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RESEARCH ARTICLE

Assessment of the effects of COVID-19 lockdown period on groundwater quality of a significant rice land in an urban area of Türkiye

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Abstract

In the current research, the impact of the COVID-19 lockdown period on groundwater quality of Lower Meriç Plain (Thrace Region of Türkiye) was evaluated. Some significant nutrient characteristics (NO_3^-, NO_2^-, and PO_4^{3-}), salinity characteristics (EC, TDS, and salinity), and physical characteristics (temperature, DO, pH, and turbidity) were investigated in groundwater samples collected from 45 sampling points in pre-lockdown and lockdown periods. Water quality index (WQI) and nutrient pollution index (NPI), Pearson correlation index (PCI), cluster analysis (CA), one-way ANOVA test (OWAT), and factor analysis (FA) were applied to assess ecological risk. Excluding recorded statistical differences in temperature and DO due to climatic conditions ($p < 0.05$), levels of all the investigated water quality parameters show no statistically significant differences and no significant reduction in pollutants measured in the lockdown period. On the contrary, the WQI and NPI scores have increased between the rates of 4.76–27.10% during the lockdown period. In the lockdown period, although the reduction of industry or limited production of many industrial facilities reduced the inorganic contaminant releases to the environment, ongoing agricultural activities and domestic wastes caused to prevent the reduction of organic pollutants in groundwater of the region during the lockdown period.

Keywords COVID-19 pandemic · Lower Meriç Plain · Tap–groundwater quality · Ecological indicators · Lockdown period

Introduction

The pandemic of COVID-19 that first appeared in Wuhan, China, on December 1, 2019, has dramatically changed our lives in a very short time and reminded us how ineffectual we are during even the period of modern science. Many countries including Türkiye have implemented many restrictions to slow the spread of COVID-19 pandemic. Türkiye is one of the most disciplined and successful countries on fighting and managing the pandemic. On the March of 2020, when the first COVID-19 patient was reported in Türkiye, numbers of restrictions were immediately started to be implemented by the government and some of them are still going on. However, some restrictions mainly the reduction of industry has started to be gradually deregulated in June 2020. These restrictions and the lockdown implementations of course adversely affected economies, industries, and life of many people adversely, it while probably leads to significant regenerations in many of the environmental components

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(Şimşek 2020; Önmez et al. 2020; Tokatlı and Varol 2021; Ali et al. 2022a,b; Tokatlı 2022).

Water is one of the most basic needs for life to continue for all life forms on the world (Bytyci et al. 2018; Islam et al. 2022; Elbeltagi et al. 2022) and it is also one of the most significant natural resources on which the socio-economic growth, as well as the sustainable development of a society (Pobi et al. 2019; Proshad et al. 2020; Varol et al. 2022; Kumar et al. 2022). However, despite its importance to mankind, it is one of the most poorly managed resources in the earth and facing a serious threat because of anthropogenic activities (Islam et al. 2014, 2015, 2017a, 2021; Ustaoğlu and Islam 2020; Yüksel et al. 2021; Ali et al. 2021a,b; Rani et al. 2021; Varol and Tokatlı 2021; 2022; Pal et al. 2022; Proshad et al. 2021a,b). With the increasing use of a wide variety of remedial measures against COVID-19 pandemic situation in Türkiye in way of disposing waste indiscriminately to the environment, there is little awareness of detrimental health effects of post operation measures for COVID-19. Therefore, the researchers have started to focus on evaluating the hydrogeochemical distribution of some physicochemical parameters in groundwater with their ecological and human health risks (Kumar et al. 2016; Wang et al. 2018; Saleem et al. 2019; Islam 2021; Khan et al. 2021; Haakonde et al. 2020).

Thrace Region is in the north-west part of Marmara Region of Türkiye and it has a great agricultural potential due to its fertile clayey soil. Therefore, approximately 80% of the Thrace Region occurs agricultural lands for crop production. İpsala District is in the Meriç Plain in the west part of Thrace Region and it is very suitable for wet agriculture applications due to its rich groundwater and surface water resources. For this reason, İpsala District is among the most important regions of Türkiye in paddy cultivation and production. Approximately 1/4 of Türkiye's total paddy production is provided from Thrace Region mainly from the Meriç Plain. For rice cultivation, huge amount of surface and groundwater is required for irrigation. Therefore, surface and groundwater resources of Thrace Region, Meriç Plain, and İpsala District have been exposed to various pollution problems due to intensive agricultural applications and runoff from these lands (Tokatlı 2017; Anonymous 2018; Tokatlı and Ustaoğlu 2020; Tokatlı and Varol 2021).

