**Status of water quality and some related factors at connected water supply stations in Cai Lay District, Tien Giang Province**

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**ABSTRACT**

**Objectives:** To determine the percentage of water samples taken from connected water supply stations in Cai Lay District, Tien Giang Province that met the Vietnamese Standards (QCVN 02:2009/BYT) and to determine the factors related to the water quality.

**Methods:** The study used test results of 81 water supply stations collected from the Tien Giang Center for Disease Control in 2020 and compared these with the QCVN 02:2009/BYT.

**Results:** 86.4% of stations had water quality that met QCVN 02:2009/BYT, 90.1% and 96.3% of samples met physicochemical and microbiological criteria. State-owned enterprises had the highest sample rate (100%), followed by the cooperative model (92.3%), the private enterprise model (88.2%), and the cooperative group model (81.0%). Water supply stations with self-inspection of water quality, with correct collection of prescribed prices, with operating models of settling and filtering systems, had better water quality.

**Conclusions**: Water supply facilities should perform self-inspection of water quality and need to have an annual plan for renovation and upgrading of the system, including the installation of settling and filtering systems. The water fee should be raised according to regulations to have reserve funds for investment in construction and repair of water supply systems when they are degraded. Authorities need to take measures to provide technical support, convert inappropriate models, and need to take strict measures against water suppliers that do not comply with regulations.

***Keywords:*** *Water quality, connected water supply stations, Cai Lay District, Tien Giang*

**INTRODUCTION**

Water supply and water use are crucial in people's daily life, but this varies across areas. According to the World Health Organization, only 74% of the global population used a safely managed drinking-water service, that is, one located on-premises, available when needed, and free from contamination. At least 2 billion people still use a drinking water source contaminated with faeces, which poses the greatest risk to drinking-water safety (1). In Vietnam, the management and testing of water quality have been paid great attention by the Provincial People's Committee. Besides the achievements, the Mekong Delta is facing many challenges, which greatly affect the rural water supply. The risk of saltwater intrusion is deepening as countries in the upper Mekong River adopt many policies to increase water use in this river basin, such as building many hydroelectric dams and transferring water to other river basins (2). In particular, the most obvious damage is the situation of drought and saltwater intrusion in the Mekong Delta in recent times (2). Cai Lay is 70 km from the sea estuary, but saline intrusion in 2020 at the peak time reached 8.6 g/liter, which had negative impacts on the groundwater, and the situation is predicted to continue in the following years (3,4).

Challenges related to the quality of rural domestic water supply do not meet regulatory standards, especially arsenic, iron and microorganisms have been reported in different areas worldwide and in Vietnam, including Cai Lay District (1, 5-8). The results of various studies in different regions in Vietnam showed the presence of microbial, physical and chemical hazards in rural domestic water supplied sources at elevated levels compared to the current allowable limits (5-8). According to a report by the Cai Lay District Health Center, through the water quality tests from 2016 to 2019, the situation of arsenic contamination still occurred. Each year there are from 5 to 9 centralized water supply stations with arsenic test results exceeding QCVN 02:2009/BYT and some drilled wells had to find alternative water sources (4), which was a high-risk factor affecting people's health.

Another challenge facing many provinces in the Mekong Delta including Cai Lay District is the current inefficient exploitation and supply of rural water. The mechanism of management and exploitation of concentrated water supply works in many places was not effective and unsustainable. The basic operation method was still service-oriented, the management model in many places was not suitable, and the capacity of officials and workers to manage and operate was still weak... (9). These have been affecting the quality of water supply, and if this situation is prolonged, it will significantly affect the health of people, especially increasing the risk of waterborne diseases.

