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# Evaluation of Groundwater Quality in Hau Giang Province, Vietnam

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**Abstract**

*The study was carried out to assess groundwater quality in Hau Giang province in the period of 2017-2019. Groundwater quality data was collected at 8 monitoring stations, each with 3 boreholes with the frequency of two times per year. Groundwater samples were analyzed for criteria of pH, Fe, $SO_4^{2-}$, $N\text{-}NO_2^-$, $N\text{-}NO_3^-$, hardness, $N\text{-}NH_4^+$, $Cl^-$ and permanganate. Each parameter was evaluated using national technical regulation on groundwater quality (QCVN 09-MT:2015/BTNMT). The results showed that the indicators of pH, $SO_4^{2-}$ and $N\text{-}NO_3^-$ did not exceed the allowable thresholds of the regulation; Fe, $N\text{-}NO_2^-$, $N\text{-}NH_4^+$, $Cl^-$ and permanganate sometimes exceeded the permissible limits by 1.4-2.4, 1-3.43, 1.04-2.99, 1.01-4.1, 1.25-16.41, 1.72-4.07 times, respectively. The main causes of groundwater quality degradation could be from agricultural activities, and geological characteristics. More attention needs to be paid for managing the groundwater quality in Hau Giang province.*

## 1. Introduction

Hau Giang province in particular and the Mekong River Delta in general are moving together with the whole country in economic restructuring towards industrialization and modernization. The speed of economic development is being accelerated with a variety of economic activities forming industrial zones and clusters, attracting investment in industrial development. Along with the acceleration of economic development and the process of urbanization, many environmental challenges have also been raised; urban and rural environments are increasingly polluted due to untreated wastewater and waste from production, business, service and community activities; In addition to the above pollution, waste in agricultural production also contributes to environmental pollution. On the other hand, the rapid growth of industry and urban areas, along with the uncontrolled treatment of wastes has made the ecological environment, especially the water environment, increasingly polluted. According to preliminary statistics, the amount of exploited water used for urban areas ranges from a few hundred to millions of m3/year, of which about 50% of water supply for urban areas is exploited from underground water sources. The underground water sources to be exploited are located in urban areas or near urban areas. Therefore, over time, many water sources have been exhausted or are being polluted by rapid urban encroachment, the water level of the exploited aquifers is continuously lowered over time. Groundwater is widely used for irrigation. Groundwater is also used to irrigate rice against drought. According to the research

on groundwater by [1], it shows that aquifers formed a long time ago associated with the alluvial history and topography of the Mekong Delta. Therefore, groundwater becomes the main source of water for living and domestic activities in the area because of its higher stability and less pollution than surface water [1, 3]. According to the International Children's Organization [2] in 2015, an estimated 20.48% of Vietnam's population (16.5 million people) is using borehole water. However, if the extraction rate is always higher than the natural regeneration rate, then groundwater has become a non-renewable resource [1]. The continuous decline of water level has adversely affected the ability to absorb and store aquifers, leading to subsidence of the land surface, lowering of groundwater, affecting the ecosystem using groundwater [4]. The research revolves around finding the source of groundwater pollution, the factors affecting the water level and the quality of groundwater. Former study revealed that wells and abandoned boreholes or poorly designed manure storage and septic tanks are all points of rapid conduction of contamination into the watercourse [5]. Besides promoting economic development, the problem of environmental degradation and pollution is inevitable. Groundwater resources, an area that is still limited in the in-depth research assessment of reserves as well as quality in the Mekong Delta. The potential exploitation reserve of underground water in Hau Giang is considered to be quite abundant to meet the exploitation demand for water supply for drinking and daily life and production. This study aims to assess the quality of groundwater environment of Hau Giang province in the period 2017-2019 and the causes affecting groundwater quality. The findings could provide information on the status of quality and pollution sources contributing to the management of groundwater quality in Hau Giang province.

## 2.0 Materials and methods

### *2.1 Site description*

Hau Giang province is centrally located in the Hau River sub-region of the Mekong Delta, the provincial capital is Vi Thanh city, 240km southwest of Ho Chi Minh City, more than 47km from Can Tho city along the route, Highway 61C. The administrative boundary of Hau Giang province borders Can Tho City to the North, Soc Trang Province to the South, Kien Giang and Bac Lieu Provinces to the West, Hau River to the East, and the administrative boundary with Vinh Long Province. The sampling location is shown in detail in Table 1 and Figure 1.

