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Assessment of spatial and seasonal variation of water quality in the plain river network area of Taihu Lake, East China

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Introduction

- To understand the water quality changes of the plain river network area and reveal the driving factors of water quality changes in different periods, based on water quality index method (WQI), our main works are as follows:
- Samples were collected and analyzed seasonally from August 2018 to January 2019 in Changxing County.
- Analyzed the spatial-temporal distribution characteristics of water quality and the causes of pollutants.
- Researched the relationship between land use types and the water quality, and analyzed the sources of pollution.
- Provided some policy recommendations for water environment management.

Materials and Methods

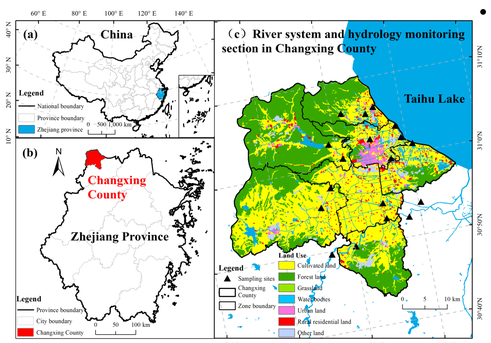

Fig. 1. Study area and sampling sites.

- The 18 sampling sites for Changxing Country were investigated in this study (Fig. 1c), and sampling was conducted synchronously to monitor hydrology and water quality. Water samples were taken 30 cm below the water surface in 2.5 L pre-cleaned plastic bottles. The samples placed in a cooler at 4~6 ℃ were transported to the laboratory as soon as possible for further analysis.

Table 1 The land use proportion in different zones.

Land use (%)	Zones							
	1	2	3	4	5	6	7	All
Cultivated land	21.1	31.1	43.2	82.5	61.9	54.7	45.4	48.7
Forestland	71.3	61.2	24.0	7.5	30.9	22.8	45.1	39.8
Waters	2.3	1.5	3.8	1.4	2.1	7.4	2.6	2.7
Urban land	0.8	2.0	18.0	0.8	0.6	1.1	0.2	2.3
Rural residential land	1.8	3.1	6.1	4.6	1.1	7.2	1.7	3.0
Other land	1.8	0.7	4.4	3.2	2.5	6.2	4.1	2.9

- Eight parameters, including water temperature, pH, dissolved oxygen (DO), permanganate index (COD_{Mn}), total phosphorus, total nitrogen, ammonium (NH_4-N), and chlorophyll-a (Chla) were measured to calculate the WQI, weight and assignment of water quality parameters is shown in Table 2.

☐ Water quality index calculations

$$WQI = \sum_{i=1}^{n} S_i \omega_i \Big/ \sum_{i=1}^{n} \omega_i$$

Where n is the total number of the selected parameters included in the study, S_i is the normalized value of parameter i, and ω_i is the weight of parameter i.

Table 2 Weight and assignment of water quality parameters for WQI calculations.

Parameter		T (°C)	pH	DO (mg/L)	COD_{Mn} (mg/L)	TP (mg/L)	TN (mg/L)	NH_3-N (mg/L)	Chl.a (μg/L)
Weight		1	1	4	3	1	3	3	3
Normalized value	100	16-21	7	>7.5	<1	<0.01	<0.1	<0.01	<1
	90	15-16, 21-22	7-8	7-7.5	1-2	<0.02	0.1-0.2	0.01-0.05	1-4
	80	14-15, 22-24	8-8.5	6.5-7	<3	<0.05	0.2-0.35	0.05-0.1	4-7
	70	12-14, 24-26	8.5-9	6-6.5	<4	<0.1	0.35-0.5	0.1-0.2	7-10
	60	10-12, 26-28	6.5-7	5-6.5	<6	<0.15	0.5-0.75	0.2-0.3	10-15
	50	5-10, 28-30	6-6.5, 9-9.5	4-5	<8	<0.2	0.75-1	0.3-0.4	15-20
	40	0-5, 30-32	5-6, 9.5-10	3.5-4	<10	<0.25	1-1.25	0.4-0.5	20-30
	30	−2-0, 32-36	4-5, 10-11	3-3.5	<12	<0.3	1.25-1.5	0.5-0.75	30-40
	20	−4-2, 36-40	3-4, 11-12	2-3	<14	<0.35	1.5-1.75	0.75-1	40-50
	10	−6-4, 40-45	2-3, 12-13	1-2	≤15	≤0.4	1.75-2	1-1.25	50-65
	0	>45, <−6	1-2, 13-14	<1	>15	>0.4	>2	>1.25	>65

Results

- The mean WQI value was 58.9, 54.8, and 67.0 in wet, flat, and dry water periods, respectively. The paired t-test showed that the WQI value in dry-water period was significantly higher ($p<0.05$) than that in wet-water period and flat-water period (Fig. 2). Based on the WQI classification, the water quality was rated at a "medium" level during all three water periods.

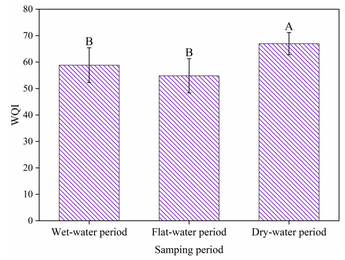

Fig. 2. WQI values in different sampling periods and zones.

