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Assessing existing surface water supply sources in the Vietnamese Mekong delta: case study of Can Tho, Soc Trang, and Hau Giang provinces

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Abstract:

In the recent past, the quality of surface water for domestic use in the Vietnamese Mekong delta (VMD) has been seriously affected by severe water pollution and intense saltwater intrusion. This study aims to assess existing surface water sources in the provinces of Can Tho, Hau Giang, and Soc Trang. By assessing the existing salinity status to point out areas of low salinity frequency hazards, this work identifies suitable areas through water quality assessments. The results indicated that the Hau river and its tributaries from Ke Sach (in Soc Trang) toward inland has a lower risk of salinity. This indicated that water sources in Ke Sach could be a possible raw water source for water supply treatment plants in Soc Trang. Specifically, water sources including the Hau river's mainstream, Cai Khe canal, Khai Luong canal, and Thom Rom canal in Can Tho city, the Hau river's mainstream, the Mai Dam river in the Hau Giang province, and the Cai Con river, the Hau river's mainstream in Ke Sach, and the Cai Vop and Cai Tram canals in the Soc Trang province, could be exploited for water supply. However, a treatment for pollutants such as BOD_5, COD, TSS, and total coliform in these water sources musts be taken into consideration.

Keywords: **saltwater intrusion, surface water quality assessment, surface water supply.**

Classification number: **5.1**

Introduction

The VMD, home to over 21 million people, is a part of the Mekong delta that covers an area of approximately 3.9 million hectares with a dense maze of canals and rivers [1]. Water plays a significant role in strategies for economic growth for the region in general and specifically for the provinces of Can Tho, Hau Giang, and Soc Trang [2]. Nonetheless, in recent years, the impacts of climate change and sea level rise are serious threats as they cause extreme phenomena such as salinity intrusion and severe droughts [3, 4]. These negative effects on water supply security in the delta creates possible threats to water supply systems. While groundwater is widely used in coastal areas, surface water is still a primary source of water in the provinces. However, the substantial extraction of groundwater for domestic use causes delta-wide subsidence that necessarily restricts excessive groundwater extraction [5, 6], therefore, the probability of switching to surface water needs to be taken into account. Rivers and canals in this region are usually considered as surface water resources for water supply systems. Nevertheless, the degradation of surface water quality due to pollution from anthropogenic activities has also limited the availability of surface water for domestic use in these provinces [7]. Assessing the water quality from the rivers and canals therefore is an important part of identifying acceptable areas for surface water supply abstraction to support water supply management. Currently, most water treatment plants in the VMD experience low capability of desalination followed by expensive construction and operation costs [8, 9]. Meanwhile, salinity is a significant criterion for the selection of water sources. Selected water sources are characterized by low frequency of salinity. Geographic Information System (GIS) software has continually demonstrated very informative spatial analyses in water monitoring research that supports water supply management. This paper aims to evaluate existing salinity and surface water quality in Can Tho, Hau Giang, and Soc Trang provinces, thereby building effective strategies and providing support to water utilities for water supply security in the context of climate change and local human activities.

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Methodology

Scope of the study

This study was undertaken in three VMD provinces with low-lying terrain, namely, Can Tho, Hau Giang, and Soc Trang (Fig. 1). Located in the South of Hau river, the study area comprises a relatively dense network of river courses and canals including natural river systems and canals. The 3 selected provinces are characterised by monsoon-dominated seasonal climate divided into the rain season (July-October) and the dry season (December-May). The tidal regime includes two tidal cycles on a daily basis that play an important role in saline water dynamics and water quality [10].

Method of research

This study uses an approach of evaluating surface water quality for water supply to identify areas of low salinity effects and water quality assessment [11]. This approach assesses existing salinity to find out areas with low salinity frequency and thereby evaluate the water quality to select the areas of acceptable condition for exploiting water supply. Research process were described as Fig. 2 as follow:

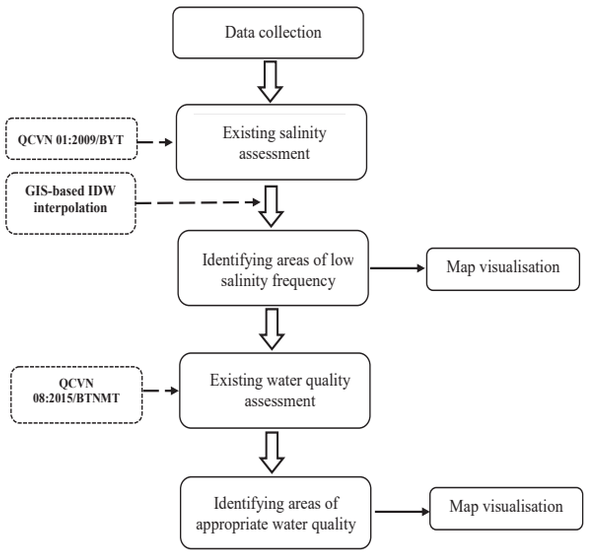


Fig. 2. A flowchart of research steps.