Table 1. Sampling locations in Hau Giang province

| No. | Site | Code | Impact |
|---|---|---|---|
| 1 | People's Committee of Thanh Hoa Commune, Phung Hiep District | QT 02 | Agricultural production activities such as farming, animal husbandry, aquaculture |
| 2 | Area 3 – Ward 5, Vi Thanh City | QT 03 | The process of urbanization |
| 3 | Irrigation station in Long My town | QT 04 | Irrigation and living activities |
| 4 | Department of Agriculture – Ngay Bay town | QT 05 | The process of urbanization |
| 5 | People's Committee of Phu Huu Commune, Chau Thanh District | QT 07 | Agricultural production activities such as farming, animal husbandry, aquaculture |
| 6 | People's Committee of Vi Thang Commune, Vi Thuy District | QT 13 | Agricultural production activities such as farming, animal husbandry, aquaculture |
| 7 | Hamlet 3, Luong Tam Commune, Long My District | QT 14 | Salinization |
| 8 | People's Committee of Truong Long Tay Commune, Chau Thanh District | QT 15 | Agricultural production activities such as farming, animal husbandry, aquaculture |

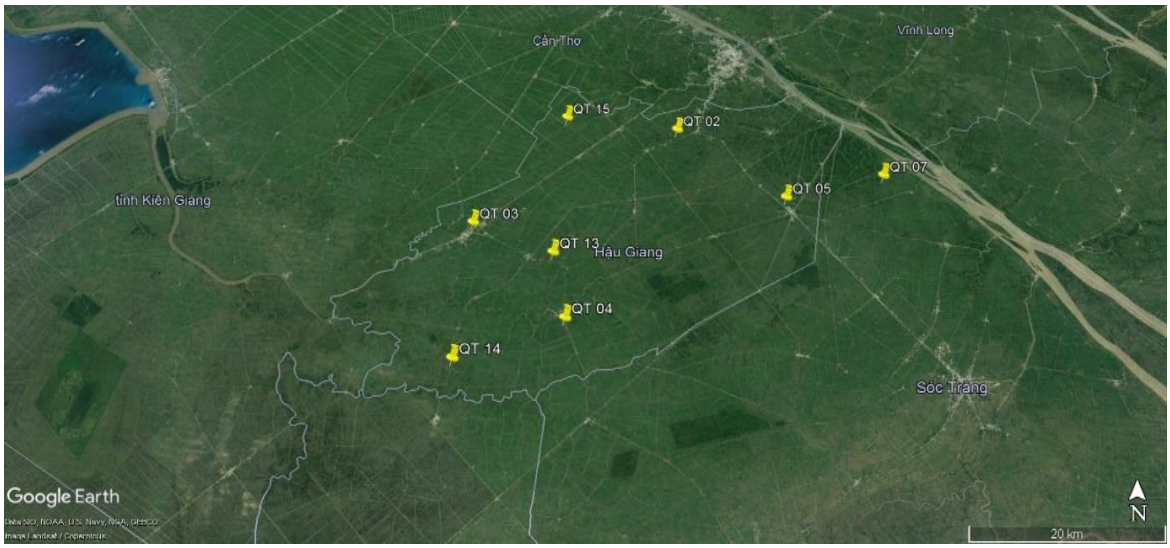


Figure 1. Location map of water sample collection in Hau Giang province

*2.2 Groundwater sampling and analysis*

The underground water quality for the period of 2017-2019 was collected from the Department of Water and Mineral Resources under the Department of Natural Resources and Environment of Hau Giang province. Monitoring was carried out in 04 layers: porous aquifer of shallow Pleistocene (qp1), porous aquifer of Middle - upper Pleistocene (qp2-3), porous aquifer of Pleistocene (qp3), Holocene aquifers (qh). On the basis of specific programs and plans, groundwater quality monitoring is carried out with 8 monitoring stations with 3 holes each station for 2 collection times. Methods of sampling in the field and analyzing in the laboratory fully and strictly comply with Vietnam's standards and technical regulations on instructions for sampling, preserving and analyzing samples in the laboratory, such as TCVN 5992:1995 (ISO 5667-2: 1991) Water quality – sampling. Technical manual for sampling. TCVN 5993:1995 (ISO 5667-3: 1985) water quality – Sampling. Instructions for sample preservation and handling.

Table 2. Laboratory analysis methods

| No. | Parameters | Unit | Analytical method |
|---|---|---|---|
| 1 | pH | - | pH meter |
| 2 | Nitrite ($N\text{-}NO_2^-$) | mg/l | Spectrophotometer |
| 3 | Nitrate ($N\text{-}NO_3^-$) | mg/l | Spectrophotometer |
| 4 | Ammonium ($N\text{-}NH_4^+$) | mg/l | TCVN 4563:1988 |
| 5 | Hardness ($CaCO_3$) | mg/l | Titration |
| 6 | Chloride ($Cl^-$) | mg/l | TCVN 6194-1996 (ISO 9297 – 1989)/SMEWW 4500 – Cl-D |
| 7 | Permanganate | mg/l | TCVN 6186:1996 or ISO 8467:1993 (E) |
| 8 | Total iron (Fe) | mg/l | TCVN 6177 – 1996 (ISO 6332 – 1988)/ SMEWW |

*2.3 Data analysis*

The analysis results are compared with the national technical regulation on groundwater quality (QCVN 09:2015/BTNMT) [6]. This regulation regulates the limits of underground water quality parameters, applied to assess the quality of groundwater, as a basis for quantification for different uses, including those for domestic use.

