Systematic Assessment and Analysis of Drinking Water Quality in a Typical Sub-new Residential Area in Guangzhou

Yue Lei *

Guangzhou Foreign Language School, Guangzhou, China

* Corresponding Author Email: Leiyue0319@outlook.com

Abstract. The safety of drinking water quality is crucial for public health and social stability. This study systematically assessed the tap water quality in a typical sub-new residential area in Guangzhou, comparing different water supply modes. Five sampling points were established in villa and high-rise areas to analyze key indicators including chromaticity, turbidity, pH, total hardness, total dissolved solids, chloride, and permanganate index. Results indicated that the drinking water quality generally met the Sanitary Standard for Drinking Water (GB 5749-2022). However, the turbidity at the outlet of the secondary water supply system reached 1.2 NTU, exceeding the standard limit. Further analysis revealed that organic matter content and turbidity within the residential area were significantly higher than at the municipal control point. Total dissolved solids and organic matter levels increased notably in morning samples due to pipeline detention effects. The villa area exhibited greater water quality fluctuations compared to the high-rise area, likely due to its pipe network structure and hydraulic conditions. This study provides a scientific basis and practical recommendations for refined water supply management and water quality risk prevention in similar residential areas.

Keywords: Sub-new residential area, drinking water quality, water quality management.

1. Introduction

The quality of drinking water directly affects public health and social stability. As urbanisation accelerates and people's living standards improve in China, residents' requirements for drinking water quality have evolved from merely safe to healthy. Although finished water from waterworks conforms to the Sanitary Standard for Drinking Water (GB 5749-2022), water quality may decline due to ageing, leakage and secondary pollution in the distribution network and secondary water supply facilities (e.g. pumps, tanks and underground pools) before reaching users' taps [1]. Therefore, monitoring end-users' tap water is the most direct and effective way to assess residents' actual drinking water safety [2].

Sub-new residential districts are generally those built and occupied between 5 and 15 years ago. These areas have not yet entered the overall ageing stage of the old residential area, nor do they have the new equipment of the new residential area. Therefore, their water quality is often easily ignored [3]. Conversely, after several years of continuous operation, practical problems may arise in the secondary water supply system in residential areas, especially in key facilities such as underground pools and roof water tanks. These problems include untimely cleaning and non-standard management measures, which have become potential risk points for water quality safety [4]. Therefore, it is of great practical significance to carry out special water quality research for this "middle age" community to find potential problems in time, warn water quality risks, and guide property service enterprises to carry out targeted maintenance, which can also effectively fill the gaps in the existing research in this field.

Based on the above background, this study selected a typical new residential area in Guangzhou for research, using systematic sampling to test tap water and municipal household tap water under different water supply modes (municipal direct supply and secondary pressurised supply). A number of water quality indicators were compared and analysed according to national standards, and the terminal water quality was assessed comprehensively. The impact of secondary water supply on water quality was explored in depth, providing a theoretical basis and practical guidance for the scientific maintenance and effective management of water supply facilities in residential areas.

2. Material and method

2.1. Overview of the study area

This study focuses on a residential community in Guangzhou City that was built around 10 years ago. The community comprises two areas: a villa area and a high-rise building area. The villa area has three floors above ground and two underground, while the high-rise area comprises an 18-storey residential building. The residential area's water supply system adopts a combined mode of "municipal direct supply and secondary water tank pressurisation": the first to third floors of the villa area are supplied directly by the municipal pipe network, while the fourth floor and above in the high-rise building are pressurised by the underground reservoir and supplied by the roof water tank. To fully reflect the water quality of the different supply modes and building types in the residential area, this study set up five representative sampling points (see Table 1), covering municipal direct supply, secondary pressurised water supply, and different floors of the buildings. This ensures the scientificity of the sampling scheme and the comparability of the data.