Therefore, the issue of water quality has been of great concern to the people and local authorities of the Cai Lay District. Demand for water supply through pipes for domestic use is very high because surface water is increasingly polluted and inappropriate for daily consumption. Therefore, concentrated water supply stations in Cai Lay District have developed very quickly. Currently, the district has 81 centralized water supply stations and supplies 50,580 households, accounting for up to 98.06% of the district's population (10). Recent assessments showed that the percentage of water supply stations with testing criteria that meet QCVN 02:2009/BYT standard was still low, most of the tested water samples did not meet the criteria of Arsenic, hardness, salinity, *Coliforms*, *E.coli*, and salinity. Specifically, in 2018, 231 water samples in Cai Lay District were tested with 13 criteria of groups A and B, with 16 out of 231 samples not meeting standards, leading to 11 out of 77 water supply stations not meeting water quality standards. In 2019, 14 out of 78 water supply stations did not meet water quality standards (4). In addition, many stations have not strictly implemented the quarterly internal inspection according to Circular No. 50/2015/TT-BYT (11) and Circular 41/2018/TT-BYT (12) while the protection of the raw water source area was inadequate. This paper describes the results of the assessment of domestic water quality according to QCVN: 02/2009-BYT (13) and some related factors at rural water supply stations in the Cai Lay district, Tien Giang province in 2020.

**METHODS**

**Research subjects**

The subject of this research included all 81 rural water supply stations and finished water product samples in Cai Lay district, Tien Giang province to describe the quality of water supply facilities. Selection criteria: Rural water supply stations that were still in operation in Cai Lay district, Tien Giang province, and voluntarily agreed to participate in the study. The exclusion criterion was the water supply station having no test results in 2020.

**Study design, time, and place**

This was a cross-sectional study, being implemented from December 2020 to July 2021 at all 81 centralized water supply stations, using 243 water quality test results in the Cai Lay district that was collected and analysed in 2020.

**Sample size and sampling method**

The sample size included all 81 rural water supply stations operating in the Cai Lay district in 2020, which included 243 water test samples (3 samples from each station) and interviewing representatives of 81 water supply stations to describe the general information of water supply facilities. If at least 1 criterion in 3 water samples of 1 water supply station failed, the test results of that station were not satisfactory.

**Data collection tool and method**

Collected test results of 81 water supply stations from Tien Giang CDC according to a data collection form, from which to summarize on excel software. To collect general information about the water supply facilities: interview one owner according to a pre-designed set of questions based on external audits on sanitation and water quality. To assess water quality: Using test results from the Tien Giang CDC in 2020, with each water supply station taking 3 samples, including 1 water sample at the water supply station, 1 sample in the middle, and 1 sample at the end of the distribution pipeline. This water sample was taken to the ISO/IEC 17025 standard laboratory of the Tien Giang CDC to conduct testing for 13 indicators of levels A and B. Because Tien Giang province has not yet issued local technical regulations on clean water, the test results were compared with QCVN 02:2009/BYT to assess the quality of rural domestic water (13). The physical and chemical parameters included: colour, taste, turbidity, pH, total iron content, permanganate index, hardness, chloride content, arsenic, ammonium, and fluoride content. Microbiological parameters included total *Coliform, E.coli* or heat-resistant coliform.

**Research variables**

General information about water supply stations: Management model, total population supplied with water. Variables on the implementation of state management regulations on water supply included: construction, water treatment process, chemicals used in water treatment, implementation of internal inspection regime of water supply facilities. Variables to assess water quality included 13 indicators at levels A and B according to QCVN 02:2009/BYT (13). The physical and chemical parameters included: color, taste, turbidity, pH, total iron content, permanganate index, hardness, chloride content, arsenic, ammonium, fluoride content. Microbiological parameters included total *Coliform, E.coli* or heat-resistant coliform. The test results included 13/14 indicators according to QCVN 02:2009/BYT (13) were provided by the Center for Disease Control (CDC) of Tien Giang province in 2020 (missing 01 criteria for residual chlorine, because 72/81 water supply stations did not disinfect water with chlorine).

**Data processing and analysis**

Data were entered using Epidata 3.1 software and processed on SPSS 19.0 software. Analytical statistics: using χ2 test, odds ratio (OR) to compare the proportions with the threshold of significance p<0.05. Assessment of water quality: If the water sample was assessed to meet the standards, all testing criteria must meet QCVN 02:2009/BYT; A qualified water supply station was a station where all water samples must be tested according to regulations (13).