## 3.0 Results and discussion

*a. pH*

pH in groundwater in Hau Giang province during 2017-2019 was presented in Figure 2. The mean pH values at 4 groundwater layers (qp1, qp2-3, qp3 and qh) were from 6.48-7.78, 7-8, 6.47 – 7.4 in 2017, 2018 and 2019, respectively. Former studies reported that pH of groundwater ranged from 6.5 to 6.8 and from 5.25 to 7.8 [5-6]. Based on Figure 2, it shows that the fluctuation of pH over the years is not much, the fluctuation range of the years is also low. pH values of all samples were within the allowable threshold of QCVN 09:2015/BTNMT [6] indicating the groundwater at the study sites suitable for domestic use. This result is consistent with the study of [4] where the pH value of groundwater is relatively stable over time.

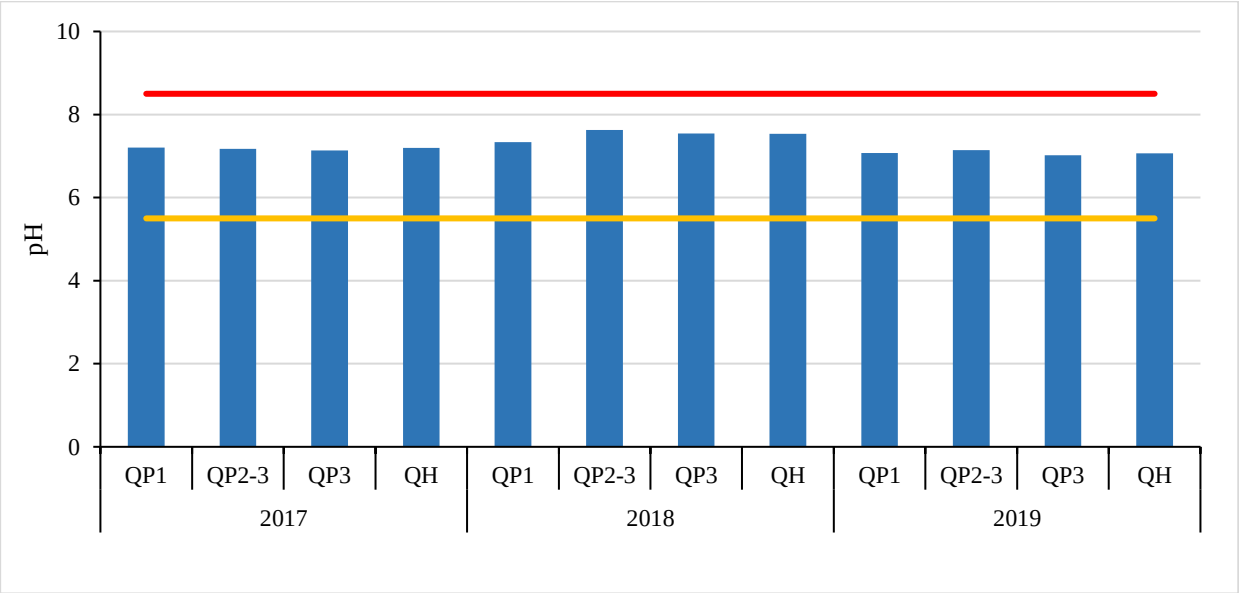


Figure 2. pH in groundwater in Hau Giang province

*b. Iron*

The research results showed that the iron concentrations in groundwater in the years 2017, 2018, 2019 fluctuated from 0.05-7.01, 0.1-12, 0.09-3.4 mg/l, respectively. In general, Fe concentration in 2018 tended to increase compared to that of 2017 and 2019. According to [7] Fe concentration in the groundwater in Bac Ninh varied from 0 to 35.53 mg/l. Because iron (II) ions are easily oxidized to iron (III) hydroxide, self-precipitate and settle, iron is rarely present in surface water, except the surface water influenced by acid sulfate soil. For groundwater, under anoxic conditions, iron usually exists in the form of Fe(II) ions and dissolves in water. When oxidized, iron (II) will be converted to iron (III), yellow precipitate of iron hydroxide will appear, easy to settle. In the case of water sources with a lot of organic matter, iron can exist in colloidal form (organic complexes) which is difficult to handle. According to [8], Fe in groundwater often exists in the form of Fe (II) ions, the amount of Fe above 1 mg/l can cause bitter taste, make the water smell fishy and have many yellow stains which could affect the quality of drinking and domestic water. At all sampling locations, the iron concentration was within the allowable limit of QCVN 09:2015/BTNMT [6].

