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# ASSESSING GROUNDWATER STATUS OF UTILIZATION IN THE COASTAL AREA OF SOC TRANG PROVINCE, VIETNAM

The research was conducted on groundwater exploitation and usage in Ward 2, Vinh Chau Town, Soc Trang Province. A total of 405 households were interviewed about end-use water status. Groundwater samples from 9 wells were monitored once for water quality status. The results of the study indicated that there was a total of 520 wells installed at 405 households showing that water is urgently needed for domestic use (88.7%), and agricultural use (69.5%). There were 41.4% of the wells drilled since 2010 up to now and 74.3% of the wells drilled over 100 m. To get more water, particularly in dry seasons, the farmers applied large intake pipes (96.4% of the well's pipe diameters were 49 and 60 mm) and illegally pumped (syringes pump, air pump, or rocket pump) which led to a decrease in groundwater levels and caused pressure on water source. Groundwater quality is within threshold values of national technical standards. Appropriate pumping technique was a suggestion to the farmers. Local authorities need to pay more attention to groundwater management in this area that help farmers use this resource.

## 1. INTRODUCTION

It is estimated that about 50% of the residents of the Mekong Delta of Vietnam depend on fresh groundwater for not only domestic use but also agricultural cultivation [1]. Especially in Vinh Chau Town of Soc Trang Province, groundwater exploitation has the highest exploitation capacity of 58 341 $m^3$/day with 24 570 drilled wells (ca. 53 wells/$km^2$) that belongs to the group of localities with a high density of exploitation wells in the province [2]. Considering the sustainable exploitation threshold of 20% of potential exploitation reserves, Vinh Chau needs to limit the exploitation or must have reasonable exploitation measures. Compared to safe reserves, Vinh Chau is considered a water-

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deficient locality [3]. However, people in the town were not yet aware of the impacts of groundwater sustainable exploitation, leading to overwater source exploitation and not taking good care of the wells [4].

With a more than 50 km long coastal area, Vinh Chau Town is mainly based on groundwater for both domestic use and agricultural production causing groundwater sources to rapidly decrease in quality and quantity [5]. Hang et al. [6] reported that 90% of surveyed households agreed that the groundwater level has dropped in recent years affecting the dynamics of groundwater resources. For use purposes, groundwater, which is the main source of daily life consumption for residents, accounts for 99.1% and 95.5% in dry and rainy seasons, respectively [7]. Besides that, groundwater is also used for agriculture cultivation with two key agricultural products – red onion and white radish. Den et al. [8] calculated that red onion needs a water volume of 369.9±10.7 $m^3$ per 1000 $m^2$ for each crop of 70 days, and white radishes need a water volume of 260.3±4.5 $m^3$ per 1000 $m^2$ for each crop of 55 days [8]. Giao et al. [9] noted that groundwater in the period from 2016 to 2018 was of good quality, except $Cl^-$ level, while 78% of the households owned the wells but without any license. These studies assessed that the local people had limited awareness of the impacts of sustainable exploitation of groundwater sources, leading to inadequate use and unwell protection of groundwater sources. Quynh et al. [10] reported in 2015 that only 2.5% of groundwater well owners in Vinh Chau Town registered to local authorities for the exploitation license, even though the registration is required by the Law on Water Resources [11].