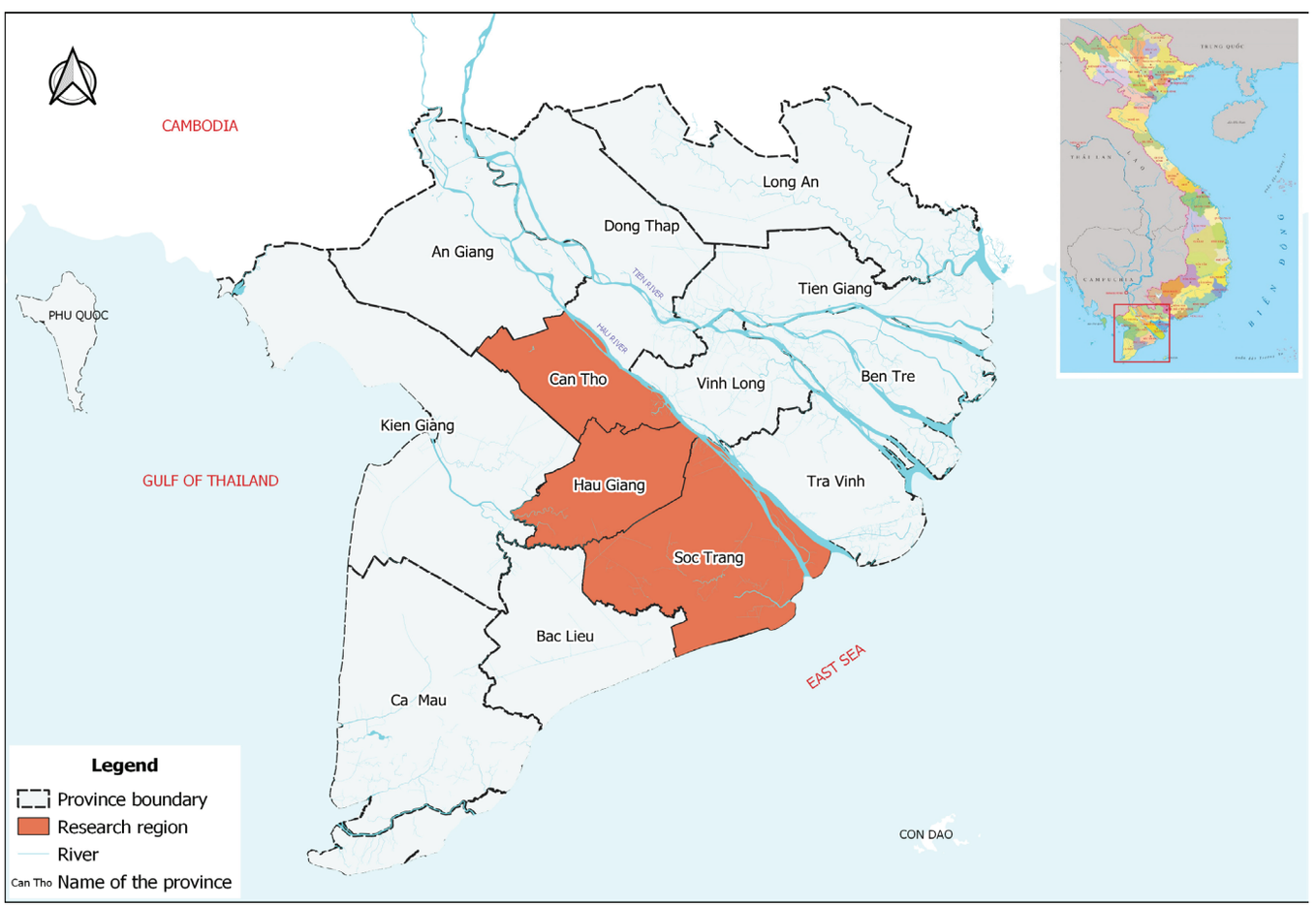


Fig. 1. Map of the study area.