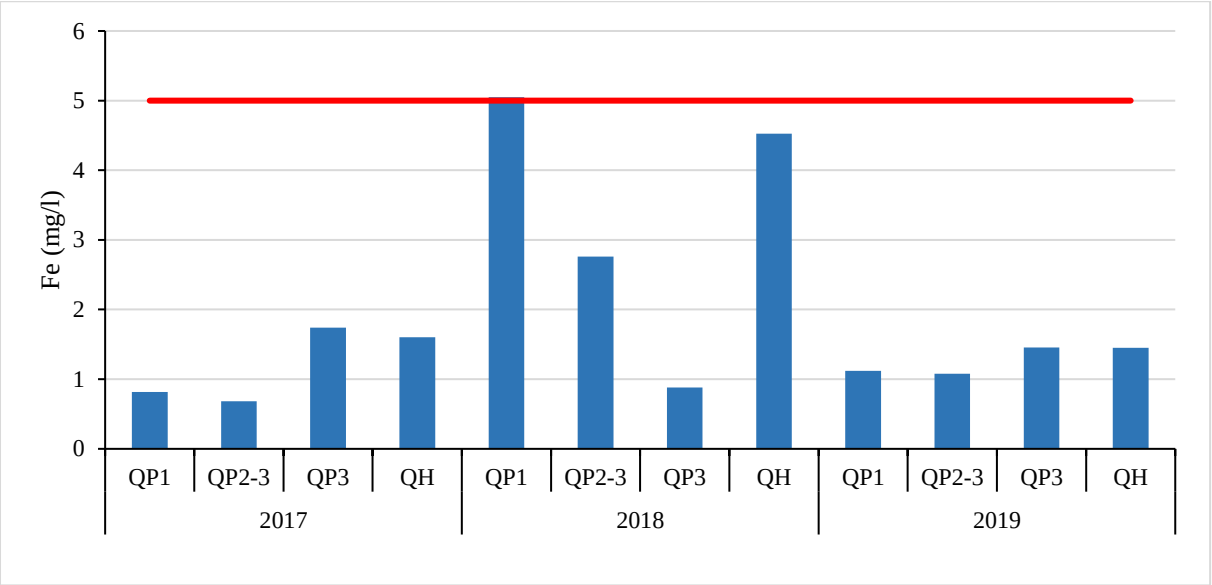


Figure 3. Fe in groundwater in Hau Giang province

*c. Sulfate*

The analysis results show that the $SO_4^{2-}$ concentration has an average value of 17.75 - 241.7 mg/l in 2017, 6.66 - 217 mg/l in 2018 and 11 - 133 mg/l in 2019. Sulfate in groundwater in 2019 tended to decrease compared to that ò 2017 and 2018. Previous studies showed that the sulfate concentrations in groundwater were normally in the ranges of 32 – 50 and 7.86 – 17.35 mg/l [9,10]. Sulfates are often present in water due to oxidation of sulfide-containing organic substances or pollution from wastewater from the textile, dyeing, tanning, metallurgy, and papermaking industries. According to [8] water with high sulfate concentration of greater than 250mg/l is toxic to human health. In this study, Sulfate in groundwater at monitoring points were within the allowable threshold of Vietnam groundwater quality standard of QCVN 09:2015/BTNMT [6] (allowable limit is 400 mg/l).