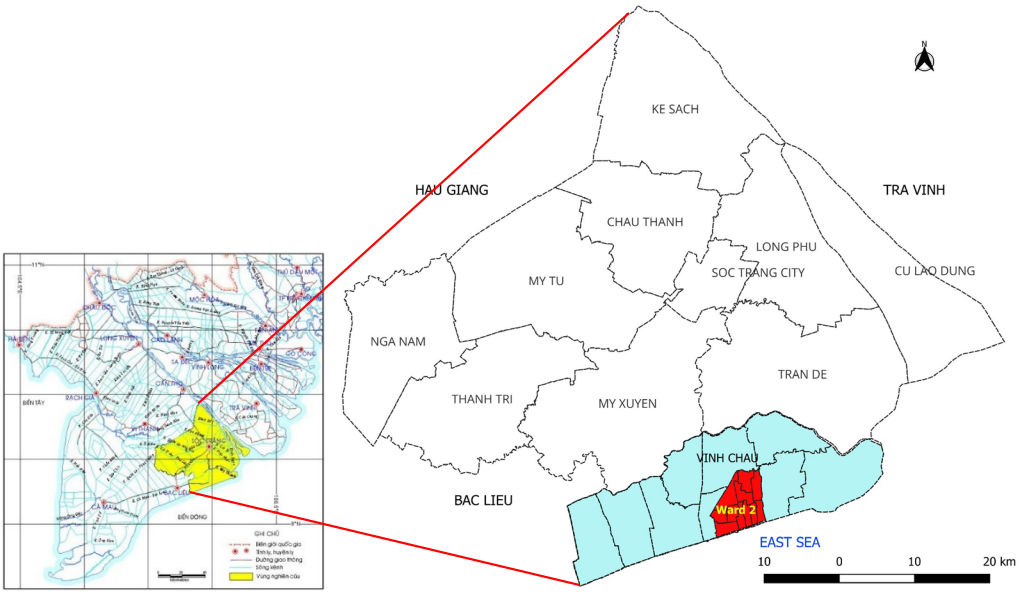


Fig. 1. Location of the study area in Soc Trang Province referring to the Mekong Delta map

In Ward 2 of Vinh Chau Town (Fig. 1), the agricultural land accounts for 91.2% of the total natural area [12] with the main crops such as red onion, white radish, chili, garlic, etc. Groundwater volume exploitation tends to increase due to broader saline intrusion to the inland and lack of fresh water in the climate change context. According to the report from the Department of Natural Resources and Environment of Soc Trang Province [13], groundwater sources in the province are widely exploited leading to an annual decrease in water levels from 0.5 to 1.0 m at the –90 m groundwater layer and from 3.0 to 4.0 m at deeper groundwater layers. This fact showed a high stress on groundwater management in the town, especially under the pressure of economic development, population growth, climate change, and sea level rise. This study aims to survey the status of groundwater exploitation for agriculture irrigation and its quality at Vinh Chau Town, Soc Trang Province and makes suggestions for sustainable management and exploitation of groundwater resources in the region.

## 2. METHOD

*The study area*. Ward 2 (9.3413° N, 106.0288 °E) is in the center of Vinh Chau Town with one side facing the sea. The ward has 11 hamlets with 4470.84 ha of natural area and a population of 26 175 people living in 5566 households [14]. This is an extremely economically difficult ward, where many ethnic minorities have been living. In this ward, groundwater is the most needed water source because some areas are not connected to the clean water supply network, and most people's livelihoods are based on vegetable crops but there is no surface water available, especially in dry seasons.

The study area has a sub-equatorial tropical monsoon climate with two distinct seasons: the rainy season from May to November, and the dry season from December to April of the following year. The average annual temperature is 26.6 °C; the highest temperature of the year is in April (28.2 °C) and the lowest in January (25.4 °C). The average total amount of radiation during the year is relatively high, reaching 140–150 kcal/cm$^2$. The average total sunshine hours in the year are 2292.7 h (about 6.28 h/day); the highest one is usually in March with 282.3 h and the lowest is usually in September with 141.5 h. The average annual rainfall is 1600–2230 mm with large seasonal differences. The rainy season accounts for 90% of the total rainfall; the dry season is minimal, and there are months without rain. The average humidity throughout the year is 84% (highest 89% in the rainy season, lowest 75% in the dry season). Located in the tropical monsoon climate zone, Ward 2 has the following main wind directions: West, South-West, North-East, and South-East. The rainy season is mainly influenced by the south-west monsoon; the dry season is mainly influenced by the north-east monsoon with an average wind speed of 1.77 m/s [15].

*Data collection.* In March 2019, a field survey and interviews with the households who owned wells were conducted in Ward 2, Vinh Chau Town, to collect information

on the groundwater usage of the residents. The survey and interviews focused on the status of the wells (in use or out of use, easy to pump water or not), the purposes of using groundwater (domestic use, agricultural irrigation, aquacultural production, crop types), well technical parameters (built year, well depth, pipe diameter, well operation and maintenance), type of pumps (conventional submersible electrical pumps, upgraded pumps), groundwater quality, ways to treat groundwater, etc. Multi-choice and unstructured questionnaire sheets were pre-designed and processed in a pilot survey to test the reliability of the questions through 10 respondents within the campus of Can Tho University, Vietnam. All the biases, errors, illogical and unclear questions, or questions that did not match the research objectives had been verified and adjusted carefully before the questionnaire was officially used for the survey.