The process consisted of 5 steps. Firstly, the study collected relevant data and performed data analysis (step 1). Then, the collected data of salinity was compared to the National Technical Regulation on the Drinking Water Quality (QCVN 01:2009/BYT). Step 3 involved defining areas that had low salinity effects by GIS-based interpolation. Spatial-analytical tools have increasingly been utilized for spatial assessment on water quality. Particularly, Inverse Distance Weighted (IDW) interpolation is easy implement and is available in almost any GIS-based platform under a wide range of conditions [12]. To create thematic maps, the boundary of the study area was digitised from collected toposheets using QGIS software, a popular Open Source GIS. In step 4, the selected areas of low salinity were then assessed for water pollutants. Statistical analysis, like mean, standard variation, etc., was used to evaluate the collected data. The results were compared to the National Technical Regulation on surface water quality (QCVN 08:2015/BTNMT) to find the areas of acceptable water quality. The precise locations of the monitoring sites were recorded using GPS receivers and were then imported into the GIS platform. This results in areas of appropriate water pollution were visualised on a map in step 5.

Data sources

Monitored salinity data (2015-2019) and monitored surface water quality (2016-2018) were collected from local Departments of Irrigation and Centers for Environmental Monitoring. The monitored surface water quality included parameters: pH, DO, TSS, BOD_5, COD, NH_4-N, NO_2-N, NO_3-N, PO_4-P, total iron, and total coliform. The study then applied statistical analysis to calculate the maximum and minimum values, the total amount, and the frequency of occurrence.

Results and discussion

Assessment of salinity hazard in existing water sources

Assessment of existing salinity data: salinity is considered as a crucial parameter in planning for water exploitation plants since saltwater intrusion severely influences water supply sources in coastal provinces. Based on the results shown in Table 1, salinity in 2016 was somewhat higher than in 2017. According to a report of CGIAR [13], the 2016 drought and salinity intrusion greatly influenced 11 out of the 13 provinces in the MRD causing a lack of freshwater for domestic use and farming activities. Data at monitoring points in the Soc Trang and Hau Giang provinces that reside closer to the sea, more exceeding the permitted salinity according the QCVN 01:2009.

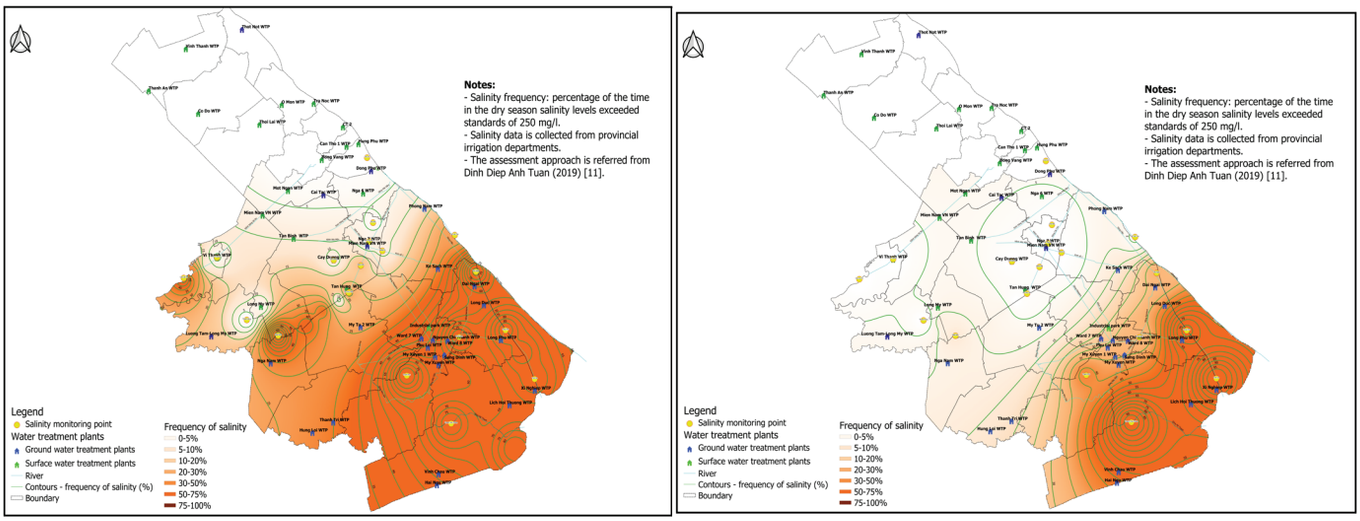
Table 1. Salinity values at monitoring points in the Can Tho, Hau Giang and Soc Trang provinces.