Table 1. Description of sampling information points in the study area

Serial number	Sample point information	Explain
1	V1, 1st floor of villa area	Direct water supply of municipal pipeline network in representative community
2	V2, 2nd floor of the villa area	The outlet of the domestic water pump house represents the water quality at the starting point of the secondary water supply system.
3	V3, 3rd floor of the villa area	On the top floor of the municipal direct supply area, the water pressure is low, and it is vulnerable to the reverse pollution of the pipe network.
4	CK, municipal pipe network direct water supply	Municipal direct household users outside the residential area represent the background value of municipal tap water that has not entered the secondary water supply system of the residential area.
5	H, Water in the upper zone	Represent secondary pressurized water supply for high-rise residential building

2.2. Sampling and testing methods

All water samples were collected in strict accordance with the requirements of the Standard Test Method for Drinking Water (GB/T 5750-2023). The multi-parameter portable water quality analyser was used for on-site measurement of pH, chroma, turbidity, conductivity and other physical and chemical parameters to ensure real-time accuracy of the data. Total hardness, total dissolved solids (TDS), chloride and permanganate index were collected and sent to the laboratory for analysis using the national standard method. See Table 2 for specific test items and method standards.

Table 2. Method and standard of each monitoring index

Indicator category	Test items	Methodological standards
Sensory properties	Color, Turbidity, Odor and taste	GB/T 5750.4-2023
Physical and chemical indexes	PH, Total Hardness, TDS, Chloride	GB/T 5750.4-2023 & GB/T 5750.5-2023
Organic pollutants	Permanganate index	GB/T 5750.7-2023 Acidic Potassium Permanganate Titration
Microbial indicators	Total number of colonies/total coliform	GB/T 5750.12-2023

To fully understand the spatial and temporal characteristics of water quality variation, samples were taken in the morning (6:30-7:30, when water consumption starts) and in the evening (19:00-20:00, after the peak of water consumption). Samples were collected from each sampling point for three consecutive days, and the final data were averaged to eliminate accidental errors.

3. Results and Discussion

3.1. Villa Area Test Results

See Table 3 for the detailed results of the water quality tests conducted at each sampling point in the villa area. The chromaticity detection values of all sampling points were lower than 5 degrees, which is far better than the national standard limit of ≤15 degrees. This indicates that the water's sensory properties were good and that there was no abnormal chromaticity problem. In terms of turbidity, the measured value at the control point (CK) was 0.5 NTU, indicating that the municipal tap water is clear. However, after entering the residential area, the turbidity at V1 (on the ground floor) and V3 (on the third floor) rose to 0.8 and 1.1 NTU respectively, while the turbidity at V2 (at the pump house outlet) reached 1.2 NTU, exceeding the national standard limit of ≤1 NTU. This result suggested sediment accumulation or biofilm exfoliation inside the secondary water supply system (e.g. underground reservoirs and water supply pipelines), leading to increased water turbidity and indicating secondary pollution [5, 6].

The total hardness and TDS detection values are far below the national standard limits, belonging to the category of soft water, with good taste and low scaling risk. It should be noted that the TDS values of V3 point and CK control point were slightly higher than those of other points, which may be related to the residence time and micro-dissolution effect of different branch pipelines, but all values were within the safe range. Permanganate index (COD_{Mn}) was used to reflect the total amount of organic matter and oxidizable inorganic matter in the water.The content of CK was the lowest (0. 8 mg/L) at the control point, and increased to varying degrees at all points in the plot, with the highest at V3 point (1. 5 mg/L). This may be related to the dissolution of organic matter (such as biofilm) attached to the inner wall of the pipe network in the community. The longer the water stays in the pipe network, the more such substances may be dissolved [7]. Although all the detected values did not exceed the standard, the rising trend implied that there was a certain risk of organic pollution in the pipeline network.

Compared with the municipal household tap water (CK point), it is found that the water quality in the new residential area has changed significantly after entering the secondary water supply system: (1) turbidity and organic content (represented by COD_{Mn}) generally increase, and the turbidity exceeding the standard at V2 point is the most serious problem in this test; (2) The spatial difference of water quality indicators in the residential area shows that the impact of secondary water supply facilities and each section of the pipe network on water quality can not be ignored.

