**ORIGINAL ARTICLES**

# Drinking water quality and associated factors at water supply stations in Quang Ngai Province in 2022

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## ABSTRACT

**Objectives:** This paper aims to describe drinking water quality at water supply stations in Quang Ngai province according to Vietnam Standards (QCVN 01-1:2018/BYT) and to identify some associated factors affecting water quality.

**Methods:** The study used test results of 41 centralized water supply stations collected from Quang Ngai Center for Disease Control in December 2022 and compared them with QCVN 01-1:2018/BYT.

**Results:** 58.5% of stations had water quality that met QCVN 01-1:2018/BYT; 65.9% and 80.5% of stations with physicochemical and microbiological parameters met the standards. The parameters not meeting the standards were mainly nitrate content, hardness, chloride, taste, residual chlorine, *Coliform* and *E. coli*. In particular, 34.1% of stations did not meet the standard for the nitrate parameter. Private enterprises had the highest rate of meeting the standard (85.7%), followed by state enterprises (79.0%), private stations (25.0%) and cooperatives (14.3%). The Chi-square test showed that water supply stations had water quality checked, applied the right prices, trained operators in water supply, had a system of settling, filtering, disinfecting, and cleaning facilities and stations with operating time within five years had better water quality.

**Conclusions:** Water supply facilities, especially private stations and cooperatives need to improve their management, comply with regulations on internal inspection and pay attention to treating nitrate contamination. There should be a plan to send operators to specialized training in water supply. It is necessary to invest in the construction of a treatment and disinfection system, to replace the degraded, leaking distribution pipeline and to make an annual plan for the maintenance and cleaning of water supply facilities. The authorities need to provide specialized training on water supply and guide the management regulations for facility owners and operators. At the same time, there should be sanctions and strict handling measures for domestic water supply stations that violate regulations.

***Keywords:*** *Drinking water quality, associated factors, water supply stations, Quang Ngai Province.*

## INTRODUCTION

Clean water is one of the core elements of human resource development to drive Vietnam's current and future productivity and growth. Lack of safe drinking water remains a major challenge affecting children in rural areas of Vietnam, increasing the incidence of diarrhea, pneumonia and parasitic infections (1). Around the world, people's access to clean water has increased, but according to WHO in 2020, 2 billion people still lack safe drinking water (2). Another study found that about 1.8 billion people globally use contaminated water with 1.1 billion people using water with at least > 10 *E. coli* per 100

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ml of water (3). The rate of water pollution in rural areas is higher than in urban areas and is most common in Africa and Southeast Asia (3). According to a study by Nguyen Van Loi (2021), the percentage of water samples meeting the standard QCVN 02:2009/BYT was 86.4%, of which the rate met the microbiological standard of 96.3%, and the physicochemical standard of 90.1%. Water supply stations with settling, filtering, internal control systems and applying the correct prices had a higher standard of water quality (4). The issue of unsatisfactory water quality used in daily life is still a matter of public health concern in many countries, including Vietnam.

In Vietnam, the National Strategy on Rural Water Supply and Sanitation to 2020 was approved by the Government on August 25, 2000, with the target that 100% of people living in rural areas will use clean water of high quality according to national standards QCVN. However, according to aggregated reports of localities, by 2019, the proportion of rural people using hygienic water was only 88.5%; of which about 51% could use clean water that met QCVN 02:2009/BYT (5). This data has shown that the quality of the water supply for domestic use was still one of the remaining challenges in Vietnam.

Quang Ngai province, after implementing the National Strategy on Rural water supply and Sanitation for the period 2016-2020, the percentage of households provided with hygienic water in 2021 was 95.5% and the rate of households using clean water meeting the QCVN 01-1:2018/BYT standard accounted for 59.3% (6). Currently, Quang Ngai province has 41 centralized water supply stations to provide clean water for people's daily domestic use, applying QCVN 01-1:2018/BYT (7). Although the supply of clean water for domestic use in Quang Ngai province is always paid attention by the authorities at all levels. However, according to the report of the Provincial Center for Disease Control over the years, the quality of domestic water of centralized water supply stations met the standards of QCVN 01:2009/BYT and QCVN 02:2009/BYT was still low (90% in 2020, 90.7% in 2021) and the main unsatisfactory criteria were chloride content, iron content, turbidity, hardness, *Coliform* and *E. coli* (8).

