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IMPACT OF FLOOD ON WATER QUALITY: A CASE STUDY IN A FLOOD-PRONE AREA OF THUA THIEN HUE PROVINCE

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Abstract. People living in flood-prone areas are vulnerable to damages caused by annual floods, including changes in water quality. Seasonal flooding alters water quality in many aspects by introducing silt, nutrients, organic compounds, and sometimes bacteria. In this study, 50 household interviews in Quang Thanh commune - Quang Dien district, the flood-prone area in Thua Thien Hue province, were conducted to identify the flood characteristics. A total of 36 water samples, including surface- and pipe water, were collected and analyzed the basic parameters in December 2019 and June 2020 to preliminarily demonstrate the main impacts of the flood on water quality. In general, in some aspects, flood helped reduce the organic contaminants (based on DO, BOD, and COD values assessment) and salinity, and somehow increase the total coliform and E. coli at most of the sampling stations. Unpredictable weather and hydropower plant from upstream were believed to be the main causes of flood volume reduction in recent years, which also contributed to changes in water quality.

Keywords: impact of flood, water quality, surface water, pipe water, Thua Thien Hue.

1 Introduction

Central Vietnam is located in the humid monsoon tropics, characterized by the combination of low mountains, short and steep rivers, and a long coastline. Annually, heavy rain is one of the main causes of flash floods in the region, especially in the coastal flood-prone areas [1]. In general, the two major anthropogenic activities that directly affect the flood characteristics are deforestation, which increases runoff, and the building of upstream dams, which have controlled the water and sediment flows [2]. Recent studies on the impacts of floods mainly focus on assessing the livelihood, economic, social, and environmental damages [3-5]. However, the various aspects of flooding investigated mostly pertain to flood extent, water depth, and flow velocity, whereas there are few mentions of floodwater quality, which is linked directly to many health problems [6-7] due to the large-scale contamination of drinking water (surface water, groundwater, and distribution systems). In general, the main water quality parameters that should be considered for floodwater management at the coastal area include water

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temperature, pH, salinity, dissolved oxygen (DO), suspended solids (SS), phosphorus and nitrogen, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and bacteria. On the one hand, the levels of DO, BOD, COD provide information on organic pollution, while nitrate, nitrite, ammonia are the indicators for nutrient pollution. Salinity, pH, temperature, and bacteria, on the other hand, can affect aquatic organisms.

Basically, floods can change the water quality in both directions. It could either decrease water quality due to spatial contaminant transmission; or improve the quality or create no specific change with its capacity to dilute the contaminants/pollutants already existed in the waterways. Given its importance and the limited knowledge, taking Quang Thanh commune (10,75 km², 9534 population) in Quang Dien district, the flood-prone area in Thua Thien Hue province, Central Vietnam as a case, this study seeks to i) identify the flood characteristics and ii) demonstrate the main impacts of the big flood in 2019 as a case to both surface- and pipe water quality in the flood-prone area. The data obtained from this study could serve as the background information for local authorities to establish suitable water quality management and scenarios to cope with the effects of flooding on water quality in the region.

2 Materials and methods

2.1 Study site

Thua Thien Hue province, belonging to Central Vietnam, is a narrow territory in which the delta is in between the mountainous upstream area and the coastal area with sand dunes. The region has a typical tropical monsoon climate with high humidity (average 88%, 2017), heavy rainfalls in the wet season (September to March next year, total rainfall 4105 mm, 2017), and drought in the dry season (April to August, sunshine duration 1746 h, 2017) [8]. This study was conducted in Quang Thanh commune (10,75 km², 9534 population) in Quang Dien District, Thua Thien Hue province. The commune is considered to be highly affected by annual floods due to its topography of a low-lying basin downstream of the Bo River - an important tributary of the Huong River, and bordering the Tam Giang lagoon from the North [9] (**Figure 1**).

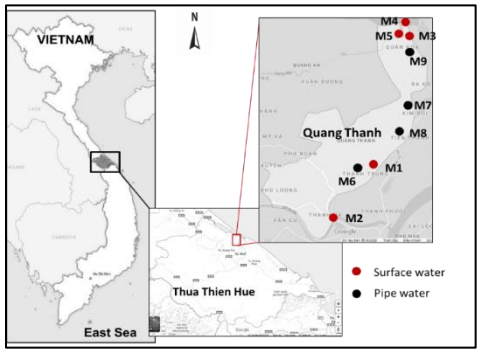

Fig. 1. Study area and sampling stations

This study combines both household survey and monitoring study to link the flood characteristics with its potential impacts, particularly, on water quality at the study site.