	Monitoring points	Salinity in 2016 (mg/l)	Salinity in 2017 (mg/l)	QCVN 01:2009
Can Tho	Cai Cui	12-**350**	6-120	250-300
Hau Giang	Cay Duong	22-**680**	25-65	250-300
	Ranh Hat	26-**1,305**	15-**756**	250-300
	Mang Ca	19-**1,290**	11-**360**	250-300
	Cho Noi	18-**535**	12-65	250-300
	Ho Thu NB	14-160	15-65	250-300
	Ho Thu TPH	15-**605**	11-50	250-300
	Cau Cai Tu	14-**13,826**	13-50	250-300
	Ho Thu VT	16-**398**	15-20	250-300
	Thuan Hung	19-210	16-120	250-300
Soc Trang	Thanh Thoi Thuan	388-**8,912**	88-**5,669**	250-300
	Tran De	1,772-**13,340**	831-**9,078**	250-300
	Long Phu	167-**10,517**	37-**7,510**	250-300
	Thanh Phu	45-**6,643**	39-**2,796**	250-300
	An Lac Tay	36-**3,820**	36-**1,112**	250-300
	Dai Ngai	111-**6,643**	75-**2,994**	250-300
	Nga Nam	54-**12,344**	65-**8,428**	250-300

Notes: values exceeding the standard are outlined in bold.

Map of frequency of salinity occurrence: as a result of GIS-based spatial interpolation techniques, the frequency of salinity occurrence in all provinces in 2016 was reported more severe than in 2017 (Fig. 3). In the drought of 2016, the study area was severely affected by salinity intrusion. In Hau Giang, saltwater has greatly intruded at some points in Vi Thanh city and the Long My district. Soc Trang, a coastal province, showed high frequency of salinity occurrences at Thanh Thoi Thuan, Tran De, and Long Phu. Can Tho had low salinity frequency although saltwater also occurred in 2016.

In 2017, salinity had generally not affected Can Tho city. Salinity of surface water is characterised by high spatial variability depending on the distance to the sea [14]. A detailed analysis shows that the saltwater intrusion is weaker further inland from the sea where river salinity is lower. The Hau river and its tributaries from the Ke Sach district (Soc Trang) towards the inland were less affected by the salinity compared to other areas. Therefore, it is possible to take raw water in these areas for water supply treatment plants.



(A) Salinity frequency in 2016 (severe salinity year). **(B) Salinity frequency in 2017 (normal salinity year).**

Fig. 3. Severe and normal salinity years in the Can Tho, Hau Giang, and Soc Trang provinces.

Water quality assessment of surface water supply source

Existing surface water supply sources: from the results of selecting areas of low salt frequency, the study then assessed the surface water quality in these areas. A summary of the physical, chemical, and microbiological parameters per province is presented in Table 2.

Table 2. Summary of characteristic of physical, chemical and microbiological of surface water in Can Tho, Hau Giang, and Soc Trang.

Parameters	Can Tho	Hau Giang	Soc Trang	QCVN 08:2015 (level A2)
pH	7.35±0.04	7.11±0.06	6.96±0.13	6.0-8.5
DO (mg/l)	**5.68**±0.16	4.32±0.46	3.11±0.64	5
TSS (mg/l)	**48.70**±6.76	**64.30**±14.98	**95.79**±8.45	30
BOD_5 (mg/l)	**6.01**±0.49	**12.71**±1.46	**8.06**±2.67	6
COD (mg/l)	12.58±1.23	**20.32**±2.35	**27.76**±4.29	15
NH_4-N (mg/l)	0.13±0.02	**0.35**±0.05	**0.82**±0.20	0.3
NO_2-N (mg/l)	0.02±0.004	0.04±0.009	**0.09**±0.03	0.05
NO_3-N (mg/l)	0.86±0.17	0.26±0.04	0.32±0.11	5
PO_4-P(mg/l)	0.07±0.01	**0.22**±0.15	**0.23**±0.009	0.2
Total Fe (mg/l)	0.29±0.04	**2.00**±0.54	**2.25**±0.48	1
Total coliform (MNP/100 ml)	1,982±106	**10,248**±384	**77,548**±1656	5,000

Notes: DO: dissolved oxygen; TSS: total suspended solids; BOD: biochemical oxygen demand; COD: chemical oxygen demand; NH_4-N: ammonium; NO_2-N: nitrite-nitrogen; NO_3-N: nitrate-nitrogen; PO_4-P: phosphate phosphorus; total Fe: total iron. Values exceeding the standard are outlined in bold.