Table 3. Test Results of Sampling Points in Villa Area

Test items	Reference limit	V1	V2	V3	CK
Chromaticity	≤15	<5	<5	<5	<5
Turbidity (NTU)	≤1	0.8	1.2	1.1	0.5
PH value	6.5-8.5	7.12	7.22	6.86	7.08
Total hardness (mg/L)	≤450	128	136	118	142
Total dissolved solids (mg/L)	≤1000	186	198	245	203
Chloride (mg/L)	≤250	24.3	26.8	19.5	22.7
Permanganate index (mg/L)	≤3	1.2	0.9	1.5	0.8

3.2. Temporal and spatial variation characteristics of water quality

To reveal the dynamic changes in water quality, this study further analyzed the differences in water quality between morning and evening (see Fig. 1). Overall, all indicators met the national standard limits in both periods, but there were some differences between different sampling points and indicators. Regarding the pH value, each sampling point had a higher pH value in the morning than in the evening, particularly at point V3 (7.31 vs 6.86), indicating that the water samples were slightly alkaline in the morning. The difference in total hardness between the morning and evening was small, ranging from 2 mg/L to 15 mg/L, with no consistent pattern of high or low hardness observed between the two time periods.

The results of the total dissolved solids (TDS) test showed that TDS values were higher in the morning than in the evening, particularly on the ground floor (V1: 248 mg/L in the morning vs. 186 mg/L in the evening) and the basement (V2: 242 mg/L in the morning vs. 198 mg/L in the evening). The chloride concentration was lower in the morning than in the evening at all sampling sites. The chloride concentration was significantly higher in the evening (26.8 mg/L) than in the morning (19.8 mg/L) at the V2 site.

These differences are closely related to water usage patterns, pipe network water retention times and secondary water supply system operation modes. The sample collected in the morning was the first water used, having experienced static retention in the water pipe for several hours. This prolonged contact with the inner wall materials of the pipeline may lead to the dissolution of more inorganic salts (such as calcium and magnesium ions), which could explain the generally high TDS levels observed in the morning [8]. At the same time, the relatively static body of water may also promote the dissolution of small amounts of residual organic matter in the pipe network or the shedding of biofilms, resulting in a slightly higher permanganate index in the morning than in the evening at V1 and V2.

The samples collected in the evening were after the peak period of water consumption, and the water in the pipe network experienced better circulation and renewal, and the retention time was shorter. Therefore, the water samples in the evening are more representative of the water quality in the flowing state, and are relatively less affected by the inner wall of the pipeline, and their TDS is generally lower than that in the morning. The high concentration of chloride at night may be related to the large water consumption and fast water flow at night, which enhances the scouring effect on the sediments at the bottom of the pipeline, especially at the outlet of the pump house at V2 point, where the disturbance of the water flow may bring up some sediments.

The pH value of V3 point has the largest difference in the morning and evening (the difference between morning and evening is 0.45), and the value of evening is close to the lower limit. This point is located on the top floor of the municipal direct supply area, with low water pressure. A slight negative pressure may be formed in the pipeline after the peak period of water consumption at night. There is a risk of inhaling trace air or reverse pollution. The dissolution of carbon dioxide may lead to a slight decrease in pH value [9].

To sum up, the water quality in the new residential area has obvious fluctuations in time, which is closely related to the law of water use and the detention effect of the pipe network. The quality of water used for the first time in the morning may be more vulnerable to the internal conditions of the pipeline, so residents are advised to release water for a short time before use to remove the retained water and ensure the safety of water use.

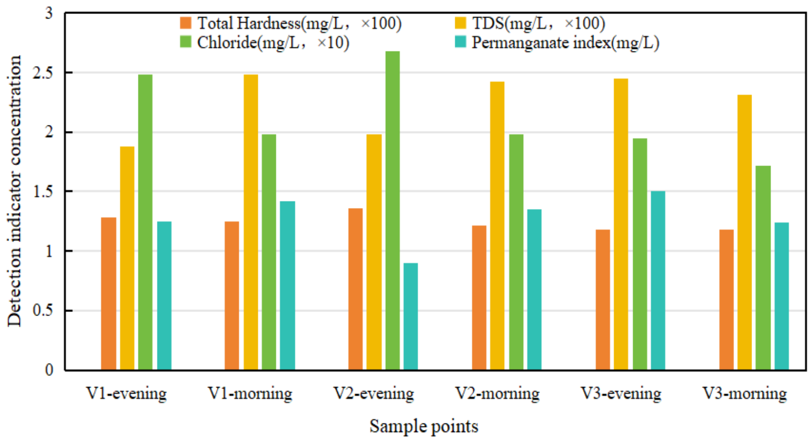

Fig. 1 Water quality sampling values at different sampling points in the morning and evening