2.2 Household survey

This study applied the social practice approach to investigate the area's historical flooding background as well as local people's perceptions and assessments of the impacts of floods on their livelihoods and water resources. Quantitative research is used, including desk study and field research. The main data collection method used for the social-economic survey of the research include survey by questionnaire (50 samples, at household level). The structured questionnaire contains three parts: Part 1 collected household characteristics; Part 2 focused on water-related issues; and Part 3 explored flood-related information. Four selected villages for field research are Quan Hoa (n = 20) - located close by the Tam Giang lagoon, Kim Doi (sample size n = 9), Tay Thanh (n = 6), Thanh Trung (n = 15) - located along the tributaries of the Bo River. The interviews were conducted in November 2019, during the flooding period of the year.

2.3 Water sampling

To understand the changes of water quality due to the occurrence of flood, this study was designed to collect two types of water, surface water, and piped water, taken at two periods. Specifically, one campaign was carried out on the 1st and 2nd of December 2019 - one day right after the last flood had receded; the following one was on the 2nd and 3rd of June 2020 - represented the normal water quality during the dry season. A total of 36 water samples were collected with 10 surface water samples and 8 pipe water samples per campaign. Sampling stations are shown in **Figure 1** and described in **Table 1**.

Table 1. Description of the sampling stations

Type of water sample	Stations	Description	Latitude	Longitude
Surface water	M1	Thanh Trung channel	16,5450	107,5724
	M2	Bo river	16,5312	107,5590
	M3	Inside the Tam Giang dike	16,5756	107,5863
	M4	Beyond the Tam Giang dike	16,5702	107,5895
	M5	Tam Giang sluice gate	16,5736	107,5764
Pipe water	M6	Household, Thanh Trung village	16,5379	107,5642
	M7	Household, Kim Doi village	16,5579	107,5786
	M8	Household, Tay Thanh village	16,5371	107,5606
	M9	Household, Quan Hoa village	16,5714	107,5761

Regarding surface water, composite water sample (1000 mL) was collected using Van Dorn sampler, at 50 cm water depth and 100 cm water depth, stored in plastic bottles previously rinsed with distilled water. Water samples for coliform and E. coli analysis were stored in 100 mL glass bottles previously sterilized.

In terms of pipe water, sample (1000 mL) was stored in plastic bottle previously rinsed with distilled water. Water samples for coliform and E. coli analysis will be stored in 100 mL glass bottles previously sterilized.

2.4 Water parameter analysis

In-situ measurement: for each sampling event, basic water quality parameters including pH, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solid (TDS), salinity, turbidity and temperature were measured in situ by a WTW Multi 340i instrument (Weilheim, Germany).

Laboratory analysis: biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), nitrogen ammonia (NH4), nitrogen nitrate (NO3), nitrogen nitrite (NO2), total dissolved iron, total coliform, E. coli, free chlorine (only for tap water samples) were analyzed, following Standard methods for the examination of water and wastewater, 23rd edition [10].

Quality control was processed through blank measurements, spiked samples, and repeatability and recovery experiments.

2.5 Data analysis

Quantitative data collected from the survey was entered into Microsoft Excel 2010 and then processed by IBM SPSS Statistic v20. Descriptive statistics such as mean, median, and frequency were applied. Qualitative data was kept in notes which later on would be categorized and analyzed accordingly.

Water quality parameter at each sampling station in a specific campaign was averaged from the two sampling dates described in **Table 1**. Water quality data between two sampling campaigns were compared. National technical regulation on surface water quality [11] and domestic water quality [12] were used as references for the water quality evaluation.

Particularly for pipe water samples, this study hypothesized that the sampling stations belonged to the same water distribution system of the city. Therefore, t-test analysis was conducted to identify if there were differences between pipe water quality parameter at the two sampling campaigns/seasons, at $p = 0.05$.