- The "medium" sampling sites were dominant in the three sampling periods, and the proportion was 62.9% (34/54). The "very bad" was only occurred once, the proportion was 1.8% (1/54). The "bad" sampling sites accounted for 12.9% (7/54). The proportion of "good" sites was 22.2% (12/54). And no "excellent" sampling site was found in these three sampling periods (Fig. 3).

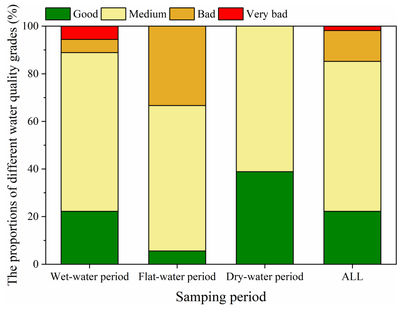

Fig. 3. The proportions of different water quality grades in the aquatic eco-functional zones of Changxing County.

- Fig. 4 displays the variation of the water quality of each zone in different water periods (wet, flat, and dry). The WQI values of each zone were more than 60 during dry-water period, which were in a medium state. The worst water quality states were zones 3 and 5 during flat-water period. Their WQI values are less than 50, and they were in a bad state.

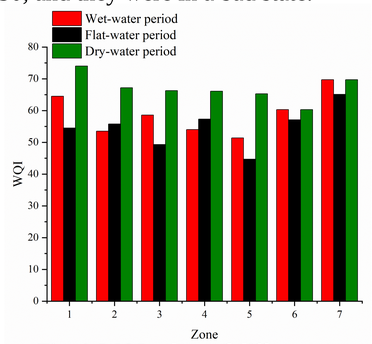

Fig. 4. WQI values of different aquatic eco-functional zones in Changxing County.

- In terms of sampling sites, the highest (80.5) and lowest (15.8) WQI values all occurred in the Z_2, which reached the "good" level and "very bad" level, respectively. In addition, the sampling sites at the "good" level were mainly located north and south of Changxing County. The sampling sites at the "bad" level were mainly located in the central part of Changxing County (Fig. 5).

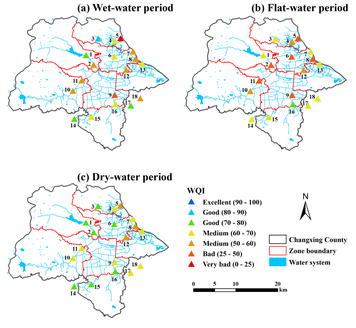

Fig. 5. The spatial distribution of WQI in wet-water period (a), flat-water period (b), and dry-water period (c) in Changxing County.

- The ratio of rural residential land was negatively correlated with WQI, especially during dry-water period.
- The water quality was better when the ratio of cultivated land is large, except for dry-water period.
- The proportion of forest land was negatively correlated with WQI only in dry-water period.
- The proportion of urban land was negatively correlated with WQI in three sampling periods.
- The proportion of water bodies was positively correlated with WQI only in wet-water period.

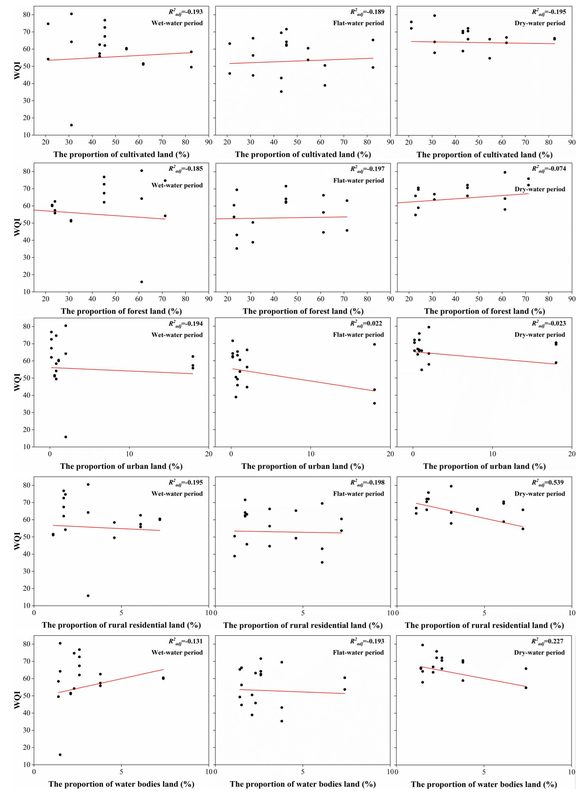

Fig. 6. Linear relationship between land use and WQI of 18 sampling sites in different water periods (wet, flat, and dry).

Discussion and Conclusion

- This study used the WQI to comprehensively evaluate water quality of 18 sites from Changxing County in three water periods.
- The water quality in Changxing County was generally "mediun" during sampling period based on the WQI classification.
- The water quality changed significantly in Changxing County, and the water quality in the zone 1 and 7 was generally better than other zones.
- The water quality exhibited distinct seasonal variation with the best water quality in dry-water period, followed by wet-water period and flat-water period.
- Agriculture land and rural residential land had adverse effects on water quality, and we think more runoff in summer would increase the quantity of pollutants and cause more serious water pollution. Therefore, improving water quality should control or ration the consumption of the relevant fertilizer.
- In our future work, we will increase the sampling points to ensure the accuracy of water quality assessment.