In addition to its huge industrial potential, the region has also very fertile soil and more than 1 million ha of the lands in the Thrace Region (about 95%) is suitable for agriculture (TZOB 2003, Anonymous 2005). Especially the Lower Meriç Plain, located in the southwest of the region, is one of main wet agricultural areas of Türkiye and about 1/4 of Türkiye's total paddy production is provided from this plain. However, the cultivation is ongoing as a monocultural approach (without any crop rotation) for a long time in almost all around the Thrace Region, which caused the soil to weak in terms of nutrients and minerals. Also, the pests of agricultural product have gained resistance in years because of these monocultural applications (TZOB 2003, Arda et al. 2015; Tokatlı 2021). Social studies conducted around the region also clearly reflect that the local people are not susceptible enough to their environment and the sustainable development of the agriculture (Tokatlı and Gürbüz 2014; Helvacıoğlu et al. 2016).

Despite all these polluting factors, it has been reported that although the aquifer structure of the Meriç Plain is quite shallow and the water table level is quite close to the surface, groundwater resources of the region have been less affected by surface pollutants because of its clayey soil structure (Tokatlı 2019).

To the best of author's knowledge, no systematic investigation has been carried out to find the physicochemical parameters in groundwater samples collected from Lower Meriç Plain located in the Thrace Region, Türkiye, during pre-lockdown and lockdown periods and water quality parameters. The present investigation was the first study, therefore, aimed (1) to determine the physical and chemical characteristics of tap (drinking) and groundwater of Lower Meriç Plain, (2) to determine the spatiotemporal variations of organic pollutants, (3) to assess the tap and groundwater qualities by using some basic drinking water quality evaluation indices and multistatistical methods, and (4) to show the effects of the lockdown period on the tap and groundwater quality of this great importance agricultural land.

Materials and methods

Water collection

Within the scope of this study, 45 sample locations were selected in the region (23 stations for the tap (drinking) water and 22 stations for the groundwater). Location map for selected tap (İ1-İ23) and groundwater (Y1-Y22) samples are given in Fig. 1 together with the topography. The coordinates with the names of locations are given in Table 1. Water samples were taken from the tap waters of the villages located in the Lower Meriç Plain, which have a direct impact on the health of the local people (the population of the region is approximately 30,000 including district center and connected villages (https://www.tuik.gov.tr/)), and from the significant drill fountains of the region, which have a direct impact on the health of the local livestock, because they drink their water from these troughs (the number of livestock in the region is about 70,000 in total, approximately 45,000 ovine, and 25,000 bovine (https://www.tuik.gov.tr/)), in January 2020 (wet (pre-lockdown) period) and June 2020 (dry (lockdown) period) by using polyethylene bottles.