3 Results and discussion

3.1 Household demographic characteristics and general flood-related information

Household characteristics

Most of the interviewed people are over 30 years old (94 %), of which 64% are in the working-age (15 - 60), while 36% are over 60 years old. 90% of them have primary or secondary school education level and 6% are illiterate.

The main source of livelihoods of households in Quang Thanh commune is agriculture - aquaculture activities. There are 33 households engaged in agricultural production (66%) including rice cultivation, vegetable growing, and livestock, while ten (20%) rely on aquaculture culture for their income, living the rest for other activities. The average rice field of each household is ca. 2340 m^2 and the average water surface area of fish pond is around 4590 m^2, much smaller compared to that in the Vietnamese Mekong Delta [13-15]. Noticeably, due to the geographical distribution of the three villages, while in Quan Hoa, aquatic products are cultured in the lagoon, freshwater fish cage rafts along the Bo river are dominant in Kim Doi and Tay Thanh villages. In addition, fertilizers and pesticides are used commonly by rice and vegetable farmers (83%), and antibiotics are used for aquaculture production (100%). Around the paddy rice fields, pesticide containers and fertilizer packages are disposed (recorded during the field survey). This uncontrolled disposal would cause the spreading of agricultural chemicals to the surrounding environment, affecting water quality, soil microorganisms, etc.

Having developed their life along with the rivers and canals, the livelihoods of the local people are closely linked to water. Water for rice field and vegetable irrigation is pumped in from and drained out to the canal/river system, which would directly pollute the water environment due to washing out fertilizers and pesticides to the water body [14, 16, 17]. Pipe water is used for livestock of which wastewater is directly discharged to the surface water system, spreading bacteria and waste from animal manure. Additionally, there are number duck cages locating right in the river banks. Meanwhile, lagoon water is mostly used for aquaculture activities. It is required that the water used for the fish ponds must be clean, pumped in from the start of the season, the ponds will be then kept closed during the crop cycle, and discharged back into the lagoon at the end of the cycle. However, there is no wastewater treatment system in the commune.

Flood characteristics

Normally, each big flooding event (flood alert level 2 or 3) would prolong from 5 to 8 days (average 6.5 days) and happen once per year or two years. The period from July to November has mostly been agreed on by the respondents as the flood time of which flood magnitude

varies from 0.7 to 2 m (measured from the road) on average (**Table 2**). However, recently, local people have noticed that big floods have not occured in the last three years.

Table 2. Flood characteristics based on respondents' background

Duration (average, days)		6,5
Frequency (% respondent)	once/6 months	14
	once/year	38
	once/2 years	36
	no more flood recent years	12
Month occurring flood	Tieu Man	April
	Early flood	July
	Big flood	September
	Late flood	November
Flood magnitudes (average, m, from road)	Highest	2
	Shortest	0,7
Impact places	Longest flood duration	Agricultural area > Aquaculture area > Residential area
	Highest water level	Aquaculture area > Residential area > Agricultural area

In addition, the average flood duration varies between hamlets, so does its impact. Quan Hoa is a low-lying area considered as a coastal village. It locates at the estuary of Bo River, surrounded by aquaculture ponds and rice fields. This village is therefore affected by both tidal and flash floods. Flood events in this place usually maintain longer than in the other areas (8 days), which isolates the village from the neighboring ones during the flood surge. Kim Doi village is located close to Quan Hoa but upstream, where the floods stay around 7 days. Tay Thanh and Thanh Trung suffer shorter flood duration (5 days) than the other two above. The advantages of Tay Thanh and Thanh Trung are i) locating at the higher land and ii) close to the river banks which facilitates faster water receding to the river.

Floods have had a significant impact on the agricultural- aquacultural sector (long duration and high water-level). Cultivation areas have been located near the waterways for water access for production, while the public sectors (e.g., hospitals, schools, post offices, *etc*.) are built in high land. Those settings on the higher lands are also considered as shelters for evacuating local people during severe storms or big flood events.