**Ethics in research**

The study was carried out after the Ethics Committee of the University of Public Health granted approval under decision No. 41/2021/YTCC-HD3, dated February 8, 2021. There was voluntary consent from the subjects participating in the study. Research results were communicated to stakeholders to take measures to overcome existing problems. When taking samples to test water quality at a station with poor quality, immediate feedback was given to the water supply station and people, giving recommendations for people to temporarily use other water sources; at the same time, report to local authorities and water supply station owners to coordinate in taking effective remedial measures and taking samples for re-testing as soon as possible.

**RESULTS**

**Table 1. Percentage of indicators of 243 samples at 81 water supply stations that met QCVN 02:2009/BYT\***

| **Indicators** | **Frequency of water supply stations meeting**  **QCVN 02:2009/BYT (11)** | **Percentage (%)** |
| --- | --- | --- |
|
|  |
| Taste | 81 | 100 |
| Colour | 81 | 100 |
| Turbidity | 80 | 98.8 |
| pH | 81 | 100 |
| Iron content | 80 | 98.8 |
| Permanganate index | 81 | 100 |
| Hardness | 81 | 100 |
| Chloride concentration | 80 | 98.8 |
| Arsenic concentration | 76 | 93.8 |
| Ammonium concentration | 81 | 100 |
| Fluoride concentration | 81 | 100 |
| *Coliform* | 79 | 97.5 |
| *Escherichia coli* | 80 | 98.8 |
| The sample met 11 physicochemical criteria | **73** | **90.1** |
| Samples met microbiological criteria | **78** | **96.3** |
| Samples met both physicochemical and microbiological criteria | **70** | **76.5** |

### \*= If at least 1 criterion in 3 water samples of 1 water supply station failed, the test results of that station were not satisfactory

### Table 1 shows the physicochemical parameters including 11 indicators, 93.8%, 98.8% and 98.8% of 243 water samples taken at 81 water supply stations with Arsenic content, turbidity and chloride concentration below the standard, respectively. The rate of physicochemical indicators that met the standard ranged from 93.8% to 100%, of which 7 criteria met the standard 100%, and the arsenic indicator had the lowest rate (93.8%). 97.5% and 98.8% of samples with *Coliform* and *Escherichia coli* criteria met the standard. 90.1% and 96.3% of samples met physicochemical and microbiological criteria. 86.4% of samples met the water quality standard according to QCVN 02:2009/BYT.

**Table 2. The proportion of 243 samples of 81 water supply stations that met QCVN 02:2009/BYT**

| **Types** | **Number of water supply stations** | **Frequency met**  **QCVN 02:2009/BYT** | **Percentage (%)** |
| --- | --- | --- | --- |
| Cooperation groups | 42 | 34 | 81.0 |
| Private enterprises | 17 | 15 | 88.2 |
| State enterprises | 9 | 9 | 100 |
| Cooperative enterprises | 13 | 12 | 92.3 |
|  | χ2 = 10.1; p = 0.018 | | |

## Through the research results, in four water supply management models; The model of state enterprises had the highest percentage of passing samples (100%), followed by the form of cooperative enterprises (92.3%), private enterprises (88.2%), and the sample with the lowest percentage was the cooperative groups model (81%). The difference between the types was statistically significant (p = 0.018).

**Table 3. Factors related to water quality at the water supply stations**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Factors** | | **Frequency met QCVN 02:2009/BYT** | | | **OR** | **χ2** | **P** |
| **Met** | **Did not meet** | **Total** |
| Qualification | Trained from elementary level up | 60 | 2 | 62 | 17.5 | 12.5 | 0.006 |
| Not trained yet\* | 12 | 7 | 19 |
| Periodic water quality control | Yes | 48 | 4 | 52 | 3.8 | 8.1 | 0.004 |
| No\* | 22 | 7 | 29 |
| Water price | Correct price | 29 | 2 | 31 | 2.8 | 12.8 | 0.000 |
| Low price\* | 42 | 8 | 50 |
| Sedimentation and filtration systems are being installed | Yes | 11 | 0 | 11 | 2.1 | 6.4 | 0.01 |
| No\* | 59 | 11 | 70 |
| Water pollution at sources | There is no risk of water pollution | 45 | 3 | 48 | 4.8 | 3.4 | 0.053 |
| There is a risk of water pollution\* | 25 | 8 | 33 |