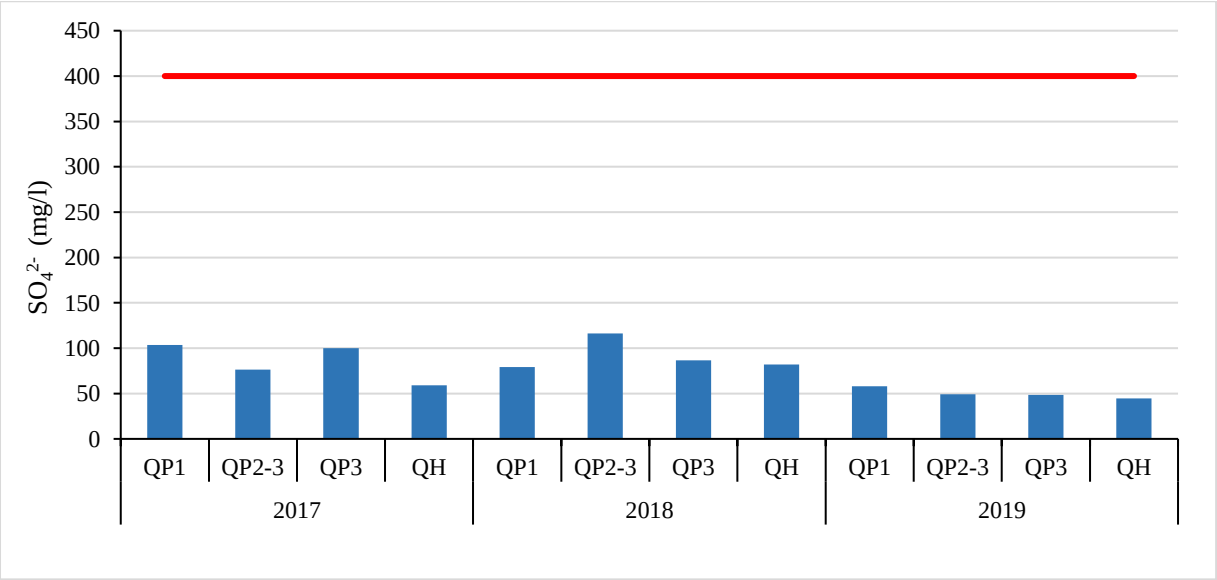


Figure 4. Sulfate in groundwater in Hau Giang province

*d. Nitrite*

Nitrite in groundwater in the years of 2017, 2018, 2019 were 0 – 0.061, 0.0015 – 0.661, 0 – 3.43 mg/l. Mean concentrations of nitrite in groundwater at all monitoring locations were within the allowable limit of QCVN 09:2015/BTNMT [6]. In 2019, there were two sampling locations having nitrite concentrations exceeding the permitted threshold of QCVN 09:2015/BTNMT [6]. The concentrations of $N\text{-}NO_2^-$ tended to increase over time, possibly due to the impact of agricultural production activities. It can be seen that the concentration of $N\text{-}NO_2^-$ in the sample in 2019 in Chau Thanh A district was relatively high and exceeded the standard, the reason could be because the use of agro-chemicals in agricultural production. According to [7], the concentration of nitrite in the groundwater environment in Bac Ninh varied from 0 to 1.15 mg/l during the period 2011-2012, which was higher than that in the present study. Nitrite is a compound of nitrogen formed during the decomposition of organic compounds. In water, nitrite is an intermediate product of the bacterial oxidation reaction from ammonia to nitrite and finally to nitrate. The lifetime of nitrite in water is very short because when it encounters oxygen in the air, it will convert to nitrate. The presence of nitrite in the water shows that the water source has been polluted for a long time.

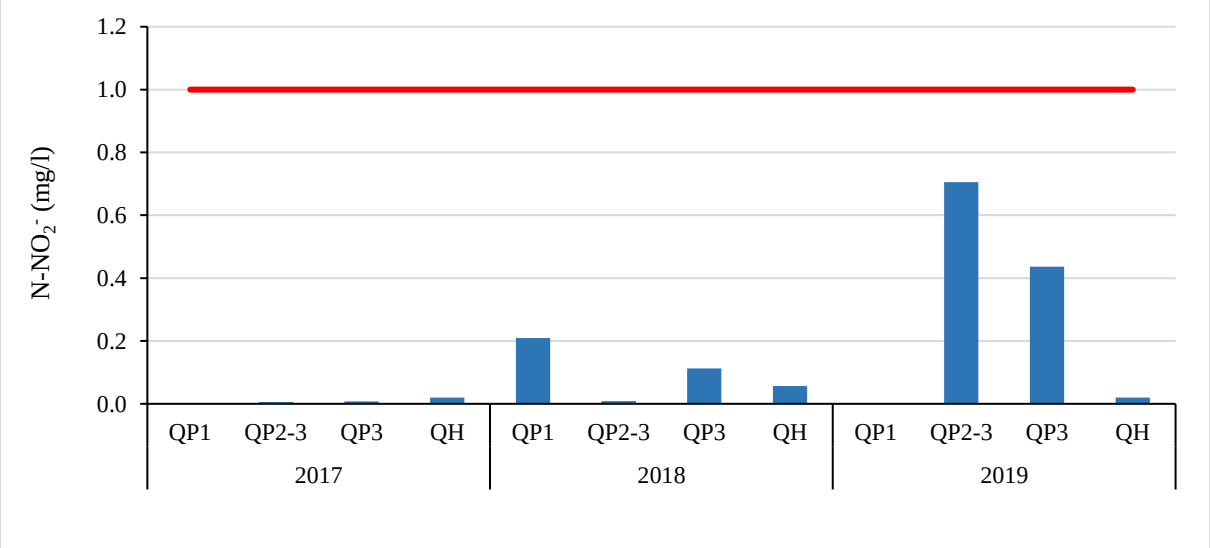


Figure 5. Nitrite in groundwater in Hau Giang province

*e. Nitrate*

Nitrate in groundwater of Hau Giang province in the tank over the years 2017, 2018, 2019 is 0-0.505, 0-0.53, 0-0.02 mg/l, respectively. According to [8], the concentration of nitrite in the groundwater environment in Bac Ninh ranges from 0 to 184 mg/l. Nitrate in groundwater in Soc Trang province in the period 2016 - 2018 ranged from 0.008 to 0.047 mg/l [11]. In general, all samples collected, the nitrate indicator was within the allowable range of QCVN 09:2015/BTNMT [6]. Nitrate is the highest oxidizing form in the nitrogen cycle and often reach significant concentrations in the final stages of biological oxidation [12-14]. In the water body, there is a lot of nitrogen in the form of nitrate, indicating that the oxidation process has ended. However, nitrates are stable only under aerobic conditions. Under anaerobic conditions, nitrate is reduced to free nitrogen that separates from water. But on the other hand, when the nitrate content in water is quite high, it can be toxic to humans, because when under the right conditions, in the digestive system they will convert to nitrite and combine with red blood cells to form a substance that does not transport oxygen, causing pallor of anemia [2].