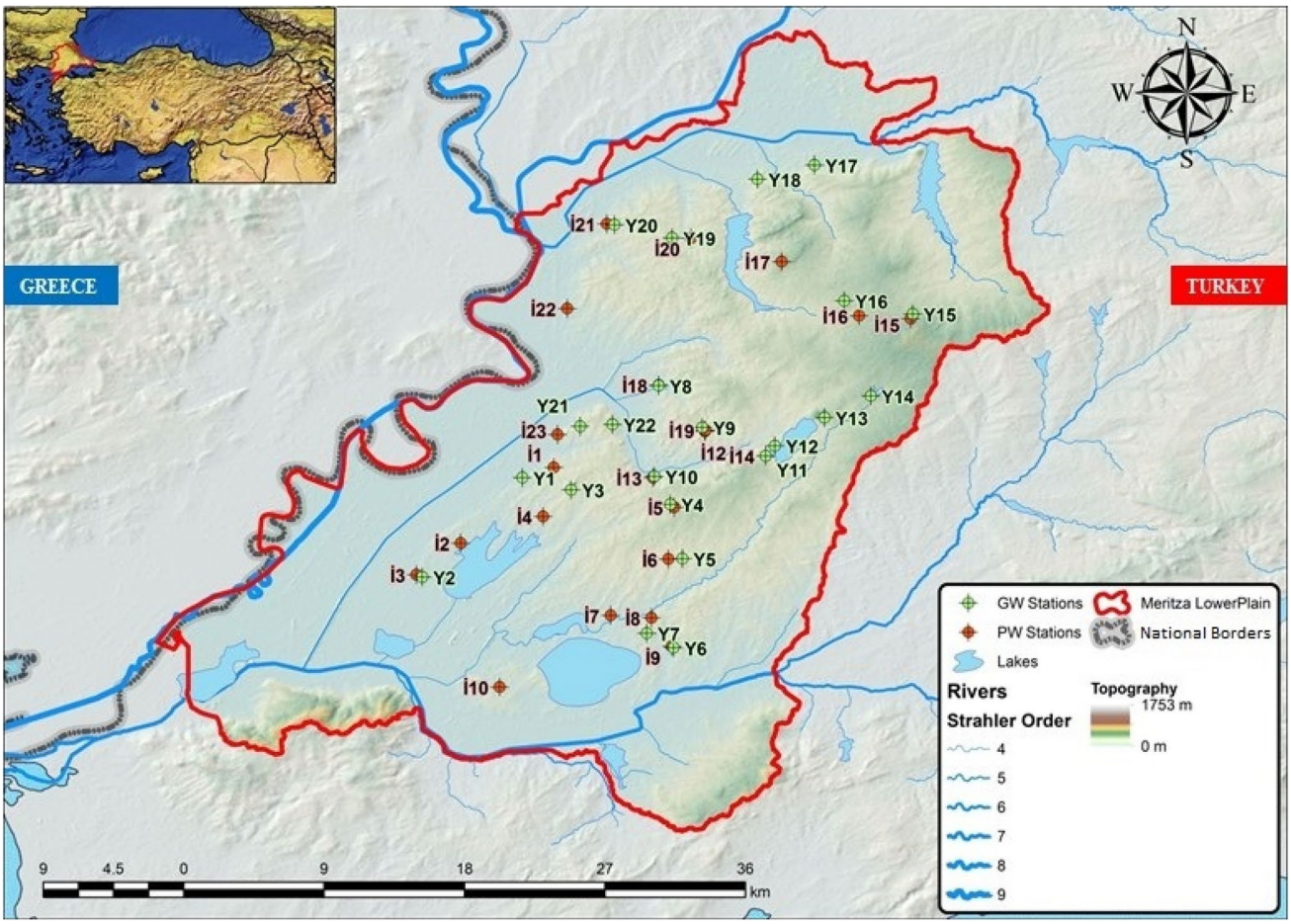

Fig. 1 Location map for selected tap (İ1-İ23) and groundwater (Y1-Y22) samples together with the topography

Water quality analysis

Temperature (T), dissolved oxygen (DO), pH, electrical conductivity (EC), total dissolved solids (TDS), and salinity (Sal) parameters were determined by using Hach Lange branded HQ40D Multiparameter device during the field studies; turbidity (Tur) parameter was determined by using Hach Lange branded 2100Q Portable Turbidity meter device during the field studies; nitrate (NO3), nitrite (NO2), and phosphate (PO4) parameters were determined by using Hach Lange branded DR890 Colorimeter device during the laboratory studies.

Water quality index (WQI)

WQI is a widely used technique to evaluate the surface and groundwater qualities (Meng et al. 2016; Wang et al. 2017; Ustaoğlu and Tepe 2019; Varol 2020; Ustaoğlu et al. 2020). The calculation formula of WQI is given in the Eqs. (1) and (2).

$$WQI = \sum \left[W_I \times \left(\frac{C_i}{S_i} \right) \times 100 \right] \quad (1)$$

$$W_I = \frac{W_i}{\Sigma W_i} \quad (2)$$

where W_I is relative weight (Table 2). C_i is the levels of investigated parameter in water samples. S_i is the limit value for drinking water specified by WHO (2011), EC (2007), and TS266 (2005) (Table 2). If the WQI value is less than 50, it means "Excellent quality"; if it is between 50 and 100, it means "Good quality"; if it is between 100 and 200, it means "Poor quality"; if it is between 200 and 300, it means "Very Poor quality"; if it is greater than 300, it means "Unsuitable for drinking purpose" (Xiao et al. 2019).