Households were randomly chosen for the interview. First, a household that owned a well was selected in each hamlet for the interview; then the respondent was asked to introduce other households who used wells to get groundwater for agricultural cultivation, and the informed households were interviewed. In this way, there were more households interviewed in the hamlets that had more agricultural activities.

The number of surveyed households $n$ was defined by the formula [16]:

$$n = \frac{N}{1 + Ne^2} \tag{1}$$

where $N$ – the total number of households in the ward (5566 households), $e$ – the tolerance, the most popular level of ±0.05 was chosen.

Table 1

Number of households interviewed in the study area

| Hamlet | Number of households |
|---|---|
| Ca Lang A | 39 |
| Ca Lang A Bien | 36 |
| Ca Lang B | 40 |
| Ca Sang | 37 |
| Dai Rung | 33 |
| Giong Me | 42 |
| San Chim | 35 |
| Soai Con | 26 |
| Vinh An | 41 |
| Vinh Binh | 40 |
| Vinh Trung | 36 |
| Total | 405 |

According to Eq. (1), to obtain reliable data, 373 households should be surveyed. In this study, a total of 405 households in Ward 2 were face-to-face interviewed, which

was sufficient for the required survey sample size. Table 1 presents the number of interviewed households from each hamlet within Ward 2.

*Collection of samples to assess water quality*. Groundwater samples from 9 wells were collected in the study area to assess the quality of groundwater sources being exploited and used by households (Table 2 and Fig. 2). In this study, water samples were just collected once to double-check interviewees' complaints about groundwater quality, and to the results from previous studies implemented in 2016, 2017, and 2018 [8, 9].

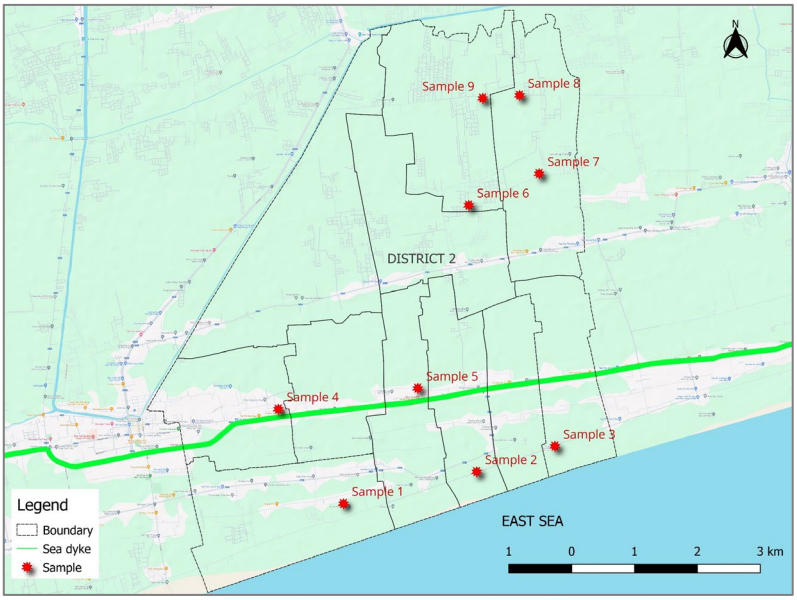


Fig. 2. Location of groundwater sampling

Table 2

Wells to collect water samples for quality assessment

| Sampling place | Dwelling data | | |
|---|---|---|---|
| | Start of use | Depth [m] | Diameter [mm] |
| Ca Lang A Bien hamlet | 2006 | >100 | 49 |
| Vinh Binh hamlet | 2012 | >100 | 60 |
| San Chim hamlet | 2016 | >100 | 49 |
| Ca Sang hamlet | 2011 | >100 | 49 |
| Vinh An hamlet | 1999 | >100 | 49 |
| Giong Me hamlet | 2018 | 105 | 49 |
| Vinh Trung hamlet | 2017 | 102 | 60 |
| Vinh Trung hamlet | 1999 | 120 | 60 |
| Giong Me hamlet | 2003 | 95 | 42 |

Groundwater samples were taken following TCVN 6663-11:2011 [17] and examined on-site by use of the In-Situ Aqua Troll 400 Multiparameter Probe. The measured parameters included pH, salinity, electrical conductivity (*EC*), total dissolved solids (TDS), and oxidation-reduction potential (ORP).