\* = reference group

There was a statistically significant relationship between the level of expertise in water supply, stations conducting periodic water quality checks, applying water prices following regulations of the Provincial People's Committee and the water treatment system in the stations with water quality (p<0.05). The water supply stations with trained staff were 17.5 times more likely to have water quality that met the standard than the stations with untrained staff (OR=17.5, p = 0.006). Periodic water testing stations had a 3.8 times higher chance of the water quality meeting standard than stations that did not periodically test the water (OR= 3.8, p = 0.004). The water stations applying appropriate prices for water had water quality that was 2.8 times more likely to meet standard than the ones that applied prices that were lower than the regulated price (OR = 2.8, p < 0.001). The water quality of the water supply stations with the treatment system was 2.1 times more likely than the stations without the treatment system to have water quality that met the standard (OR=2.1, p = 0.01). There was no statistically significant relationship between risk factors for water pollution and water quality (p>0.05).

**DISCUSSION**

Water supply stations were being developed widely throughout the Cai Lay district, thereby improving essential living conditions and ensuring the quality of water for domestic use in rural areas. However, there were still some stations whose water quality did not meet QCVN 02:2009/BYT (11/81 stations) and there was a potential risk that will affect the health of users. 76.5% of water supply stations met the water quality standard, showing that the water quality in the Cai Lay district had a higher sample rate than in the eastern districts with a rate of only 55.2% (7). There were seven test indicators with 100% met the standard, which included colour, taste, pH, permanganate index, ammonium content, hardness, and fluoride content. 98.8% of the samples met the standard for turbidity, so for the water supply stations whose samples have not reached the turbidity standard, it was necessary to have technical measures to improve and apply the treatment. For iron content, 98.8% of samples met the standard, with concentrations ranging from 0 mg/l to 0.75 mg/l, because up to 86.42% of stations did not apply the settlement and filtration treatment. Thus the domestic water samples in the Cai Lay district had low iron content compared to other districts in Tien Giang province (7). The 98.8% of samples met the standard for chloride with values ​​ranging from 6.74 mg/l to 346 mg/l, much lower than other districts in Tien Giang province (7). Saline intrusion also significantly affected the quality of the water supply. The water quality in the eastern district was better than that of the western district (Cai Lay district) (7). High chloride content leads to changes in electrical conductivity, increased flocculation and precipitation in water, thereby increasing turbidity. The arsenic indicator had the lowest rate of meeting the standard (93.8%) and the percentage of samples that did not meet the standard was much lower than in other districts in Tien Giang province (7).

100% of samples met the standard for the taste criterion. This showed that the analyzed samples had no strange taste, showing that organic decomposition products and domestic and industrial waste were not detected. Clean water is usually odourless, and tasteless due to the presence of dissolved substances in small amounts (14). 100% of samples also met the colour, turbidity, and pH indicators. The colour of the water is caused by impurities in the water, which greatly affects the aesthetics when using water (14). When turbidity in the water increases, the treatment efficiency will be poor, affecting the colour of the water after treatment. In the Cai Lay district, the majority of rural water supply stations have been funded by the UNICEF Water Program since the 2000s (4). Most of them did not have a sedimentation system, the well water was pumped to the pressurization station and supplied to the distribution system to the households. On the other hand, the water supply stations in the Cai Lay district mainly use exploited well water for domestic use, so the colour, turbidity, and pH indicators were also relatively unstable. The greater the turbidity, the higher the degree of contamination of the water, and thus treatment measures must be taken (14). Using chemical coagulants has a great effect on the water treatment process, especially water with high turbidity (15). This result was similar to the study of Nguyen Tien Dung (2015) with all 100% samples meeting the pH indicator (7).