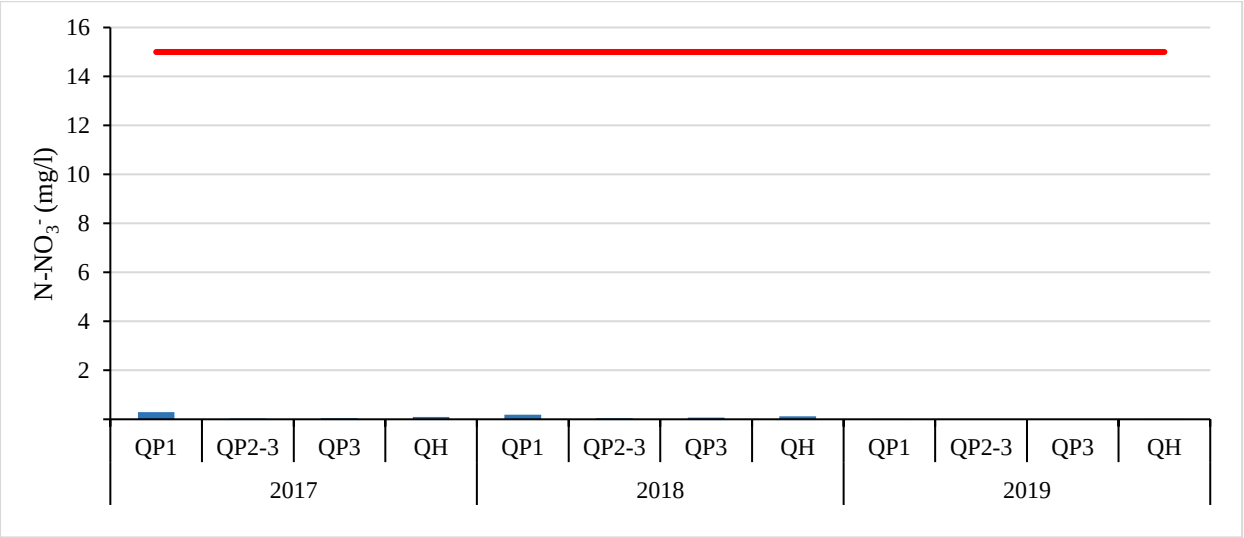


Figure 6. Nitrate in groundwater in Hau Giang province

*f. Ammonium*

There are many causes of ammonium contamination in groundwater, but the main cause is the excessive use of organic fertilizers, pesticides, pesticides, solid waste, and blanket waste. Farming and domestic water in the area is not collected and treated, organic compounds decompose to form ammonia and ammonium, which go into surface water and directly seep into groundwater, causing serious impacts on water sources [12-14]. The process of decomposition of organic matter and compounds mentioned above accelerates the process of ammonium contamination into groundwater. In addition, the degree of pollution also depends on the type of cultivation of each area, geological structure, stratigraphy and the release of pollutants on the land surface. Plants have the maximum ability to absorb about 0-45% nitrogen fertilizer, 40-45% phosphorus and 40-50% potassium, so there is about 55-65% residual fertilizer in the soil, over time. They infiltrate into groundwater and cause serious groundwater pollution [13-14].

The analysis results show that the concentration of $N\text{-}NH_4^+$ in groundwater over the years 2017, 2018, 2019 is 0.03 - 14.07, 0.065 - 14.1, 0.21 - 6.61 mg/l, respectively. Previous research also showed that ammonium content in groundwater in Soc Trang province in the period 2016 - 2018 ranged from 0.764 to 5.3 mg/l [11]. Research by [12] showed that ammonium in groundwater in Pleiku the period 2014 - 2018 was at 0.02 - 0.23 mg/l. This proves that the risk of ammonium contamination in groundwater in Hau Giang is in an alarming situation. Ammonium actually does not directly affect human health when in low concentrations, but during the extraction, storage and processing, ammonium is converted into nitrite and nitrate, which are toxic to humans as it can be converted to nitrosamines, which are potentially carcinogenic to humans. The presence of ammonium in groundwater indicates decomposition of nitrogenous organic matter, which is also a sign of water contamination. High concentrations of ammonium occurred over a large area covering almost the entire study area. It can be seen that the groundwater of the study area is heavily polluted with ammonium.