*Data analysis.* The interviewed database was then coded, validated, and interpreted using the descriptive statistics tools of the Microsoft Excel 2021 software. The Microsoft Excel 2021 software was used to analyze the input data recorded from the interviewed sheets and data logged from the U-54G multi-parameter meter.

The resulting water quality was then evaluated in terms of its potential use for various purposes by comparing to the national technical regulations on groundwater quality [18], domestic water quality [19], and tn water quality for irrigated agriculture [20].

## 3. RESULTS AND DISCUSSION

### 3.1. GROUNDWATER EXPLOITATION STATUS

*Well's ownership status.* Within a total of 405 surveyed households, a total of 520 wells were drilled for water collection, of which 311 households owned one well, 73 households owned two wells, and 21 households owned three wells. Almost all existing wells were in excellent use; only 5 interviewees complained about their well's conditions. Up to 58.6% of the wells were drilled before 2010, and 41.4% have been drilled since 2010 up to now. The households in this surveyed area highly appreciated having the groundwater source for both domestic and agricultural activities; therefore, the local people try to preserve groundwater wells and protect the pumps well (Fig. 3).

Fig. 3. An excellent way to preserve the pump

390 households (96.3%) exploited and used groundwater from wells, while 15 households owned wells but no longer used them, as they had an opportunity to access the town's domestic water supply pipeline. However, some of them have been improperly closed (Fig. 4) in violation of the guidelines [21]. It is in line with the results of previous studies that people were not fully aware of the impacts of groundwater sustainable exploitation, leading to over-exploitation of water sources and not taking good care of the wells [4]. Besides, local authorities do not have effective coordination and linkage to water users in groundwater management [5]. Another study reported that 89.8% of surveyed households knew about the water exploitation license, but only 2.5% of them asked for this procedure [10]. This situation was improved in 2019 with 22% of surveyed households owning wells with a water exploitation license [9].

Fig. 4. Well no longer in use, but not yet safely sealed

*Technical characteristics of the well.* The surveyed households informed that well drilling contracts were commonly performed to a depth of 105 m in this area. However, if there is still no water, the drilling agency must continue to drill deeper until it is water, but the water quality is guaranteed for people to use. If a well offers satisfactory water quality even not reaching 105 m, the drilling agency can stop drilling. The number of wells with a depth of over 100 m accounted for the highest ratio at 74.3%. This result is in line with the previous study that the well depth changed from 90 to 100 m in the aquifer (before 2005) up to 100–115 m in the aquifer (after 2012) [7].

The pipe diameter of a well depends on the household's needs. A well with a small pipe diameter can give enough water for domestic use, but it needs a larger pipe diameter for irrigating water. The installation of a small diameter well can be an uneconomical option because the pumping time will be long. Most of the households in the survey installed the well with pipe diameters of 49 mm (48.2%) and 60 mm (48.2%).

To get water from wells, 99.0% of the households have been using conventional submersible electrical pumps. There were 2 households using hand pumps to get water because their income was insufficient to invest in electrical pumps. A few households (0.5%) illegally maintained their pumps to take more water for other purposes. As regards maintaining methods, an air pump requires an additional air compressor to blow the air (Fig. 5), while a rocket pump places the suction head at least 2.0 to 3.0 m under groundwater level and uses a larger diameter pipe to take water (Fig. 6).

Fig. 5. The air pump with air compressor

Fig. 6. The rocket pump to take more groundwater

If farmers illegally maintain their pumps, some technical problems may happen in exploiting groundwater. Extending the pump's suction hose may result in the pump not operating at its proper capacity, or some pumps will not start. Or else, lowering the

pump elevation will ensure that the design water level meets the requirements. Depending on the type of pump, the investment cost is a significant difference. Compared to the conventional submersible pumps, investigations for air pumps and rocket pumps are 2–6 times higher. Besides, using air pumps and rocket pumps also increases operating costs compared to conventional submersible pumps. Therefore, households only use these types of pumps when they need bulky amounts of water for aquaculture or irrigation in large areas.