The results in the Table 2 indicated that all provinces had various and different pollutants, but most were generated from TSS, BOD_5, COD, and total coliform. In particular, according to the level A2 standard in QCVN 08:2015/BTNMT, the TSS, DO, and BOD_5 levels at monitoring points in Can Tho city exceeded the standard limit. These results were also similar to the study of V.T.N. Giau, et al. (2019) [15], which indicated that TSS and BOD_5 in Can Tho river were much higher than the standard over the period 2010-2014. In Hau Giang, almost all average pollution parameters were higher than the limit of seriously polluted levels. Pollution from total coliform also reached a seriously polluted level. Both COD and TSS were in the slightly polluted level with the average pollution index exceeding the standard by 150% and 300%, respectively. Similarly, the total coliform, TSS, and BOD_5 were far beyond the standard in Soc Trang. D.D.A. Tuan, et al. (2019) [11] implied that a non-point source, caused by several domestic wastewater and sewage farms, constitutes the major pollution source in the Soc Trang watershed. Consequently, these results may somehow affect water supply intake to surface water treatment plants in all three provinces.

Fig. 4 revealed that the overall frequency of occurrence of water pollutants in Can Tho City was significantly lower than that of the Hau Giang and Soc Trang provinces. On the other hand, both Hau Giang and Soc Trang were in worse situations in terms of the overall frequency. However, the frequency of occurrence of both nitrogen and phosphorus (N and P) in Hau Giang was at the slightly polluted level compared to that of Soc Trang. Excessive anthropogenic N and P input may limit trophic interactions and quality of water sources [16]. The impact of wastewater resources from concentrated populations living along rivers and canals, along with industrial waste, has caused surface water pollution in the region [17].

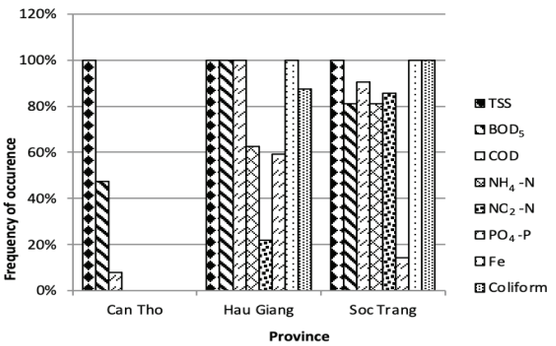


Fig. 4. Frequency of surface water pollutants in Can Tho, Hau Giang, and Soc Trang.

Potential surface water supply sources: as indicated in Fig. 5, the frequency of TSS showed up at almost all the monitoring points in Can Tho city with a substantial level over the given period. The figures of BOD_5 and total coliform experienced high frequencies at monitoring points along the Hau river, especially at the city's core urban districts like Ninh Kieu, Binh Thuy, and Cai Rang, that are shaped by the city's population density and industrial activities. Nevertheless, in general, water sources in Can Tho are still possible for water supply. Conversely, the occurrences of BOD_5, COD, and total coliform pollutants appeared at a high rate in Soc Trang and Hau Giang. Accordingly, to exploit

