the charge number of the \( i \)th ion; \( I \) is ionic strength.

According to Onsager formula, calculate the molar conductivity \( \lambda \) of various ions:

\[
\lambda = \lambda_0 - \left[ x \right] I^\frac{1}{2} \left[ 1 + I^\frac{1}{2} \right] \quad (2)
\]

In the formula, \([x]\) is a constant related to ionic valence; \( \lambda \) is ionic molar conductivity; \( \lambda_0 \) is the limit molar conductivity when the solution is infinitely diluted.

Calculate the conductivity of water sample with the formula

\[
K = \sum_{i=1}^{n} (\lambda_n M_n) \quad (3)
\]

In which \( \lambda_n \) is the conductivity of the \( n \)th ion; \( M_n \) is the concentration of the \( n \)th ion; \( K \) is the conductivity of water.

According to the consistency between the measured value of conductivity and the calculated conductivity, the accuracy of water quality analysis results can be judged.

There is a correlation between the total dissolved solids content in water samples and the conductivity of water samples. By measuring the conductivity of water samples and standard series, the conductivity values of water samples and standard series are compared and quantified. Separation method is to use instruments (such as chromatography, electrophoresis) to separate and analyze those compounds which are very similar in structure and properties, mainly based on chromatography and electrophoresis technology [7]. Its accuracy can be expressed by point estimation and interval estimation, and its error can be expressed by absolute error and relative error. For example, CaCO3, organic matter, etc., are basically composed of independent positive and negative ions. Therefore, calculating the conductivity value from ion equivalent can be used to quantify the total amount of dissolved substances in water as an evaluation parameter.
3. Materials and methods

3.1 Instrument
Hash PC510 pH/conductivity meter (or other conductivity measuring instruments); Conductivity electrode; 100 ml volumetric flask; 100 ml beaker; 50 ml volumetric flask.

3.2 Test condition
Anion chromatography: flow rate 0.9 ml/min, quantitative loop 20μL, maximum pressure 15.0MPa, collection time 8min, column temperature 45℃. Cation chromatography: flow rate 1.1 ml/min, quantitative loop 10μL, maximum pressure 12.5MPa, collection time 8min, column temperature 25℃.

3.3 Water sampling
According to "Collection and Preservation of Water Samples" in "Standard Inspection Method for Drinking Water", collect in 1000 ml plastic bucket and measure within 24 hours.

3.4 Detection method and evaluation
The water samples of different types of drinking water in the same place were collected, stored, detected and analyzed. The water quality detection was based on GB/T 5750-2006 Standard Test Method for Drinking Water and GB/T 5749-2006 Hygienic Standard for Drinking Water as the basis for hygienic evaluation.

4. Quality control based on the correlation between conductivity and total amount of ions

4.1 Method accuracy
The conductivity is related to ion concentration, ion charge number, ion migration rate and temperature. Under the condition of fixed temperature and fixed electrode, the conductivity of groundwater is mainly determined by the total amount of ions contained in the aqueous solution, that is, it is directly proportional to the total ionizable salt contained in the aqueous solution [8]. Under the optimized chromatographic conditions, the working curves of anions and cations were drawn. The results showed that there was a good linear relationship between the concentration of each detected ion (C, mg/L) and the peak area (A, μ s min) within a certain range, and the linear correlation coefficients were all above 0.999. The qualified rate of microbial indicators of water samples is only 50%, and the unqualified water samples are drinking water treated by portable filter kettle, bottled water sold in the market and direct drinking water in community. This may be due to the long filtering time and open storage of the water filter kettle when treating the water sample, which makes the water sample polluted by the outside world. The real-time data obtained are remotely transmitted to the monitoring center by wireless transmission or Ethernet, and displayed and saved by the information management system of the monitoring center, thus realizing the on-site automation and remote intelligent monitoring of drinking water treatment and achieving the purpose of saving resources.