*The purposes of groundwater use.* 88.7% of the survey households have been applying groundwater for domestic use, 69.5% for crop irrigation, 1.8% for aquaculture cultivation, and 1.5% for business. In previous research, there was a higher ratio of households in Ward 2 using groundwater for daily life of 94.5% [4]. Local authorities had extended a clean water supply pipeline to households in the area, especially for those who live near the main roads. Conversely, there was a lower proportion of households exploiting water from wells for crop irrigation 33.6%. Besides that, 3 households would like to install new wells to satisfy their demand for water sources. This indicates that the local authorities should pay more attention to the lack of water sources for agricultural production in the area.

Fig. 7. Groundwater with sediment in the bucket

Most of the households who used groundwater for domestic use did not treat water before use (96.2%). According to the interviewees, groundwater is already clean, so they can use it directly without any treatments. Only 3.8% of the households treated the groundwater from the well, but they applied a simple natural aeration and then used the water directly. However, sedimentation could be visually seen in the buckets that were used to store groundwater pumped from the well (Fig. 7). Therefore, it is necessary to have a regular monitoring program by the local authorities to assess the water quality of

the wells as well as to provide appropriate instructions to treat pollutant particles in the groundwater of the well for safety domestic use.

Due to soil characteristics, the main cultivated crops in the study area are red onion, white radish, chili, garlic, etc. The groundwater was used to irrigate red onion with the highest proportion of 61.2%, followed by white radish 25.1%, chili 13.8%, and the remaining for other crops such as maize, cabbage, water spinach, etc. (Fig. 8). The area cultivate purple onions and white radishes is 7000 ha and 1000 ha, respectively, in year crop 2023 [22], accounting for 51.33% and 7.33% of the total crop growing area in Vinh Chau Town while the need to use groundwater to irrigate purple onions was from 3591 to 3805 $m^3$/ha/crop, and white radish from 2558 to 2647 $m^3$/ha/crop [8]. Thus, each crop year the farmers in Vinh Chau Town needed to exploit a large groundwater volume from 30 523 500 to 32 342 500 $m^3$ for purple onions, and from 5 116 000 to 5 294 000 $m^3$ for white radish. This amount of groundwater was 1.42 and 1.33 times higher than the groundwater needed for purple onions and white radishes in crop year 2017, respectively [8]. The volume of groundwater needed to irrigate these two key crops will be ca. 36 638 000 $m^3$ by 2023, equivalent to an average groundwater exploitation of about 100 378.08 $m^3$/day, exceeding 8.1 times the safe exploitation groundwater volume that was suggested by the Department of Natural Resources and Environment of Soc Trang Province [13].

Fig. 8. Using groundwater to irrigate red onions

Groundwater was used for aquacultural production in the hamlets of Dai Rung, Soai Con, and Giong Me. In these hamlets, the land is unfertile and unsuitable for crops; therefore, farmers used the land for aquacultural cultivation with white-leg shrimps. However, using groundwater for shrimp production requires an exploitation permit from local authorities [23]. Besides that, since 2021 the People's Committee of Soc Trang

Province has announced a list of areas where underground water exploitation is restricted and must be registered [24]. Interviewees said that some households installed wells with large pipe diameters of 90–114 mm, but they did not register these wells with local authorities. The study area had many aquaculture households using large amounts of groundwater but there was no detailed information. Trung et al. [5] noted that there was a lack of communication and connection between local authorities and groundwater users; the inspection of groundwater exploitation has not been periodically and critically carried out in the study area.

Another issue is groundwater exploitation for crops and daily life increases during the dry season (from February to April) each year due to the decrease of water from upstream and saline intrusion. Up to 27.2% of surveyed households could not pump groundwater in the dry season and this is an indicator of a decline in the groundwater level of the area. One of the solutions implemented by most households here was to switch to air pumping or rocket pumping so that they could get water as usual. Households who still used common pumping but wanted to get sufficient water for crop irrigation must operate the pump outside of peak hours. This shift caused problems such as higher payment for electrical pumping and careless time for pumping control. Previous studies noted that groundwater sources in Vinh Chau Town speedily decrease in quality and quantity due to over-exploitation and wasteful use [4], especially worse under climate change conditions [5].