3.2 People's awareness and assessment of the effects of floods on their lives

The view of local extensionists

Recently, water flow, especially during the flooding season, is mainly controlled by the dam systems upstream; the water characteristics, therefore, have been changed with fewer nutrients and sediment. In particular, since the Binh Dien hydropower plant was established in 2009, the flood volume has been greatly reduced. Until recently, the quality of surface water is still problematic to control. According to a report of the People's Committee of Thua Thien Hue Province, the mass dead fish phenomenon in 2018 was caused by the water pollution from the intensive poultry cages and livestock close by the river and channel systems (Report No. 185 / BC - People's Committee of July 27, 2018, Thua Thien Hue Provincial People's Committee). Another explanation from local authorities was that the controlled water flow caused erratic water flow. And secondly, due to the sources of discharge from upstream along the river, the authorities were put in a passive position that they could not manage and control water quality in the upstream.

Local people's assessment

Table 3 shows the impacts of flood on living of local people according to their opinions.

Table 3. Advantages and disadvantages of flood according to local people's assessment

Effects of flood		Respondent (%), (n = 50)
Advantages	Improve soil quality	48
	Bring aquatic resources	22
	Refresh water of fish ponds	36
	Provide alluvial to reduce fertilizer usage	48
	Kill rats, insects	4
	No advantage	16
Disadvantages	Reduce agricultural production	64
	Degrade the infrastructure	36
	Cause property loss	42
	Cause waterborne diseases	8
	Pollute water sources	16
	Cause casualties	0

Most local farmers expect the annual floods to refresh the whole water system of the fish ponds (36% respondents) and enrich the soil/provide alluvial to reduce the fertilizer application (48%). Particularly, local people in Quan Hoa village - whose main livelihood is fishing and

aquaculture - consider flood as a source of natural aquatic animals. However, recently, local people complain that the amount of alluvial or aquatic resources bringing from the flood is reduced significantly due to the dam building upstream, which is inlined with the opinions that the extensionist mentioned above.

Households now assess floods as having only a short-term vulnerability. Their main concern is the loss of rice/vegetable or aquaculture production if the flood comes before the harvesting time (64% respondents). No one mentions the possibility of pollutants transportation (pesticides, fertilizers, animal waste, etc.) via waterborne during flooding time. The understanding and concern of local farmers in water quality and water treatment are also limited. Diseases or injuries caused by floods are no longer a concern of the local people.

3.3 Variation of water quality due to the impact of flood

Surface water

Table 4. Water quality parameters of measured surface water samples

	Flooding season (Dec 2019)					**Dry season (June 2020)**						
	(M1)	(M2)	(M3)	(M4)	(M5)	(M1)	(M2)	(M3)	(M4)	(M5)	QCVN 08-MT:2015/BTNMT (A2)	LODs
SS (mg/L)	5.3	5.9	7.1	7.5	11.8	6.3	6.6	7.7	7.5	11.9	30	
P-PO4 (mg/L)	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.01	< LOD	0.02	0.2	0.01
T-P (mg/L)	0.07	0.06	0.04	0.07	0.06	0.10	0.10	0.08	0.07	0.15	nd	0.02
N-NO2 (mg/L)	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.05	0.005
N-NO3 (mg/L)	0.17	0.04	0.12	0.14	0.11	0.17	0.16	0.05	0.06	0.06	5	0.01
N-NH4 (mg/L)	0.08	0.03	0.04	0.04	0.03	0.13	0.04	0.03	0.08	0.02	0.3	0.02
T-N (mg/L)	0.25	0.44	1.2	1.08	0.68	0.53	0.32	0.41	0.35	0.62	nd	0.02
BOD (mg/L)	1	5.4	1.6	1	6	2.7	6.2	0.7	0.4	7	6	nd
COD (mg/L)	< LOD	13.5	< LOD	< LOD	15	6.9	15.4	< LOD	< LOD	17.6	15	4.0
Total Fe	0.53	0.49	0.21	0.1	0.35	0.02	0.02	0.02	0.02	0.02	1	0.001

	Flooding season (Dec 2019)					Dry season (June 2020)						
	(M1)	(M2)	(M3)	(M4)	(M5)	(M1)	(M2)	(M3)	(M4)	(M5)	QCVN 08-MT:2015/BTNMT (A2)	LODs
(mg/L)												
Coliform (MPN/100mL)	1100	460	1300	150	460	460	320	700	92	40	5000	3
E. Coli (MPN/100 mL)	23	43	< LOD	75	23	9	18	4	14	8	50	3
Temp (oC)	22.2	21.5	19.9	20.4	20.6	34.1	32.2	32.8	33.5	32.7	nd	nd
EC (µS/cm)	72	101	6790	8730	3610	62	55	16170	23300	18450	nd	nd
DO (mg/L)	5.2	5.9	6.1	6.6	6.3	3.3	3	3.8	4.4	3.8	5	nd
pH	6.16	6.57	8.04	7.86	7.78	-	-	-	-	-	6-8.5	nd
Salinity (‰)	0	0	3.7	4.9	1.9	0	0	8.4	13.4	9.2	nd	nd