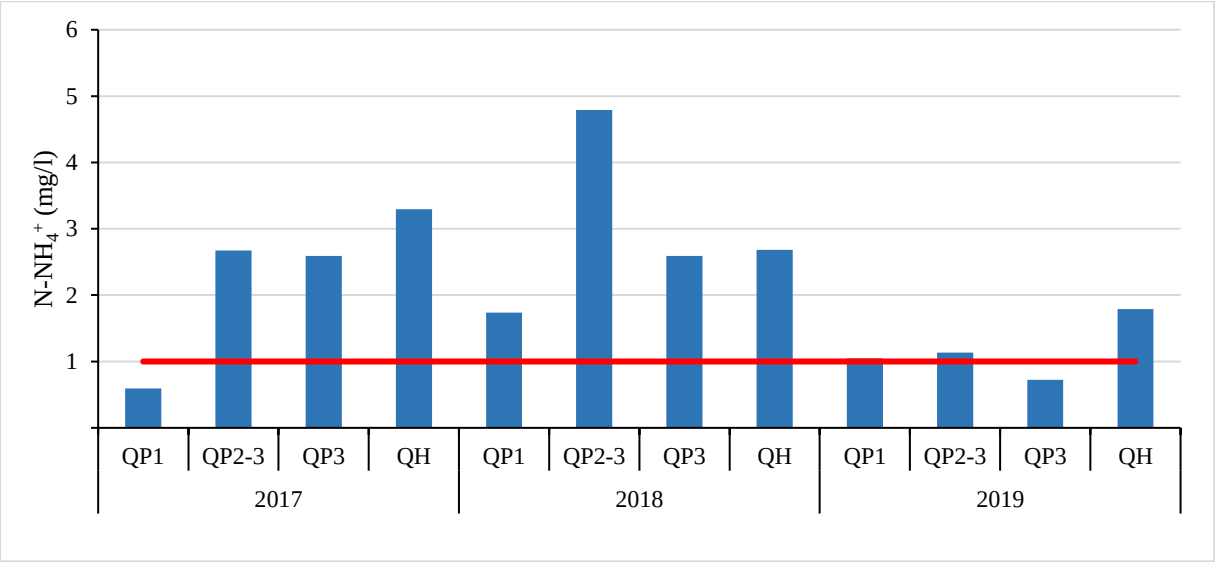


Figure 7. Ammonium in groundwater in Hau Giang province

*g. Hardness*

The hardness in groundwater in Hau Giang province over the years 2017, 2018, 2019 is 1,103-1497.5, 191.54-302.3, 0.706-1411.5 mg/l, respectively. The hardness in 2018 decreased compared to 2017 but increased again in 2019. Previous research showed that the hardness in groundwater fluctuated between 125-138 mg/l [13], 11.4-143.9 mg/l [14] and 2.33-4 mg/l [14]. Water hardness is not generally considered hazardous because it is not harmful to human health. But when the hardness in water is high, it will also affect human health such as causing kidney stones, digestive disorders, and blockage of blood vessels. In addition, according to [8], water with high hardness interferes with daily life and production: washing clothes requires soap, cooking food takes a long time to cook, and reducing product quality.

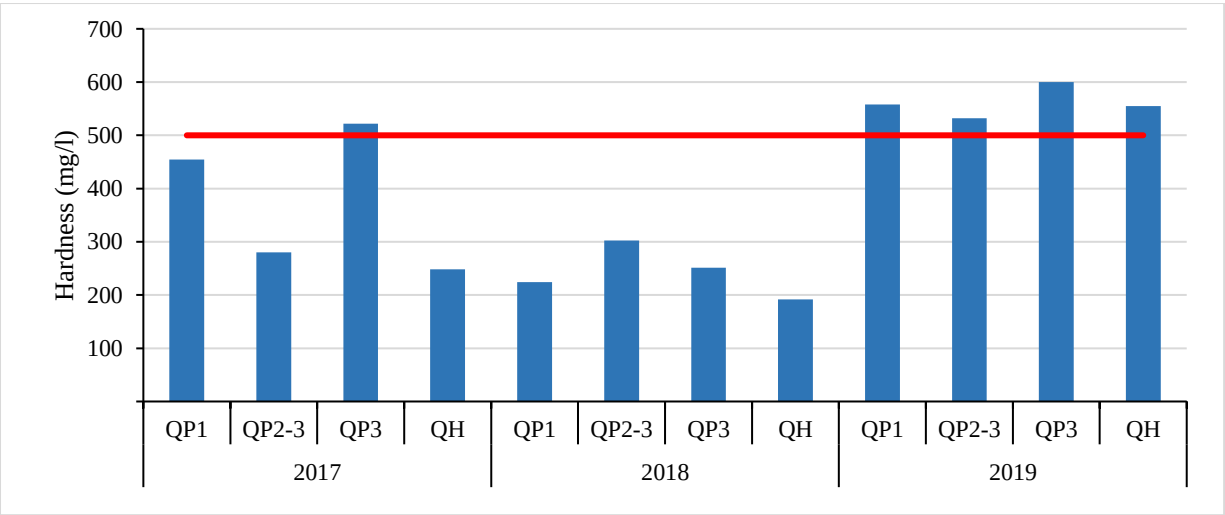


Figure 8. Hardness in groundwater in Hau Giang province

*h. Chloride*

The average chloride concentrations in 2017, 2018, 2019 fluctuated between 0.1 - 3493.5, 0.1 - 1919, 0.156 - 4104.1 mg/l, respectively. Chloride is the main ion in natural water representing salinity [7]. Chloride is most abundant in sea water and salt deposits. In fresh water and groundwater, the chloride concentration usually ranges from 20 to 800 mg/l. Former study presented that chloride in drilled well samples ranges from 5.55 to 1.86 mg/l [8]. According to [8], the large concentration of $Cl^-$ ions in water (>250mg/l) makes the water taste salty. Groundwater sources with chloride concentration up to 500-1000 mg/l can cause kidney disease [2].