### 3.2. GROUNDWATER QUALITY

pH of water samples did not change significantly between sampling points with the lowest pH reaching 7.4 at well 2 at Vinh Binh hamlet, and the highest pH reaching 7.9 at well 9 at Giong Me hamlet (Fig. 9). One farmer in Vinh Trung 1 hamlet reported that his groundwater was contaminated with aluminum, the recorded pH of 7.72 at this well was still within the limitation of QCVN 09:2023-MT/BTNMT on groundwater quality (5.5–8.0), and that of QCVN 01-1:2018/BYT on clean water quality used for daily life purposes (6.0–8.5). pH of samples of water for agricultural irrigation was also in line with the safety boundaries of 5.5–9.0.

Groundwater samples from 3 wells near the sea and well 9 at Giong Me hamlet recorded positive ORP values from 2.72 to 82.78 mV, showing that water sources can be highly oxygenated and may be harmful to water end-users. The remaining wells had negative ORP values from –123.87 to –47.34 mV, which means that water sources can prevent the invasion of harmful oxygen and make the body healthier (Fig. 10). The two parameters of ORP and pH were closely related and affected each other. When pH is higher, there will be more agents that can reduce the ORP in water. In this study, water samples with a negative ORP had pH values from 7.61 to 7.73.

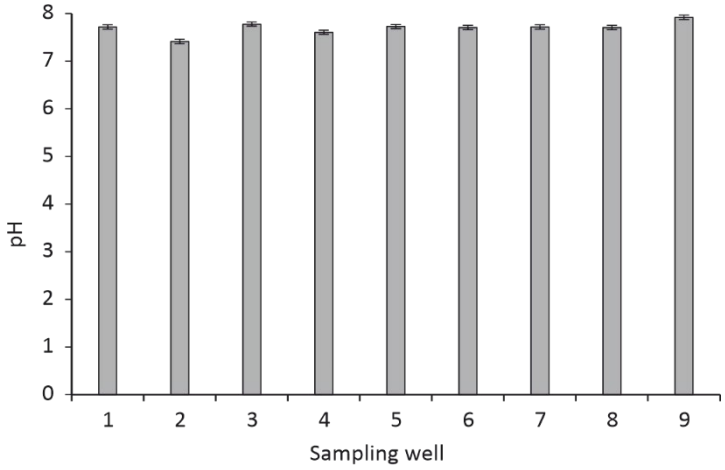


Fig. 9. pH of groundwater samples

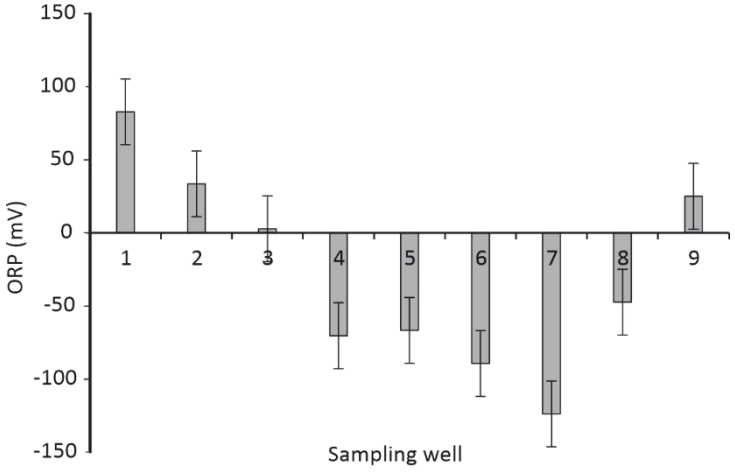


Fig. 10. ORP values of groundwater samples

Measured TDS values in groundwater samples were from 0.63 to 1.04 g/dm$^3$ (Fig. 11). For the wells located near the sea, TDS values tended to be lower than for the wells at the inland. All TDS values were within the allowable limits of the national standard QCVN 09:2023-MT/BTNMT on groundwater quality. The recorded TDS values from 9 groundwater samples were also lower than the threshold values that could apply for agricultural productions of 2.0 g/dm$^3$.

*EC* values ranged from 1096.24 to 1800.35 μS/cm at the wells near the sea; while the wells inland had EC values tending to increase (1192.33–1802.24 μS/cm (Fig. 12)). The variation of *EC* of water samples was similar to the trend of TDS with higher values recorded for the wells inland. This is because the total amount of dissolved solids was

proportional to its electrical conductivity. In other words, the higher the solids concentration, the higher the electrical conductivity is.