** nd: not defined*

< LOD: lower than limit of detection

Spatial differences

The significantly higher organic contaminants (BOD and COD) at the stations M2 (Bo river) and M5 (Tam Giang sluice gate) in both seasons (BOD values at M5 in dry season exceeded the national guideline for domestic usage purpose, 6 mg/L) compared to that at the other stations could be subjected by the domestic waste discharging directly to the Bồ river, while the Tam Giang sluice gate acted as the reservoir from the Sia river estuary, receiving all types of waste including agricultural, domestic, or handicraft activities. In the meantime, nutrient values at these two locations were slightly low.

The other parameters, such as E. coli, salinity, and EC values, at the station M4 (beyond the Tam Giang dike), were recorded higher than that at the other stations. This was simply due to the station belonged to the Tam Giang lagoon with brackish water. While the water at the station M3 (inside the Tam Giang dike) received the mixture between the Sia river water and lagoon water, resulting in lower salinity and EC values but with much higher total coliform (1300 MPN/100mL).

Water quality at the M1 (Thanh Trung channel) seemed to contain higher nutrients (compared to that at the other stations, particularly during the flooding season, except for TN and P-PO4)). This channel flows along Thanh Trung village where vegetable cultivation is the dominant production activity. Consequently, water drainage brought a large amount of fertilizers to the channel, especially after heavy rainfalls.

Temporal differences

The first obvious impact of flood to surface water was the decrease in salinity (consequently EC values) significantly at all sampling stations in flooding season compared to that in the dry season. Salinity is a very important parameter for brackish aquaculture production, directly affects the growth and yield. The sharp decrease of salinity during flooding time forced the local people at the study site to temporarily terminate the cultivation crops to reduce the risk of economic loss (*household interview results*).

Oxygen plays an important role as an indicator of water quality since it directly relates to the oxidation and reduction of organic and inorganic materials occurring in water. The measured data shown in **Table 4** indicated that BOD and COD values of the surface water samples collected in the dry season tended to be lower compared to those collected in the flooding season, which were also in accordant with the higher values of DO recorded in flooding season. This implied that the heavy rainfalls during the flooding event might help to increase the oxygen level of the surface water, which could be considered, in some aspects, as a good impact of flood on water quality. Noticeably, comparing with the National technical regulation on surface water quality [11], while most of the BOD and COD values recorded in both sampling campaigns met the guidelines for domestic usage purpose (< 6 mg/L and < 15 mg/L, respectively), most of the DO values (4/5 stations) in the dry season satisfied only for water transportation (> 2 mg/L).

Nutrients (N and P) in surface water were found to get decreasing during the period of flooding due to the effectiveness of dilution [18]. However, in this study, the variation of nutrients (N and P) did not follow a specific trend. In other words, the impact of flood/heavy rainfalls was not clear in the case of nutrient pollution. Whilst nitrogen levels (nitrate and nitrite) seemed to be higher in flooding season, the total phosphorous amount in the dry season tended to be dominant. In the meantime, ammonia and ortho-phosphorous levels occurred similarly at both seasons. This complicated dynamic was also mentioned in the work of Nergin [19]. At the study site, the sources of nutrients occurrence in surface water could be from fertilizer utilizing during agricultural activities, or from aquaculture feed or fish deaths. The positive point was that none of the sampling samples contained nutrients level exceeding the national thresholds for domestic usage purpose [11].

Theoretically, the strength and speed of flowing water during flood erodes the river banks and brings silt and suspended solids to surface water. Though, the results shown in **Table 4** noted no significant difference in SS values between the two sampling campaigns. The highest value was recorded at the Tam Giang sluice gate (M5, 12 mg/L) in both campaigns; however, it did not exceed the threshold for domestic use (20 mg/L). This was inlined with the report from local people interviewed (see **Section 3.1**) who claimed the hydropower plant at the upstream controlled and then reduced the amount of silt.