Other challenges included environmental sanitation conditions, inappropriate management models at some stations, operators being weak, disinfection and treatment system was not available... Besides, the inspection and monitoring of the quality of domestic water in the province was carried out only once a year due to limited local funding. Therefore, the effectiveness of the inspection and monitoring of the results of this work was not high, and there were certain limitations. In addition, Quang Ngai is a province affected by climate change, particularly saltwater intrusion and drought, leading to a lack of water for use. Therefore, it is still a challenge to provide clean water for people to use in the dry season to meet quality standards. The issue of water quality is of great concern to the people and the provincial government. Demand for water from centralized water supply stations for domestic use is very high due to increasingly polluted water sources, unsuitable for daily life. Many stations have not strictly implemented internal inspection following Circular 41/2018/TT-BYT (9), the sanitation of the area and the water supply system have not been ensured, so it seriously affects the quality of the finished water. This paper described the results of the assessment of the domestic water quality of the concentrated domestic water supply stations in Quang Ngai province in 2022 according to QCVN 01-1:2018/BYT and some associated factors.

## METHODS

**Study design:** A cross-sectional study.

**Study subjects:** Research subjects included all 41 domestic water supply stations in Quang Ngai province to describe the current state of sanitation at water supply facilities based on observations and interviews with facility owners and operators. Selection criteria: The centralized domestic water supply stations operating in Quang Ngai province voluntarily agreed to participate in the study. Test results of 15 parameters for stations without sterilization (or 16 parameters for stations with sterilization) according to QCVN 01-1:2018/BYT (7). The exclusion criterion was water supply stations without test results in December 2022.

**Study site and time:** The study was carried out from August 2022 to July 2023 with 41 concentrated water supply stations in Quang Ngai province.

**Sample size and sampling:** The sample size included all 123 finished water quality test results of 41 centralized water supply stations operating in Quang Ngai province in December 2022 and observed 41 water supply stations to describe the sanitary status. Assessment of the current state of environmental sanitation of water supply stations: Selection of interviewees who were establishment owners and operators to interview according to a set of pre-designed questionnaires for an external assessment of sanitation environment and water quality.

Water quality assessment: Using test results of CDC Quang Ngai in 2022, each water supply station took three samples including one water sample at the water supply station (at the storage tanks after treatment), one sample in the middle (before the water meter at households) and one sample at the end of the distribution pipeline (after the water meter, at water tap at households). These water samples were taken to the ISO/IEC 17025 standard laboratory of Quang Ngai CDC to test 15 or 16 parameters according to QCVN 01-1:2018/BYT (7). Since Quang Ngai province has not yet issued local technical regulations on clean water, the test results were compared with QCVN 01-1:2018/BYT to assess the quality of domestic water (7). The physicochemical and microbiological parameters included colour, taste, turbidity, pH, permanganate index, nitrate, nitrite, iron, manganese, chloride, arsenic, residual chlorine, hardness, sulphate, *Coliform,* and *Escherichia coli.*

**Data collection:** Summarize test results of 41 water supply stations of Quang Ngai CDC according to the data collection form, from which to summarize on the Excel software. Direct observation of 41 water supply stations based on external inspection of hygiene and water quality according to Circular 41/2018/TT-BYT of the Ministry of Health (9).