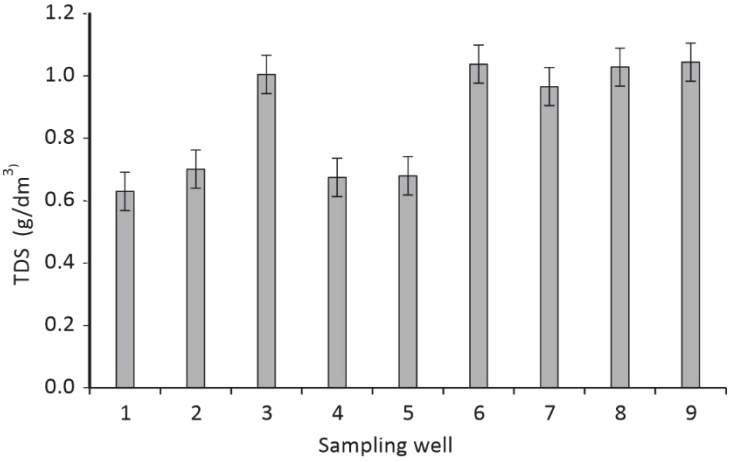


Fig. 11. TDS values of groundwater samples

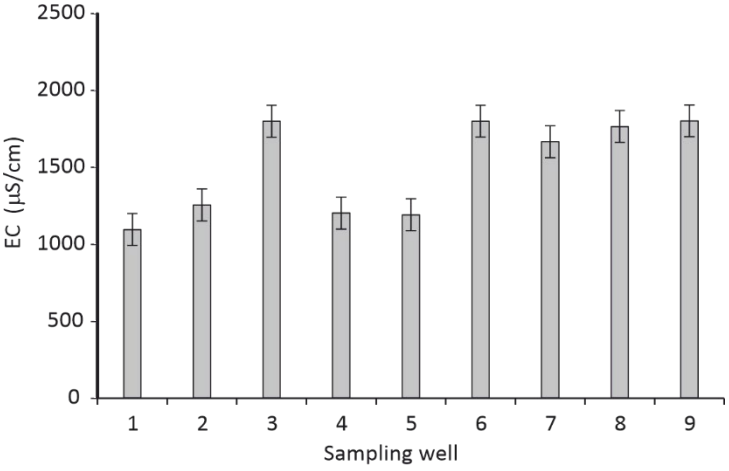


Fig. 12. EC values of groundwater samples

Water samples from the wells near the sea had actual salinity from 0.48 to 0.79 PSU and from 0.52 to 0.82 PSU for the wells inland (Fig. 13). One farmer at Giong Me hamlet reported that the groundwater at his well was salty. The testing results showed that the actual salinity at this household's well was 0.82 PSU, which was the highest value recorded among 9 groundwater samples. However, this value was not significantly different from that for the water samples collected at Giong Me and Vinh Trung hamlets. Salinity recorded at the sampling wells varied but the values were comparable

to the trend of TDS and *EC* values. Indeed, TDS value includes salinity-forming substances (dissolved salt) and other organic substances in a water sample. It means that water sources with the same conductivity have the same salinity concentration. *EC* of a water sample is influenced by the concentration and composition of dissolved salt. Salt increases the ability of a solution to conduct an electrical current, so a high *EC* value indicates a high salinity level [25].