Nutrient pollution index (NPI)

NPI is an effective evaluation method of the water quality in terms of nitrogenous and phosphorous nutrient contents

Table 1 Coordinate information of investigated stations of Lower Meriç Plain located in the Thrace Region, Turkey

Tap water stations				Groundwater stations			
Station code	Location	GPS (North)	GPS (East)	Station code	Location	GPS (North)	GPS (East)
İ1	Ahırköy Village	40.894	26.374	**Y1**	Ahırköy Village	40.888	26.356
İ2	Paşaköy Village	40.850	26.320	**Y2**	Yeni Karpuzlu Town	40.831	26.298
İ3	Yenikarpuzlu Town	40.832	26.295	**Y3**	Kumdere Village	40.881	26.384
İ4	Kumdere Village	40.866	26.368	**Y4**	Esetçe Town	40.873	26.441
İ5	Esetçe Town	40.871	26.443	**Y5**	Aliço Pehlivan Village	40.841	26.448
İ6	Aliçopehlivan Village	40.841	26.440	**Y6**	Yapıldak Village	40.790	26.443
İ7	Kocahıdır Village	40.809	26.407	**Y7**	Küçük Doğanca Village	40.799	26.428
İ8	Küçük Doğanca Village	40.808	26.430	**Y8**	Turpçular Village	40.941	26.434
İ9	Yapıldak Village	40.791	26.442	**Y9**	Hıdırköy Village	40.917	26.459
İ10	Koyuntepe Village	40.768	26.343	**Y10**	Sarpdere Village	40.889	26.432
İ11	Turpçular Village	40.941	26.434	**Y11**	Korucu Village	40.900	26.496
İ12	Hıdırköy Village	40.914	26.461	**Y12**	Korucu Village	40.906	26.501
İ13	Sarpdere Village	40.888	26.431	**Y13**	Hacıköy Town	40.922	26.530
İ14	Korucu Village	40.900	26.496	**Y14**	Beğendik Town	40.935	26.557
İ15	Pazardere Village	40.979	26.580	**Y15**	Pazardere Village	40.982	26.581
İ16	Hacıköy Town	40.981	26.550	**Y16**	Hacıköy Village	40.989	26.541
İ17	İbriktepe Town	41.012	26.505	**Y17**	Karaağaç Village	41.067	26.524
İ18	Karaağaç Village	40.941	26.434	**Y18**	Tevfikiye Village	41.059	26.491
İ19	Hıdırköy	40.915	26.461	**Y19**	Sultanköy Town	41.025	26.442
İ20	Sultanköy Town	41.025	26.453	**Y20**	Balabancık Village	41.033	26.409
İ21	Balabancık Village	41.033	26.404	**Y21**	İpsala District	40.917	26.389
İ22	Sarıcaali Village	40.985	26.382	**Y22**	İpsala District	40.918	26.408
İ23	İpsala District	40.913	26.376				

Table 2 Standard values (S_i), assigned weight (W_i), and relative weight ($W_ı$) coefficients of used parameters in WQI

	pH	EC (µs/cm)	Turbidity	NO_3 (mg/l)	NO_2 (mg/l)
Standard values (S_i)	7.5	1500	5	50	3
Assigned weight (W_i)	3	4	3	5	5
Relative weight ($W_ı$)	0.15	0.2	0.15	0.25	0.25

(Isiuku and Enyoh 2020). The calculation formula of the NPI is given in the Eq. (3).

$$NPI = (CN/MAC_N) + (CP/MAC_P) \quad (3)$$

where C_N and C_P are the mean concentration values of NO_3 and PO_4 detected in the water samples. MAC_N and MAC_P are the maximum allowed concentration values of NO_3 and PO_4 specified by Water Quality Control Regulations in Türkiye (WQCR 2015). If the NPI value is less than 1, it means "No pollution"; if it is between 1 and 3, it means "Moderate polluted"; if it is between 3 and 6, it means "Considerable polluted"; if it is greater than 6, it means "Very high polluted."