Three samples of source water, factory water and purified water with different concentrations were selected, and the standard concentrations of high (300mg/L), medium (100mg/L) and low (10mg/L) were added to measure the recovery rate six times, and the recovery rates were 98.21%, 104% and 98.6% respectively. See table 1.

| Sample No.          | Background value(mg/L) | Added standard concentration(mg/L) | Estimated value n=8(mg/L) | RSD(%) | Recovery rate(%) |
|---------------------|------------------------|-----------------------------------|---------------------------|--------|------------------|
| 1 (purified water)  | 36                     | 25                                | 55                        | 3.36   | 98.1%            |
| 2 (ex-factory water)| 322                    | 158                               | 554                       | 0.84   | 104%             |
| 3 (source water)    | 504                    | 395                               | 917                       | 1.02   | 98.6%            |

Table 1 Method recovery rate
In the process of selecting underground fluid monitoring points and identifying anomalies in the field, it is often necessary to preliminarily understand the parameters of spring (well) water flow (well depth), temperature, 9: value, total salt, etc., before making further analysis or judgment on problems or events. The general chemical indexes of all water samples meet the national standards. The overall pH value is between 6.49 and 8.29, with the maximum value of tap water being 8.19 and the minimum value of filter kettle being 6.79. The pH value of tap water treated by filter kettle is obviously lower than that of untreated tap water because of its filtering principle. There are 103 samples with the highest detection value of total coliform bacteria (> 1600 /100ml), and the scope and degree of pollution indicate that it is easy to trigger the outbreak and prevalence of water-borne infectious diseases in the region [9]. The main unqualified items in sensory indicators are turbidity and visible objects, and the chromaticity, odor and taste are all qualified. After statistical analysis. There are seven detection sensors, which are temperature, conductivity, flow rate, pressure, turbidity, dissolved oxygen and pH value.

4.2 Influence of coexisting ions

On the basis of existing instruments and equipment, we have found a quick test method for total salt. Under experimental conditions, the common ion interference in water was measured. The results show that 10 g/L Cl⁻, 1 g/L NH₄⁺, 500 mg/L NO₃⁻, SO₄²⁻ and total hardness do not interfere with the determination. The research shows that [10], when the working electrode (microelectrode) has a very small area relative to the auxiliary electrode (less than 1/100 of the area of the auxiliary electrode), the extremely small polarization current on the microelectrode reduces the voltage drop of the system, so that it can be used in high resistance system to realize the detection of the characteristics of low concentration electrolyte solution.

The fluoride content of the water samples ranged from 0.26 mg/L to 0.95 mg/L, and the fluoride content in drinking water was less than 1.0 mg/L, which indicated that different types of drinking water in Baota District of Yan'an were not harmful to human health. Sample solution will be determined under the same conditions as standard solution, and the results are shown in Table 2. It can be seen from Table 2 that the four trace elements of Cu, Zn, Fe and Mg in all tested water samples are lower than the national standard limit value, which conforms to the drinking water quality standard in China.

| Sample                        | Cu   | Zn   | Fe   | Mg  |
|-------------------------------|------|------|------|-----|
| Tap water                     | 0.0114 | 0.1074 | 0.0272 | 14.23 |
| Commercially available barreled water | 0.0127 | 0.0338 | 0.0142 | 10.11 |
| Community drinking water      | 0.0226 | 0.0211 | 0.031 | 9.21 |
| Commercially available mineral water | 0.0203 | 0.0105 | 0.0214 | 5.02 |

Different trace elements have their own effects on human body. Copper is an important component of various enzymes in human body, which is especially important for nervous system and bone development. When human body lacks copper, it will appear emotional Instability and other symptoms. The copper content in the water samples measured this time is low, which meets the national standard.

There are more and more physical quantities collected, and the requirements of speed and accuracy are constantly improving. How to solve the problems of slow transmission speed and high error rate of collected data and realize fast, accurate and large data collection and processing is the key to restrict the development of data collection system. Due to the characteristics of conductivity sensor, such as
high selectivity, low cost, high sensitivity, good stability, high degree of automation, and fast continuous online monitoring in complex systems, it has developed rapidly in the field of environmental protection. Fig. 1 is a sample titration curve.

**Figure 1** p-m titration curve

Microbial index is the main factor of low qualified rate of water quality, among which the qualified rate of total coliform bacteria is the lowest. The total hardness, sulfate, chloride and soluble solids of water have exceeded the national standard over the years, and the content has an increasing trend year by year. It is understood that this is related to the geology of underground rock strata, and the specific reasons need to be further studied. Because rural drinking water is mainly distributed, it is impossible to change to centralized water supply in a short time. Therefore, while improving water, farmers should be organized to repair the incomplete and damaged well walls, and do a good job of environmental sanitation around wells to prevent well water from being polluted. The middle of the working electrode array is the heat conducting surface of temperature sensor Pt1000, and the surface is located and protected against corrosion by thermal grease. The integrated electrode has compact structure, good stability and easy maintenance, and can be directly installed in the pipeline for online water quality detection.