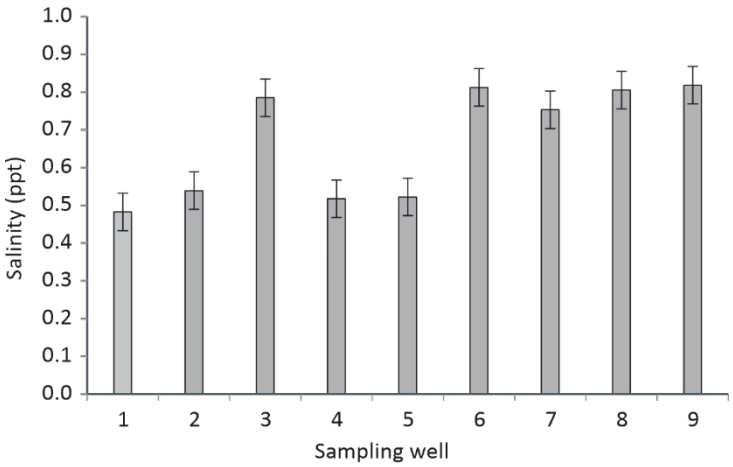


Fig. 13. Salinity of groundwater samples

Although all groundwater samples in this study were collected once, they all showed good water quality for domestic use and irrigation demand. This result was in line with the previous study in 2017 stating that groundwater samples in Vinh Chau Town met the national technical regulations on groundwater quality QCVN 09-MT:2015/BTNMT, except for sulfates, total Coliform, and E. Coli parameters which exceeded the standard [8]. Another study also reported that groundwater quality samples observed from 2016 to 2018 at the same site also met the national standard QCVN 09-MT:2015/BTNMT of groundwater quality [9].

### 3.3. TECHNICAL SOLUTION TO IMPROVE GROUNDWATER USAGE

Since the farmers in the study area applied illegal methods to upgrade their wells, it is recommended to focus on those technical solutions for wells that cannot take water from normal pumps. To solve the problem of the pump not starting or not operating at its proper capacity when extending the pump's suction hose, it is necessary to install an additional vacuum pump system. Installing a fixed submersible pump helps convenient operation, maintenance, and repair of the pump; it does not change the structure of the well's suction pipe but requires purchasing a new pump and paying expensive installation costs.

It is also needed to pay more attention to managing groundwater quality. The recorded groundwater quality parameters were within the allowable thresholds of national technical standards but farmers complained about its quality. As Soc Trang local authorities had plans for the exploitation, use, and protection of groundwater resources only to 2020 [13], it is needed to prepare new plans for the Soc Trang Province with a vision for 2030, in which the local authority should allocate budget for a periodic groundwater quality monitoring program. Besides that, the responsible agencies need to advise and encourage local people to treat groundwater sources properly before using them for domestic purposes. Giving instructions to local people on how to seal damaged wells which can no longer be exploited to promptly prevent polluted components from the ground entering aquifers and circulating between different aquifers and layers through wells.

## 4. CONCLUSIONS AND RECOMMENDATIONS

The research focused on the status of exploitation and usage of groundwater in Ward 2, Vinh Chau Town, Soc Trang Province, and recorded that groundwater was the main water source for all activities of the local people in Ward 2, especially during the dry season. Groundwater was not only used for domestic demand but also for agricultural irrigation and aquacultural production. Regarding the two main annual crops of red onions and white radishes in the study area, the volume of groundwater source was needed to be taken exceeded the safe exploitation requirements of groundwater reservation. The number of households using groundwater for agricultural production increased compared to the previous period, creating competition for exploiting groundwater sources among the households. There were households exploiting groundwater for aquacultural production even this action is legally banned. The results of the interview showed that it is hard to pump groundwater in dry seasons as its level fluctuates seasonally in the study area. Thus the farmers applied illegal ways to get more water such as air pumps or rocket pumps putting more pressure on the groundwater resource.

For water quality, water characteristics at nine sampling wells were relatively good and met the requirements for agricultural purposes. However, for domestic use, the quality of groundwater has begun to approach some threshold parameters and it is needed to pay more attention to this matter. In the case of using groundwater taken from the wells for daily life use, local people had been advised to treat the groundwater before using it, but most of them did not follow the advice; only a few households applied a natural aeration method to treat the water. The local authorities must provide positive and regular recommendations on water treatments to local people to ensure that local people treat the groundwater properly before using it for domestic activities. Besides that, there is a need for the local authorities to design a regular monitoring program of groundwater quality for management purposes. This monitoring program needs to cover

at least nine basic parameters of water quality as mentioned in the national standards of QCVN 09:2023-MT/BTNMT including pH, TDS, hardness, Coliform, ammonia, nitrate, permanganate, As, $Cl^-$.

To improve groundwater exploitation and usage conditions in the short term, it would be wiser to apply water-saving irrigation methods for purple onions and white radishes to reduce the amount of groundwater needed for irrigation. Other instruments could also be considered to improve the situation: revising land-use planning with a new agricultural production structure, changing crop varieties to grow and develop in highly drought-resistant conditions, and ensuring livelihoods for the local people in the area. Finally, encouraging the farmers to apply their crop productions in accordance to the planning approved to help reduce the use of groundwater resources as well as preserve the groundwater resource better in the area.

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