Statistical analysis

By using the "SPSS 23" package statistical program, one-way ANOVA test (OWAT) was applied to the detected data to describe the statistically significant variations of water quality parameters between the wet (pre-lockdown) and dry (lockdown) periods and factor analysis (FA) was applied to the detected data to determine the effective factors on the groundwater quality. By using the "PAST" package statistical program, Pearson correlation index (PCI) and cluster analysis (CA) were applied to the detected data to present the statistically significant relations among the investigated parameters and classify the investigated tap (groundwater) resources of the region in terms of their similar water quality characteristics, respectively.

Results

Distribution of detected parameters in water samples

Spatiotemporal data of measured water quality parameters in tap and groundwater of Lower Meriç Plain are given

in Fig. 2; GIS-based distribution maps of the investigated parameters in both tap and groundwater were given as supplementary material in Fig. S1–S10 and the Turkish water quality criteria, drinking water standards of TS266 (2005), EC (2007), and WHO (2011), and temporal mean values with the percentage exchange rates are given in Table 3.

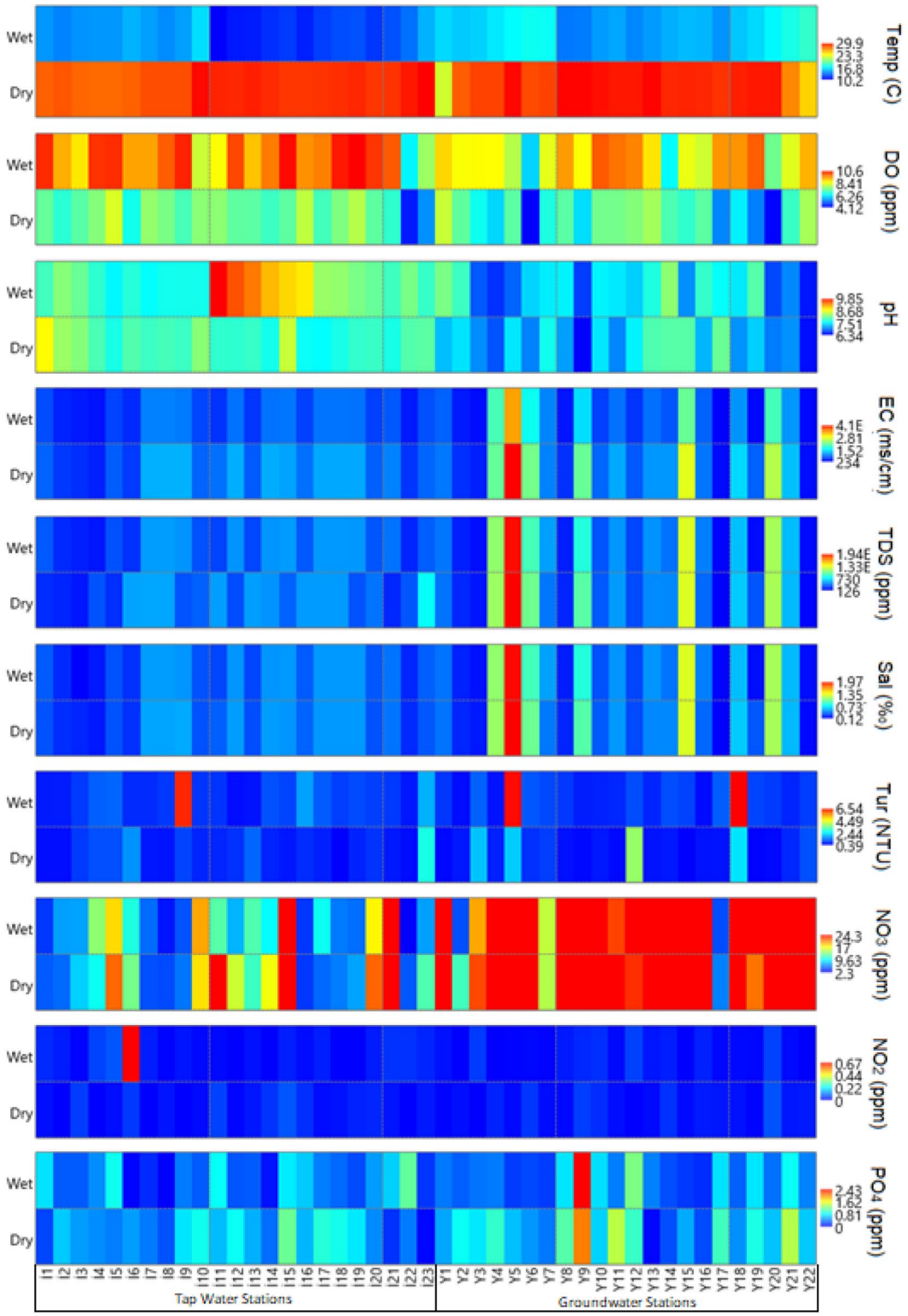

Fig. 2 Spatial – temporal variations of physical and chemical parameters in the tap – groundwater samples of Lower Meriç Plain

Table 3 Water quality criteria, drinking water standards, mean values, and percentage exchanges

Parameter	Turkish water standards				Drinking water standards			Lower Meriç Plain (mean)					
	*Water quality classes (WQCR, 2015)				TS266 (2005)	EC (2007)	WHO (2011)	Tap (drinking) water			Groundwater		
	1 (clean)	2 (slightly polluted)	3 (polluted)	4 (highly polluted)				Wet	Dry	% Exchange	Wet	Dry	% Exchange