**Study variables:** Water quality assessment variables include 15 (or 16) parameters according to QCVN 01-1:2018/BYT (7). Variables on management factors included implementation of regulations on water quality control, number of working years and professional qualifications of operators, inspection and supervision, management form of water facilities, water price, and input water quality. Technical and operational factors: disinfection system, treatment, distribution, station capacity, periodic maintenance, construction and operation time, improvement of facilities; Environmental variables: geographical area, exploitation source, sanitary conditions of water supply facilities.

**Data analysis:** Data entry using Epidata 3.1 software and processing on SPSS 20.0 software. Chi-square ($\chi 2$) tests were used to

determine the differences among proportions as well as the relationship between the two variables. The dependent variable was water quality according to QCVN 01-1:2018/BYT and the independent variables were factors associated with water quality. A p-value ≤ 0.05 was set as statistical significance.

Evaluation criteria: According to Circular No. 41/2018/TT-BYT of the Ministry of Health (9) and QCVN 01-1:2018/BYT on the National Technical Regulation on domestic water quality to develop evaluation criteria in the study (7). Assessment of sanitary conditions of water supply facilities using the scoring method is considered satisfactory if achieved 100% of the score on the checklist. Assessment of water quality: For standard water samples, the test parameters must meet QCVN 01-1:2018/BYT; A qualified water supply station was the one with the results of three samples meeting the water quality according to the Ministry of Health's regulation (7).

**Ethical approval:** The study was approved by the Ethics Committee of the Hanoi University of Public Health following Decision No. 453/2022/YTCC-HD3 dated December 16, 2022. The consent of the study subjects was obtained. The investigators carefully explained the purpose of the study and only analyse the information in the questionnaire. The data collected was used for scientific research purposes only. When the study was completed, the results were reported to the locality for appropriate management activities in the field of domestic water supply. The study was supported by the Quang Ngai CDC Board of Directors.

## RESULTS

Table 1 shows 16 physicochemical and microbiological parameters. The results of testing water quality parameters of 123 water samples from 41 water supply stations in Quang Ngai province showed that 74/123 samples met all the requirements of the test parameters accounting for 60.2%. 100% of the parameters of colour, turbidity, permanganate index, pH, nitrite content, manganese content, total iron content, arsenic content, and sulphate content were per the standard.

**Table 1. Proportions of parameters meeting the standard according to QCVN01-1:2018/BYT**

| No. | Indicators | Limits according to QCVN01-1:2018/BYT | Water samples at water supply stations | | Water samples in the middle of the distribution pipeline | | Water samples at the end of the distribution pipeline | |
|---|---|---|---|---|---|---|---|---|
| | | | Frequency (n=41) | Proportion (%) | Frequency (n=41) | Proportion (%) | Frequency (n=41) | Proportion (%) |
| 1 | Color | 15 TCU | 41 | 100 | 41 | 100 | 41 | 100 |
| 2 | Taste | Tasteless, scentless | 40 | 97.6 | 40 | 97.6 | 40 | 97.6 |
| 3 | Turbidity | 2NTU | 41 | 100 | 41 | 100 | 41 | 100 |
| 4 | pH | 6.0-8.5 | 41 | 100 | 41 | 100 | 41 | 100 |
| 5 | Permanganate index | 2 mg/l | 41 | 100 | 41 | 100 | 41 | 100 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 6 | Nitrate content ($NO_3^-$ in N) | 2 mg/l | 27 | 65.9 | 27 | 65.9 | 27 | 65.9 |
| 7 | Nitrite content ($NO_2^-$ in N) | 0.05 mg/l | 41 | 100 | 41 | 100 | 41 | 100 |
| 8 | Chloride content | 250 (or 300) | 40 | 97.6 | 40 | 97.6 | 40 | 97.6 |
| 9 | Iron content | 0.3 mg/l | 41 | 100 | 41 | 100 | 41 | 100 |
| 10 | Sulphate content | 250 mg/l | 41 | 100 | 41 | 100 | 41 | 100 |
| 11 | Hardness | 300 mg/l | 39 | 95.1 | 39 | 95.1 | 39 | 95.1 |
| 12 | Arsenic content | 0.01mg/l | 41 | 100 | 41 | 100 | 41 | 100 |
| 13 | Manganese content | 0.1 mg/l | 41 | 100 | 41 | 100 | 41 | 100 |
| 14 | Residual Chlorine Content (n=28) | (0.2-1.0) mg/l | 27 | 96.4 | 26 | 92.9 | 26 | 92.9 |
| 15 | *Coliform* | <3 CFU/100ml | 37 | 90.2 | 35 | 85.4 | 33 | 80.5 |
| 16 | *E. coli* | <1 CFU/100ml | 39 | 95.1 | 38 | 92.7 | 37 | 90.2 |
| 17 | Physicochemical parameters | / | 27 | 65.9 | 27 | 65.9 | 27 | 65.9 |
| 18 | Microbiological parameters | / | 37 | 90.2 | 35 | 85.4 | 33 | 80.5 |
| 19 | Physicochemical microbiological parameters | / | 25 | 61.0 | 25 | 61.0 | 24 | 58.5 |