The percentage of stations that met the standard for the total *Coliform* criterion was 97.5%, higher than the 2015 study in Tien Giang (92.8%) (7). Water contaminated with *Coliform* has the risk of causing gastrointestinal diseases. Due to the improper treatment of domestic water and animal manure, water sources are susceptible to *Coliform* contamination. In recent years, the situation of livestock and poultry raising in the Cai Lay district has developed strongly, especially pig raising. Pig raising households discharging untreated waste into the environment still existed, thereby affecting the domestic water sources. According to regulations in the supply of water, the presence of *E.coli* bacteria is not allowed (13). There were 98.8% of water supply stations met the target of no *E.coli* contamination, higher than the result in the study by Nguyen Tien Dung (95.6%) (7).

Research results showed that the professional qualifications of untrained stations accounted for a high rate of 23.46%. Of the four operating models, the cooperative group model was the most popular (80.95%). The cooperative group model was service-oriented, there were no specific plans, regulations, and ineffective modes of operation; Therefore, there was a need for a solution to convert this model into a more efficient way of operating. Not performing periodic testing according to regulations, maybe the main reason why the cooperative group model had a lower rate of water quality than other models (p<0.05). Safe and continuous supply of clean water, ensuring water supply meets prescribed standards can help to reduce the large burden of waterborne diseases (16).

The model that applied the correct price according to regulations accounts for the highest percentage (100%) was the State enterprises model and 94.1% in the private enterprise model. The survey results also showed that the cooperative group model had 100% of water supply stations that did not collect at the prescribed price. Thus, it is necessary to take measures to raise the water price to have better water quality to serve the people. The cooperative model was formed by several sponsor organizations or individuals who cooperated and invested themselves, so the application of water prices lower than the regulations was still relatively high. 100% of water supply stations under the model of state enterprises, private enterprises and cooperatives that did not propose to convert, which showed that these models were still relevant at present in the Cai Lay district. The cooperative group model was a model managed by the local community, so it was difficult to increase the price of water. The price increase must be through a meeting of the people and must be calculated at a minimum price. All 100% stations of this model applied prices lower than the specified price and did not depreciate assets, and had no repair costs when degraded.

Due to time and resource limitations, the study only analyzed some factors related to water quality, which were the implementation of water quality management by water supply facilities and the inspection and monitoring of water quality. Research has not gone into depth analysis of technical and environmental factors that affect water quality. Future studies on water quality may consider these factors.

**CONCLUSIONS**

Out of the total of 81 surveyed stations, 86.4% of the stations met the water quality standard. The percentage of samples that met physicochemical criteria was 90.1%, and microbiological was 96.3%. Regarding microbiology, 97.5% of samples met *Coliform* criteria and 98.8% met *Escherichia coli* criteria. For physicochemical criteria, 100% of samples met colour, taste, pH, ammonium content, permanganate index, hardness, and fluoride content, while only 93.8% of samples met arsenic concentration criteria. The model of state-owned enterprises had the highest sample rate meeting the standard, followed by the model of cooperative enterprises and private enterprises. The model of cooperative groups had the lowest rate of sample meeting the water quality standard.

Research results showed that there was a statistically significant correlation between periodic testing, water price, operation model, water supply station with sedimentation and filtration system, and water quality. Water supply stations with self-inspection of water quality, applying appropriate prices, operating model of state-owned enterprises, and those with sedimentation and filtration systems had higher water quality standards.

It is shown that water supply facilities belonging to water supply stations of cooperative groups and cooperative enterprises need to have an annual plan for system renovation and upgrade, a plan to invest more funds and strengthen socialization to repair and upgrade degraded systems or build new treatment systems and boreholes to improve the water quality. Owners of water supply facilities must comply with regulations on periodical testing of water quality to take timely measures to remedy unsatisfactory norms, collect water at the appropriate prices prescribed by the Provincial People's Committee to have funds reserved for investment in the construction and repair of water supply systems when they are degraded. Advise the local government to raise the water fee according to regulations, to have better funding for re-operation. The authorities need to organize specialized technical training on safe water supply for facility owners/operators. In addition, there should be sanctions and strict handling measures for water supply facilities that violate regulations on management, periodic water quality testing, etc., to show deterrence in management. The authorities need to take supportive measures to transform inappropriate and weak models. It is necessary to carry out a large-scale study to understand all the factors that can affect the water quality in addition to the current management and monitoring of water quality at rural domestic water supply stations.

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