Temp (.°C)	25	25	30	> 30	-	-	-	12.91 1. Class	28.38 1. Class	+ 119.74	15.40 1. Class	28.33 1. Class	+ 83.95
DO (mg/l)	8	6	3	< 3	-	-	-	9.34 1. Class	6.96 2. Class	− 25.51	8.46 1. Class	6.50 2. Class	− 23.10
pH	6.5–8.5	6.5–8.5	6.0–9.0	Out of 6.0–9.0	6.5–9.5	6.5–9.5	-	8.19 1. Class	7.86 1. Class	− 4.07	7.29 1. Class	7.22 1. Class	− 0.92
EC (mS/cm)	400	1000	3000	> 3000	2500	2500	-	636 2. Class	833 2. Class	+ 30.91	976 2. Class	**1259** **3. Class**	+ 28.97
[b]TDS (mg/l)	500	1500	5000	> 5000	-	-	-	365 1. Class	375 1. Class	+ 2.79	568 2. Class	587 2. Class	+ 3.35
Sal (%0)								0.36	0.37	+ 3.35	0.57	0.59	+ 3.09
Tur (NTU)	-	-	-	-	5	-	-	1.14	0.83	− 27.57	1.34	0.92	− 30.69
NO_3 (mg/l)	5	10	20	> 20	50	50	50	**10.17** **3. Class**	**11.82** **3. Class**	+ 16.27	**21.78** **4. Class**	**22.15** **4. Class**	+ 1.67
NO_2 (mg/l)	0.01	0.06	0.12	> 0.12	0.5	0.5	0.2	0.050 2. Class	0.023 2. Class	− 54.49	0.018 2. Class	0.021 2. Class	+ 15.58
[c]PO_4 (mg/l)	0.03	0.16	0.65	> 0.65	-	-	-	**0.421** **3. Class**	**0.571** **3. Class**	+ 35.60	**0.540** **3. Class**	**0.762** **4. Class**	+ 41.16

*3.–4. Class water qualities are given in bold

As a result of OWAT, temperature parameter measured in the tap (drinking) and groundwater of Lower Meriç Plain in the wet period was statistically significantly lower than the levels measured in the dry period ($p < 0.05$), while dissolved oxygen parameter measured in the wet period was statistically significantly higher than the levels measured in the dry period ($p < 0.05$). Although, all the investigated parameters detected in groundwater resources of the region showed some rises and falls, the other parameters except temperature and DO show no statistically significant variations between the wet (pre-lockdown) and dry (lockdown) periods ($p < 0.05$).