Most of the samples met the standards such as Chloride content and taste (97.6%), residual chlorine (92.9%), and hardness (95.1%). 90.2% of the water samples at the supply stations, 85.4% of the samples in the middle of the pipeline and 80.5% of the samples at the end of the pipeline (80.5%) met the standard for Coliform.

For the proportion of samples meeting the standard for the E. coli parameter: At the water supply stations (95.1%), samples in the middle of the distribution pipeline (92.7%) and samples at the end of the distribution pipeline gradually decreased to 90.2%. For microbiological parameters: the proportion of samples meeting the standard gradually decreased: at the water supply stations (90.2%), the samples in the middle of the distribution pipeline (85.4%) and the samples at the end of the distribution pipeline (80.5%). 65.9% of the samples in all three locations met the water quality standard for the physicochemical parameters (Figure 1). In addition, the nitrate content had a low rate of meeting the water quality standard (65.9%).

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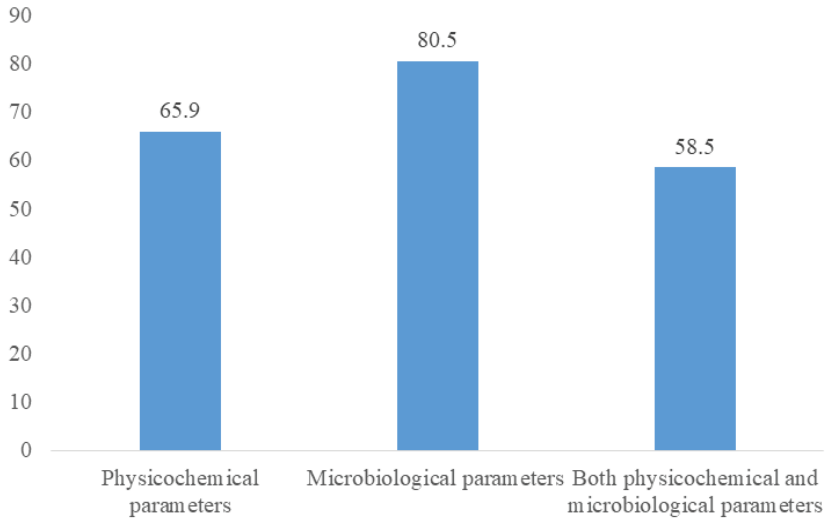


**Figure 1: Proportion of samples with physicochemical parameters, microbiological parameters and both physicochemical and microbiological parameters meeting the standard**

Results in Figure 1 showed that among 41 concentrated water supply stations in Quang Ngai province, 24 stations had domestic water quality meeting both physical, chemical and microbiological parameters according to the standards prescribed by the Ministry of Health, accounting for 58.5%. 33 out of 41 stations had water quality that met microbiological parameters according to the standards prescribed by the Ministry of Health, accounting for 80.5%. 27 out of 41 stations with water quality with physicochemical parameters meeting the standards, accounting for 65.9%.