4.3 Corrected charge

PH value sensor. Its measuring range: 0.00 ~ 14.00; Resolution: 0.01PH; Temperature compensation: 0°C ~ 99.9°C (automatic temperature compensation or manual setting); Control range: 0.00 ~ 14.00; Output load: ≤ 500ω; Ambient temperature: 0°C ~ 100°C. The World Health Organization (WHO) puts forward that the pH value standard of "healthy water" should be weakly alkaline (pH value = 7 ~ 8), and the pH value of the water samples taken is near the interval, which is suitable for drinking. Zinc is the activator of dozens of enzymatic reactions in the body. Zinc deficiency will affect all systems of the whole body, especially the gonad maturation in adolescence. When the human body is deficient in zinc, it should be supplemented by other ways such as reasonable diet besides proper drinking water. This determination is rapid and accurate, and does not consume or deteriorate the water sample, but it cannot reflect the content of non-electrolyte substances. In addition, conductivity can be used to roughly check the results of chemical analysis.

In the evaluation of drinking water, we only select several main ions for equivalent calculation, but the number of positive and negative charges may not be completely balanced, so according to the principle of electric neutrality of solution, charge correction should be carried out.

\[ q = \sqrt{(q_+ - q_-)^2} \]  

Specify 1mol molar conductance \( \Lambda_{aq} = 60 \times 10^{-4} \cdot \Omega^{-1} \cdot m^2 \cdot mol^{-1} \) (empirical value), which is
obtained by formula (4)

\[ X_{o,q} = q \cdot x \] (5)

The modified charge \( q \), \( q \ll q_+ \) or \( q \ll q_- \) in general, is also \( X_{o,q} \ll X_o \). Therefore, the specified value of \( x \) has little influence on the result, so the total equivalent conductivity of water body can be obtained by the above formula

\[ X_o = \sum_{i} M_i x_{o,i} + q x_{o,q} \] (6)

In the simple analysis of water quality, if more samples are taken, it will not only waste chemicals, but also consume too much time; If less samples are taken, the accuracy of analysis results will be affected. The volume of samples in chemical analysis can be roughly estimated by conductivity. However, due to the low iodine content in most samples and the extensive use of iodide in the laboratory, the background content of iodine can not be ignored in trace analysis, which makes it difficult to develop the determination of trace iodine because the technical indicators such as accuracy and precision can not meet the requirements. The measurement principle of coated current method is adopted, which consumes no reagent, has no film, is not affected by surfactant, and has small volume and low power consumption. With the development of portability, low cost and generalization, it supports multiple interfaces and has been widely used in many fields such as industrial field data acquisition and control.

The conductivity of natural water is related to the type, concentration and temperature of ions. Determining the conductivity of natural water can enable the performers to indirectly guess the total concentration of ion components in water. The problem of bacteria and microorganisms exceeding the standard in drinking water is always very serious, and the chemical indexes and even toxicological indexes in water quality greatly exceed the standard range. Due to water pollution, it is difficult to ensure the quality and hygiene of drinking water for urban and rural residents. Fig. 2 is the corresponding curve of total salt content in water sample and conductivity measurement. According to the curve, we can get the total salt content corresponding to different conductivity. It can be seen from the data in the figure that the test results are accurate and reproducible, which is a reliable test method for water quality analysis.

Figure 2 Corresponding curve of conductivity measurement and total salt content
When the conductivity sensor is placed in a constant temperature buffer solution, the oxygen in the solution is saturated with constant stirring. The qualified rate of microbial indicators in water quality is quite different between dry season and wet season, especially the bacterial indicators, which exceed the standard by 50 times in wet season and 3 times in dry season, indicating that the water quality in wet season is more seriously polluted by bacteria, and the disinfection work in wet season should be strengthened. The pollution of domestic sewage is becoming more and more serious, which leads to the gradual deterioration of groundwater quality. In addition, water hardness, sulfate, chloride, soluble solids and other substances can not be removed by water treatment, so the quality of surface water in our factory water is better than that of groundwater over the years.

5. Conclusion

When living conditions permit, people can choose to install household water purification equipment to effectively improve the quality and taste of drinking water. However, attention should be paid to changing filter elements regularly to reduce secondary pollution and ensure water quality safety. This method directly regresses the conductivity of water samples with the standard series to obtain the results of total dissolved solids. The method is simple to operate, low in detection limit, high in sensitivity, satisfactory in accuracy and precision, and suitable for the detection of large quantities of water samples. Evaluation of drinking water quality by ion equivalent conductivity can find out the abnormal situation of a well in time, so as to find out the causes of pollution, which has certain reference value for studying water quality trends and water quality prediction.

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