3.3. Comparison of Water Quality Between Villas and High-Rise Buildings

To explore the impact of building type and water supply mode on terminal water quality, this study compared the water quality in villas and high-rise buildings in the morning (see Fig. 2). The comparative data show that the morning water samples from both types of building are within the national standard limits and the values are relatively close, indicating good overall water quality. However, careful comparison reveals some statistically significant differences.

In terms of total hardness, the total hardness of water samples from high-rise buildings is slightly lower than that of villas (117 mg/L for high-rise buildings vs 118-125 mg/L for villas), but they all belong to the category of soft water. The results of total dissolved solids (TDS) determination showed that the TDS values (248 mg/L, 242 mg/L) at V1 and V2 points in the villa area were slightly higher than those in the high-rise buildings (239 mg/L), while the TDS values (231 mg/L) at V3 point in the villa area were the closest to those in the high-rise buildings. In terms of chloride concentration, the lowest value was 17. 2 mg/L at V3 point in the villa area, 18. 5 mg/L at high-rise buildings, and 19. 8 mg/L at V1 and V2 points in the villa area. The permanganate index also showed a similar trend, and the villa area was generally slightly higher than high-rise buildings.

These differences may be closely related to the characteristics of the pipe network, the scale of water use, the water supply mode and the material of the pipes in the two types of building. Villas typically have an independent low-pressure branch pipe network for water supply. Although the total length of the pipe network is long, the scale of water consumption is small and the flow rate is relatively low. This is especially the case when water is used for the first time in the morning, as the retention time of water in the pipeline is longer. This allows more time for contact between the water and the materials of the pipe walls, which may lead to the dissolution of more inorganic ions. This could explain why the TDS values at points V1 and V2 in villas are slightly higher than in high-rise buildings. At the same time, the longer retention time may also promote the dissolution of trace organic matter in the pipe network. This results in the permanganate index at each villa point being generally slightly higher than at high-rise buildings [10].

High-rise buildings typically use a secondary pressurised water supply system that pumps water from an underground reservoir to a rooftop tank before supplying it downward. The internal water flow speed of the system is fast and the overall retention time of water in the pipeline is relatively short. Additionally, high-rise buildings have a large number of water users and high water consumption, with a peak in consumption occurring earlier and more abruptly in the morning. The water supply network is also updated more quickly, which may result in slightly lower TDS and organic matter content (as measured by the permanganate index) in water samples from high-rise buildings compared to villas. This finding is consistent with the results reported by Li et al. regarding changes in the microbiome of tap water in secondary water supply systems in high-rise buildings [11]. This indicates that the type of building and the mode of water supply can have a subtle yet significant impact on terminal water quality.

Therefore, although the difference in water quality between villas and high-rise buildings is small and meets national standards, these subtle differences clearly demonstrate the impact of building type, water supply mode, and pipe network characteristics on terminal water quality. Due to the characteristics of the pipe network, villas may be more vulnerable to the retention effect, resulting in slightly higher TDS and organic indicators than high-rise buildings. It is therefore recommended that the water supply network in villas or similar low-pressure branch systems is regularly flushed and maintained to reduce the risk of water quality deterioration at the end of the network.