**Table 2: Water samples meeting the water quality standard of QCVN 01-1:2018/ BYT according to the management models, operation time, treatment systems and sterilization systems**

| | Number of stations | Frequency meeting QCVN 01-1:2018/BYT | Proportion (%) |
|---|---|---|---|
| **Management models** | | | |
| State-owned enterprises | 19 | 15 | 79.0 |
| Private enterprises | 7 | 6 | 85.7 |
| Cooperative stations | 7 | 1 | 14.3 |
| Private stations | 8 | 2 | 25.0 |
| | | $\chi^2 = 14.75$; p=0.002 | |
| **Years of operation** | | | |
| 0-5 years | 10 | 9 | 90.0 |
| 6-10 years | 15 | 6 | 40.0 |
| >10 years | 16 | 9 | 56.3 |
| | | $\chi^2 = 6.24$; p=0.044 | |

| | Number of stations | Frequency meeting QCVN 01-1:2018/BYT | Proportion (%) |
|---|---|---|---|
| **Treatment systems** | | | |
| Processed through filtration, settling and iron and manganese treatment systems | 28 | 20 | 71.4 |
| No treatment system | 13 | 4 | 30.8 |
| | | $\chi^2 = 6.05$; p=0.014 | |
| **Sterilization systems** | | | |
| With sterilization systems | 26 | 21 | 80.8 |
| Without sterilization systems | 15 | 3 | 20.0 |
| | | $\chi^2 = 14.47$; P <0.001 | |

The research results in Table 2 show that among the four management forms, the private enterprise model had the highest rate of 85.7% meeting the water quality standard, followed by the state-owned enterprise 79.0%, while the private stations had only 25.0% meeting the standards and the cooperative with the lowest rate of 14.3% meeting the standard. This difference was statistically significant ($\chi^2 = 14.75$; p=0.002). Also, stations with 0-5 years of operation had a higher proportion of meeting QCVN 01-1:2018/BYT (90%) compared with stations with 6-10 years of operation (40%) and over 10 years of operation (56.3%), $\chi^2 = 6.24$; p=0.044.

Research results in Table 2 also showed that there were 20/28 water supply stations with sedimentation, filtration and iron and manganese treatment systems with satisfactory results accounting for 71.4%. 4/13 water supply stations had no treatment through the filtration system, sedimentation with satisfactory results accounted for only 30.8%. This difference was statistically significant (p<0.05). Also, there were 21/37 water supply stations with a sterilization system that met the standard (accounted for 80.8%), and 3/15 water supply stations without a disinfection system that met the water quality standard (accounted for 20%). This difference was statistically significant (p<0.05).

## DISCUSSION

Water supply stations were increasingly built throughout Quang Ngai province to improve essential living conditions and ensure the quality of domestic water supply for people. However, there were still 17/41 stations whose water quality did not meet QCVN 01-1:2018/BYT (7) so there was a potential risk of affecting people's health. The percentage of water supply stations meeting water quality standards in Quang Ngai province was still low, accounting for 58.5%, and the percentage of samples meeting physical and chemical parameters was 65.9%. Among 123 tested samples in 41 stations, 9 parameters were reaching 100% of the standard including colour, turbidity, permanganate index, pH, nitrite, sulphate, manganese, iron, and arsenic. The proportion of samples meeting the standards of taste (97.6%), and hardness (95.1%) with the result that 1 station exceeded 2.4 times the allowable limit, 34.1% of stations did not meet the nitrate parameter, with concentrations exceeding 1.2-8.1 times the allowable limit. This indicated the risk of

water pollution from agricultural activities, improper wastewater treatment activities and the oxidation of nitrogenous wastes in human and animal feces while 30.8% of stations did not apply sedimentation and filtration treatment. Therefore, it was necessary to have technical measures to improve and apply special treatment measures for nitrate parameters. Similar to the study of Balamurugan Panneerselvam in South India, the results did not reach 40% (11). In Quang Ngai province, most of the water supply stations had a long operating time but did not maintain the treatment system, so the rate of water quality not meeting the regulations of the Ministry of Health was still high.