The temperature of the tap and groundwaters follow the atmospheric conditions in general. In dry (summer) season, it is normal that the waters become high temperature, while in wet (winter) season, the water temperatures gain low. In the current research, the water temperatures within summer (dry) and winter (wet) seasons were influenced mainly by seasons not the impact of COVID-19 pandemic.

The mean DO in tap water in wet (prelockdown) and dry (lockdown) were 9–7 mg/l, while it was 8.5–6.5 mg/l in the groundwater, respectively. It is clearly known that the DO in water is being significantly affected from the water temperature. Therefore, the detected significant decreases of DO in the tap-groundwater samples of the Meriç Plain in the dry (lockdown) season were influenced mainly by seasons as in temperature, in the current research.

In both tap (drinking) and groundwater resources, pH, salinity, and TDS did not show a significant change among the investigated seasons. It was also determined that in the dry (lockdown) period, temperature, EC, and PO_4 increased about 100, 30, and 40% respectively, while DO and turbidity decreased about 25 and 30% respectively, in general.

Ecological indicators

GIS-based maps showing the spatiotemporal variations of applied ecological risk assessment indices are presented in Fig. 3. As a result of WQI, although an increase of approximately 4.76% in tap (drinking) water and 6.11% in groundwater resources during the dry (lockdown) period, it was determined that the WQI scores determined in the tap (drinking) and groundwater of Lower Meriç Plain were within the acceptable limits in general (< 100). As a result of applied WQI, tap (drinking) water of all the examined villages corresponds to the "Class A—Excellent water" class in terms of water quality in both seasons. Also, groundwater samples in all the investigated locations except the stations of Y4, Y5, Y6, Y9, Y15, Y18, and Y20 (these stations were classified as "B Class—Good" water quality) were classified as "A Class – Excellent" water quality in both seasons.

As a result of NPI, 47.82% of tap (drinking) water and 4.54% of groundwater resources were found to have "No pollution," while 52.17% of drinking water and 86.36% of groundwater resources were found to have "Moderate polluted" and 9.09% of groundwater resources were found to have "Considerable polluted" in the wet (pre-lockdown) period. Significant increases of approximately 27.10% in tap (drinking) water and 18.76% in groundwater resources during the dry (lockdown) period were observed. In the dry (lockdown) period, only 21.73% of drinking water of the region were recorded to have "No pollution," while 78.26% of drinking water and 86.36% of groundwater resources recorded to have "Moderate polluted" and 13.63% of groundwater resources were recorded to have "Considerable polluted."

Multi—statistical indicators

Results of PCI for wet (pre-lockdown) period and dry (lockdown) period with the coefficients of correlations are given in Fig. 4. The ones showing a high correlation among the measured water quality parameters indicate the similar source of toxicants including the water ecosystems from similar pathways (Bhardwaj et al. 2017; Varol 2019; Rakib et al. 2021; Islam et al. 2017a,b). Statistically significant positive correlations were detected among the values of EC, TDS, and salinity in both seasons ($p < 0.01$). While significant positive correlations were detected among the variables of nitrate (EC, TDS) and salinity and turbidity (EC, TDS) and salinity in wet season ($p < 0.05$), any significant relation among any parameters was not determined with the turbidity parameter in the dry season. In addition, significant negative correlations were detected among the DO parameter with the values of temperature, EC, TDS, and salinity in the wet season ($p < 0.05$), while no significant relation among any parameters was noted with the DO parameter in the dry season.

In the current research, FA was applied to detected chemical data to describe the effective varifactors on groundwater quality of the region for the wet (pre-lockdown) and dry (lockdown) periods ($n = 45$ and eigenvalues > 1 for each application). The Kaiser–Meyer–Olkin (KMO) test was performed before implementing FA and, sampling sufficiency of KMO tests was recorded as 0.676 for wet (pre-lockdown) period and 0.705 for dry (lockdown) period, respectively which is quite enough (> 0.5) (Liu et al. 2003).