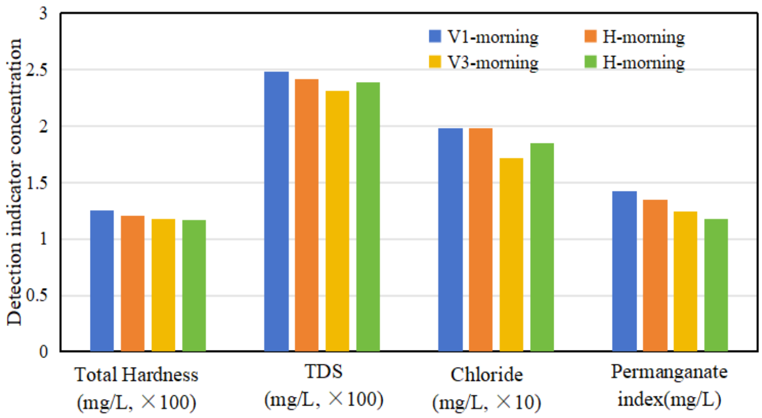

Fig. 2 Comparison of morning detection concentrations at different sampling points

3.4. Management and maintenance suggestions

Based on the investigation results of the water quality of a typical sub-new residential area in Guangzhou, especially the turbidity at the outlet of the secondary water supply system (negative second floor) exceeds the national standard limit, and the water quality indicators of different building types and different time periods fluctuate differently, it shows that there are risks of sediment accumulation, biofilm breeding and pipe network detention pollution in the water supply system of the residential area. In order to ensure the safety of residential terminal water use and prolong the service life of water supply facilities, the following systematic management and maintenance suggestions are put forward:

(1) Strengthen the standardized cleaning and disinfection management of secondary water supply facilities

The test results show that the secondary water supply link is the weak point of water quality safety risk, and the turbidity (1. 2 NTU) at the outlet of the negative second floor pump house even exceeds the national standard limit (≤1 NTU). It is suggested that property management units should strictly implement the Sanitary Code for Secondary Water Supply Facilities (GB 17051-1997), carry out comprehensive cleaning and disinfection of underground reservoirs, roof water tanks and other facilities at least once every six months, and update the cleaning records in time. After cleaning, water quality self-inspection should be carried out, focusing on monitoring turbidity, total number of colonies and other indicators to ensure the cleaning effect, and timely publicity of the results to the owners, subject to public supervision.

(2) Establish the flushing system of water supply pipe network in different zones and time periods

Water quality data show that the TDS and permanganate index of the end areas of the pipeline network, such as villas and the third floor, are on the high side when water is used in the morning, indicating that the pipeline retention effect is significant. It is suggested that the property should regularly wash the pipe network in the residential area in different areas, especially strengthen the washing frequency of long-term low flow rate or the end area of the pipe network, such as once a quarter, to reduce the accumulation of sediment and biofilm. Flushing should be carried out in the low peak period of water consumption, and the user should be notified to discharge water properly before use, so as to eliminate the first section of water that may contain residual pollutants.

(3) Promote the systematic renewal and transformation of water supply network in residential areas.

The district has been in operation for about ten years, and some of the water pipelines may have entered the early stage of aging. For pipe sections made of corrosive materials such as galvanized steel pipes, it is recommended to gradually replace them with corrosion-resistant pipes with smooth inner walls such as food-grade stainless steel and PP-R, so as to fundamentally reduce the risk of scaling and biofilm attachment [12]. The renewal work can be carried out in stages in combination with the renovation project of old residential areas, giving priority to the replacement of pipelines in areas where abnormal water quality or complaints have occurred.

4. Conclusion

This study systematically sampled and analyzed the water quality in a new residential area in Guangzhou using multiple indicators. The results showed that the residential area's drinking water met national sanitary standards, but turbidity at the secondary water supply system outlet exceeded the standard. This suggests a risk of sediment accumulation or biofilm pollution in the system. Water quality differs between the morning and evening, and between different building types. In the morning, the TDS and organic matter content increases due to the long detention time in the pipelines. Water quality in villas is more likely to fluctuate due to the influence of the pipeline network structure and water flow conditions. Cleaning and maintaining secondary water supply facilities has a significant impact on terminal water quality; cleaning and managing underground pools and roof water tanks urgently needs to be strengthened. To ensure drinking water safety for residents, the property should strictly implement cleaning and disinfection standards for secondary water supply facilities, establish a regular pipe network flushing mechanism and gradually renovate corrosion-prone pipelines. This study provides a scientific basis and practical reference for water quality management and risk prevention and control in the sub-new residential area.

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