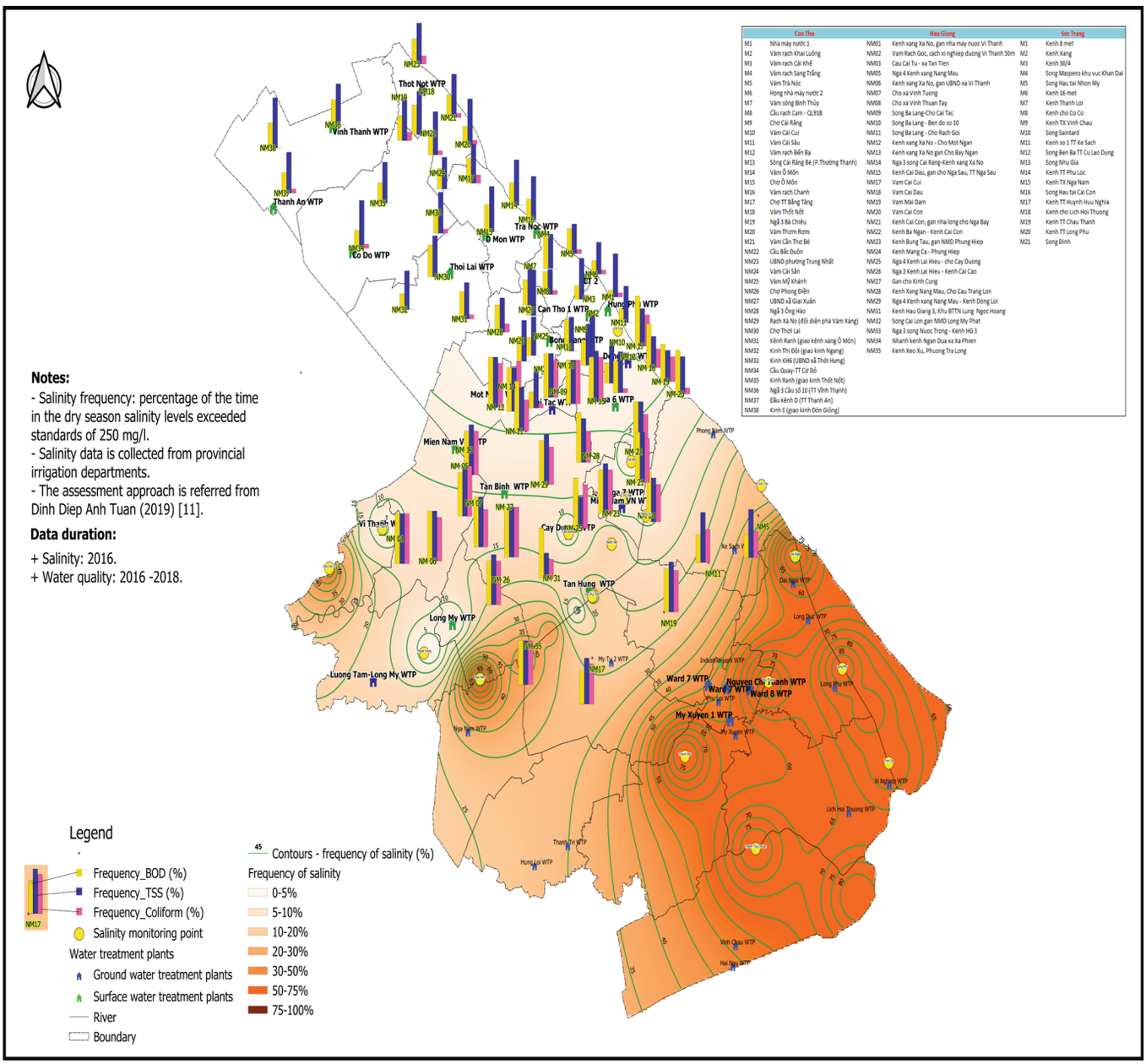


Fig. 5. Frequency of water pollutants and salinity occurrence in Can Tho, Hau Giang, and Soc Trang.

water from these sources, the appropriate preliminary treatment for water supplies must be implemented.

Given the results of surface water quality, the three provinces could exploit water sources from the Hau river and its main tributaries. In detail, surface water sources at sites off the Hau river's mainstream in Can Tho city. In Hau Giang, it is possible for abstracting water for the treatment plants along the Hau river's mainstream, the Mai Dam river, and the Cai Con river. Moreover, the water resources from the Hau river in Ke Sach, and Cai Vop, Cai Tram canal located in Ke Sach, Soc Trang can be considered as a suitable surface water resource for the water treatment plants in Soc Trang as well.

Conclusions

This study used an integrated approach of assessing current salinity to select areas of low saltwater frequency associated with assessing water quality in these areas. This research also applied the IDW technique to interpolate areas of salt influence and generated a GIS-based map to display more robust and informative data.

It is concluded that salinity tends to decline towards inland. Surface water sources in Soc Trang are somehow the worst influenced zone by saltwater intrusion among the three provinces. The Hau river and its tributaries from the Ke Sach district (Soc Trang) towards inland had a lower risk of salinity. This indicated that water sources in Ke Sach could be a possible raw water source for water supply treatment plants in Soc Trang.

The results of this study will contribute to urgently needed decision-making about water quality assessment and the water source selection process in these three provinces. However, further study needs to be implemented to collect the primary data for calibration data.

COMPETING INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this article.

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