In terms of bacteria pollution, it is obvious that floods contributed to the spreading of total coliform and E. coli bacteria to surface water since the measured levels at all sampling stations (except M3) in flooding season were noticeably higher than that in the dry season (**Figure 2**). Particularly, E. coli levels found at M4 in the flooding season was higher than the threshold for domestic usage purpose (> 50 MPN/100mL). The sources of bacteria could be originated from the human and farm animal wastes washed off by heavy rains [20].

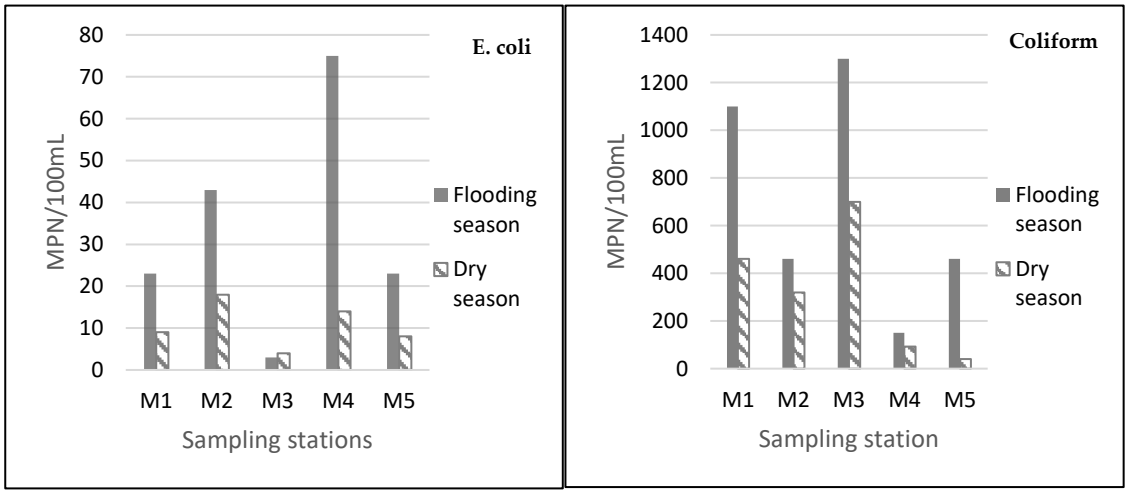

Fig. 2. The variation of coliform and E. coli at the sampling stations

Pipe water

Table 5. Water quality parameters of measured pipe water samples

	Flooding season (December 2019)				Dry season (June 2020)					
	M6	M7	M8	M9	M6	M7	M8	M9	QCVN 02 : 2009/BYT	LODs
SS *(mg/L)*	1.0	0.4	0.6	0.4	1.8	1.6	1.4	3.6	nd	nd
BOD (*mg/L*)	1.2	1	0.8	0.9	1.3	1.5	2.1	2.9	nd	nd
COD *(mg/L)*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	nd	4
N-NH4 *(mg/L*	< LOD	0.08	< LOD	< LOD	< LOD	0.03	< LOD	< LOD	3	0.02

	Flooding season (December 2019)				Dry season (June 2020)					
	M6	M7	M8	M9	M6	M7	M8	M9	QCVN 02 : 2009/BYT	LODs
Total Fe *(mg/L)*	0.02	0.03	0.06	0.02	0.02	0.01	0.05	0.03	0.5	0.001
Free chlorine *(mg/L)*	< LOD	< LOD	< LOD	< LOD	0.12	0.14	0.12	0.23	0.3-0.5	0.05
Coliform *(MPN/100mL)*	39	< LOD	43	< LOD	< LOD	20	45	40	150	3
E. Coli *(MPN/100 mL)*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	20	3
Temp *(°C)*	23.1	22.9	23.8	22.8	31.9	32.7	31.2	31.2	nd	nd
EC *(μS/cm)*	50	78	68	89	89.5	87.8	88.8	83.6	nd	nd
pH	6.9	6.9	6.8	6.9	-	-	-	-	6-8.5	nd
Salinity *(‰)*	0	0	0	0	0	0	0	0	nd	nd

Pipe water in this region is a part of the city water distribution system, implying that the water quality of the system should not be different. Though, there was a variation of the water quality parameters measured at different sampling stations (M6 to M9) in both seasons (**Table 5**). The main reason could be referred to the difference of the water pipes and the systematic errors of measurement methods.