The rate of stations that met microbiological parameters according to QCVN 01-1:2018/BYT accounted for 80.5%, lower than the result reported in a study in Tien Giang province by Nguyen Van Loi, which was 96.3% (4). The rate of concentrated water stations that met the *Coliform* parameter was 80.5%. Water contaminated with *Coliform* can cause gastrointestinal diseases. Due to improper treatment of domestic water and livestock manure, water sources are susceptible to *Coliform* contamination. The rate of water supply stations meeting the *E. coli* parameter was 87.8%, which was similar to the research results of Nguyen Thi Hai Ha (89.7%) (10).

The research results also showed that the model of water supply station with the highest rate of meeting the water quality standard was private enterprise (85.7%), followed by the state-owned enterprise (79.0%), private stations (25.0%) and the lowest was the cooperative model (14.3%). The private model operated in the service-oriented direction, without a specific plan and inefficient operation methods. Therefore, a solution is needed to convert this model to a more efficient way of operating. The fact that operators were trained in the water supply may be the reason why the private enterprise model had a statistically significantly higher quality rate than that of other models ($p<0.05$). The water quality did not meet the standard due to water was pumped up from the raw water source directly into the distribution system without treatment (80%) nor disinfecting the supply water (69.2%). There was a statistically significant relationship between disinfection and treatment systems and water quality ($p<0.05$). Thus, in the coming years, water treatment stations in Quang Ngai need to include treatment and disinfection systems to improve water quality.

The stations applying the correct price had water samples meeting the water quality standard (74.2%) higher than that of not applying the appropriate price (10%). However, the stations currently applying improper water prices were difficult to increase water prices because the water supply in rural, mountainous and island areas for people living in difficult situations, so profits were low and most stations did not invest in facilities. Finally, due to time and resource constraints, the study analyzed only a few factors related to water quality. The study did not assess the seasonal variation in water quality, the depth of the input water source and the full range of clean water quality parameters for domestic purposes according to local technical regulations. Future studies on water quality may consider these factors.

## CONCLUSIONS

58.5% of stations met water quality standards, 65.9% and 80.5% of samples met physicochemical parameters and microbiology. 80.5% and 90.2% of the samples met the standard for *Coliform* and *E. coli* parameters, respectively. For physical and chemical parameters, 09 parameters were

meeting the standard at 100%, including colour, turbidity, pH, permanganate index, nitrite, manganese, total iron, arsenic, and sulphate; the lowest was nitrate with only 65.9% of samples meeting the standard. The model with the best water quality was centralized water supply stations managed by private enterprises, followed by governmental enterprises, private enterprises and cooperative enterprises.

Research results showed that there was a statistically significant correlation between water prices, management models, treatment and disinfection systems, station operating time, professional qualifications, sanitary conditions and water quality. It showed that water supply stations managed by cooperatives and private stations need to improve their management, comply with regulations on implementing internal audits following the regulations to promptly overcome unsatisfactory parameters, especially nitrate; publicize water quality information, report test results and keep water quality monitoring records as prescribed.

For water stations that did not meet the standards, it was necessary to invest in building and upgrading the treatment and disinfection system, replace the degraded and leaking distribution pipelines and perform annual maintenance and cleaning of the water supply system. At the same time, send operators to train professionally in water supply and learn from experiences with water supply stations with high results to improve the quality of water supplied to the people. The authorities need to provide specialized training on water supply and guide the management regulations for facility owners and operators. There should be sanctions and strict handling measures for domestic water supply stations that violate regulations to show deterrence in management. Furthermore, advise the People's Committee to take measures to support water supply stations to switch from inappropriate and ineffective management models to other more effective models to ensure the quality of water supplied to people.

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