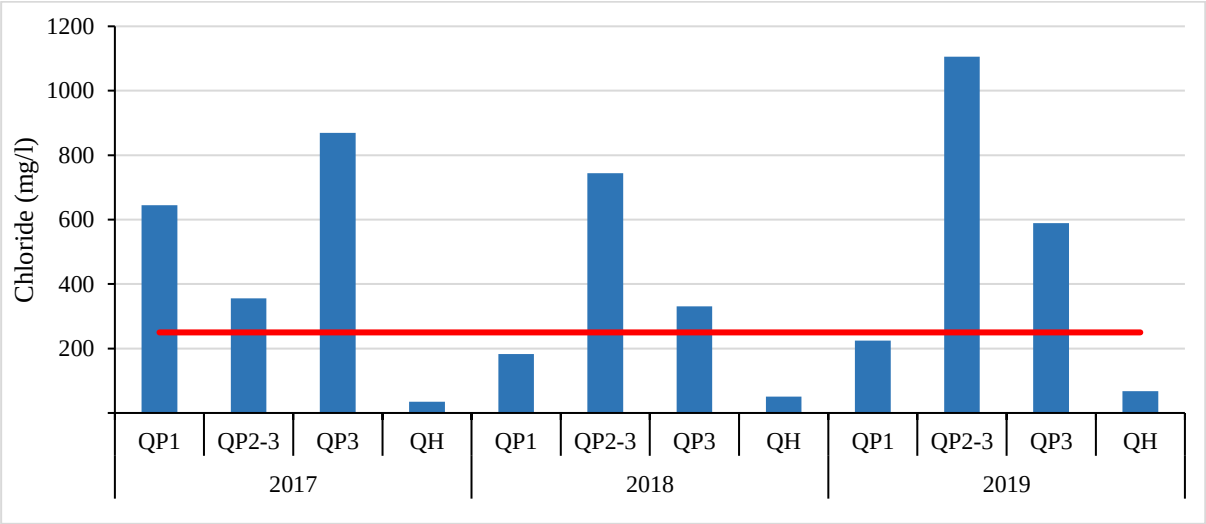


Figure 9. Chloride in groundwater in Hau Giang province

*l. Permanganate*

The average permanganate index in groundwater in 2017 was 0 - 2,075 mg/l, in 2018 it was 0.2 - 16.29 mg/l, in 2019 it was 0 - 10.8 mg/l. In general, the permanganate index was quite low in 2017 and had a large fluctuation in 2018 increasing sharply compared to 2017 and decreasing gradually in 2019. Previous studies have shown the permanganate index in groundwater at about 0.33 – 2.63 mg/l [11], 0.47 – 0.63 mg/l [12]. Oxidation capacity index refers to the contamination of organic substances in groundwater. In areas of agricultural and industrial development, the amount of permanganate index is often elevated and this is a sign of the presence of organic matter and a lack of oxygen in the water.

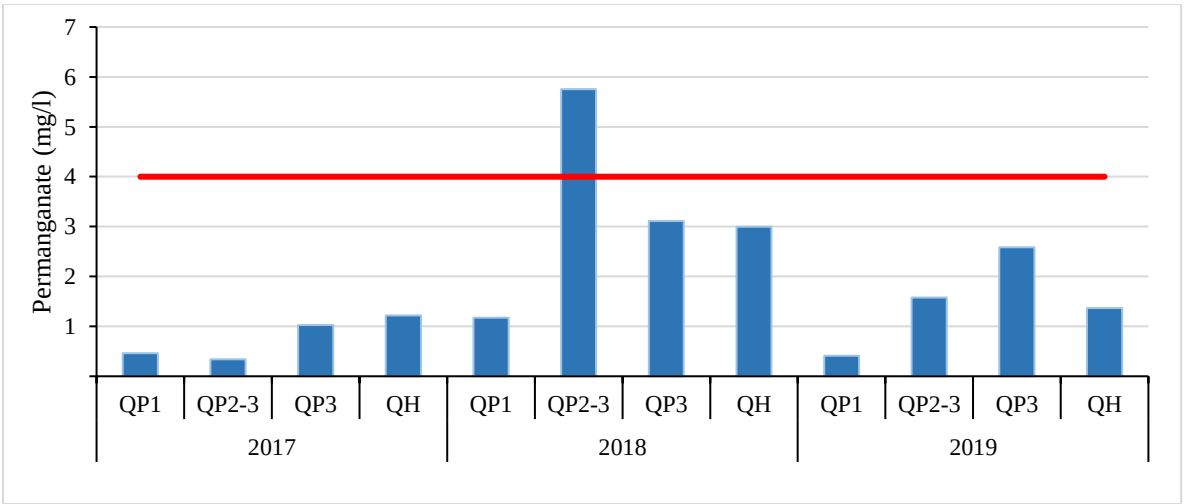


Figure 10. Permanganate in groundwater in Hau Giang province

## 4.0 Conclusion

Groundwater quality parameters including pH, Fe, $SO_4^{2-}$, $N\text{-}NO_2^-$, $N\text{-}NO_3^-$, hardness, $N\text{-}NH_4^+$, $Cl^-$ and permanganate showed that up to all parameters at 8 sampling points exceeded the permissible thresholds of QCVN 09:2015/BTNMT except pH, $SO_4^{2-}$ and $N\text{-}NO_3^-$. All groundwater indicators tended to increase in 2018 and decrease in 2019, except for $N\text{-}NO_2^-$, hardness and chloride tended to increase gradually over the years. Main causes of groundwater pollution in the study areas could be from domestic, agricultural and industrial wastes. More attention needs to be paid for managing the groundwater quality in Hau Giang province.

## Acknowledgements

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