All of the measured values met the national regulation for domestic water supply [12], except the free chlorine parameter which was lower than the threshold (0.3 - 0.5 mg/L). This could be explained by the loss of chlorine from the chemical reactions along the water pipe. Supply water with chlorine values below the specified threshold is susceptible to microbiological contamination, which can cause colic, diarrhea, etc.

In flooding season, t-test analysis showed that the SS, BOD, and free chlorine values were statically lower than that in the dry season ($p = 0.03, 0.039, 0.029$, respectively) (**Figure 3**). This result demonstrated that although applying the same water treatment process and the same supply water distribution network, flooding also decreases the risk of organic pollution (based on BOD), suspended solids, but increases the risk of infection due to lack of chlorine disinfection in water. Meanwhile, no differences were detected for the other parameters between the two seasons.

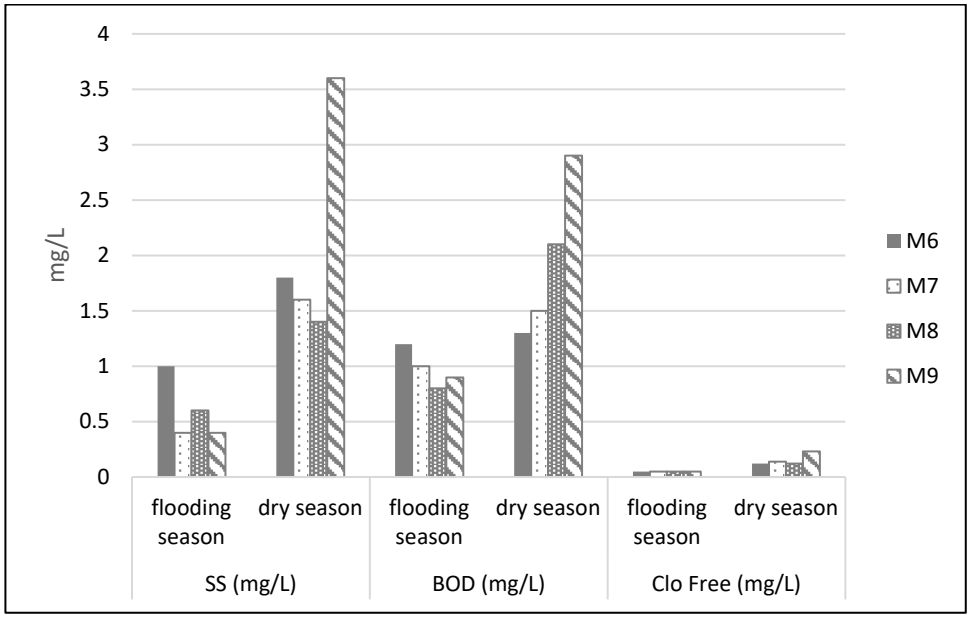

Fig. 3. The variation of SS, BOD, and free chlorine at the sampling stations

4 Conclusion

Quang Thanh commune is in a low-lying area which is prone to floods annually. Most people in this area had agricultural and fishery livelihoods. Their livelihoods have been closely attached to waters; however, knowledge of water management and usage remains poor. Wastewater from rice fields, vegetable areas, aquaculture ponds, breeding facilities, or poultry grazing has been discharged directly to the surface water system without any treatment.

Annually, two to three floods hit the area in which flood duration varied from 5 to 8 days, depending on the village, and the depth of flood fluctuated from 0.7 to 2 m. Unpredictable weather and hydropower plant from upstream were believed to be the main causes of flood volume reduction in recent years, which also contributed to changes in water quality. In general, floods, in some aspects, helped reduce the organic contaminants (based on DO, BOD, and COD values assessment) and salinity, and somehow increase the total coliform at most of the sampling stations. However, its role in nutrient and suspended solid contaminants was still unclear.

Due to the limitation of the study area and sample size, it is recommended to conduct a more comprehensive and extensive study to find out the main sources of impact on water quality, and propose suitable mitigation measures.

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