As a result of wet (pre-lockdown) FA, 3 factors explained 84.53% of the total variance. Component 1 (F1, first factor) was named as "Salinity Factor" and explained 43.10% of total variance. It was related to the variables of salinity, TDS and EC. Component 2 (F2, second factor) was named as "Climatic Factor" and explained 24.92% of total variance. It was related to the variables of temperature and DO. Component 3 (F3, third factor) was named as "Agricultural Factor"

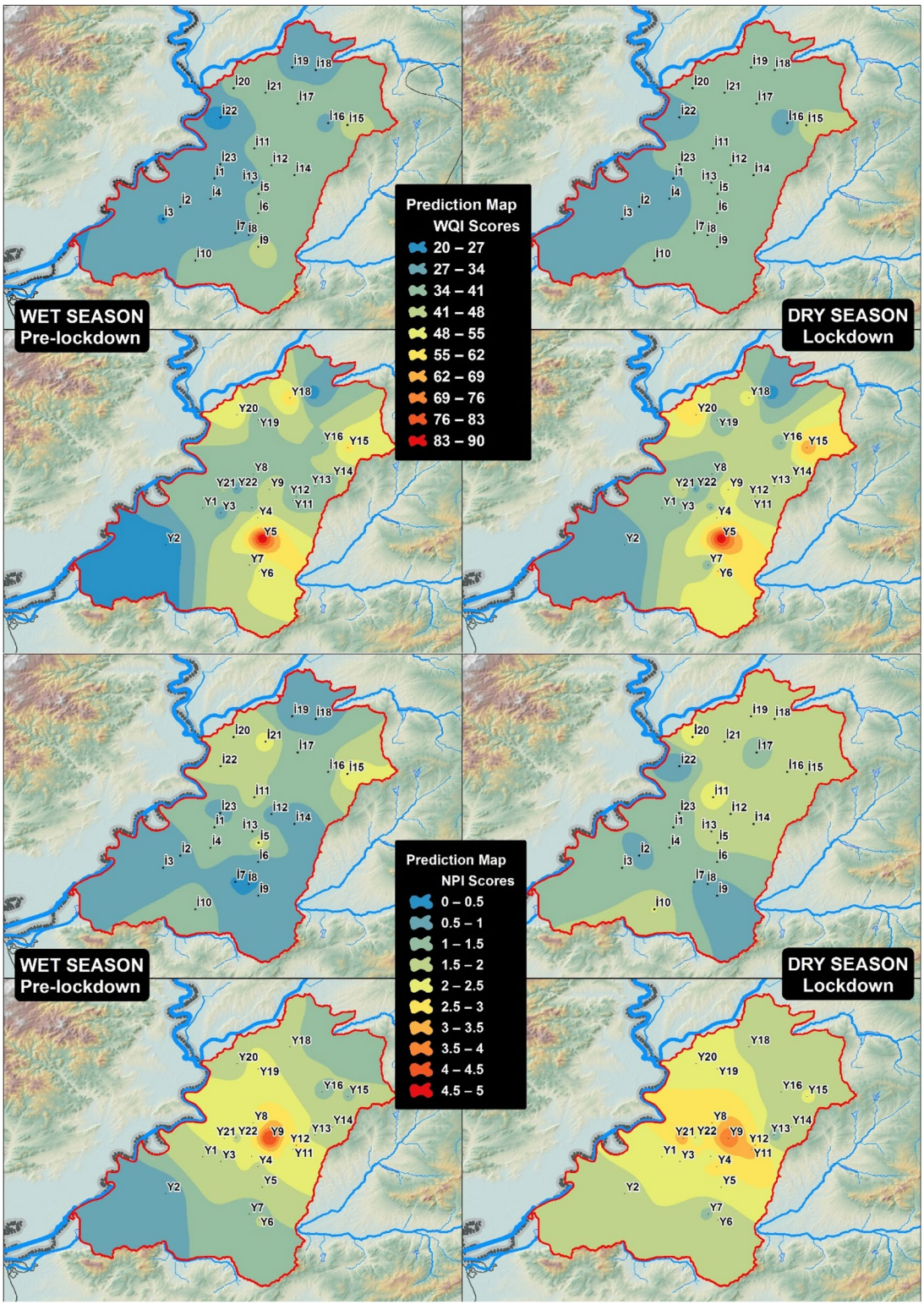

Fig. 3 Spatial – temporal variations of applied NPI and WQI in the tap – groundwater samples

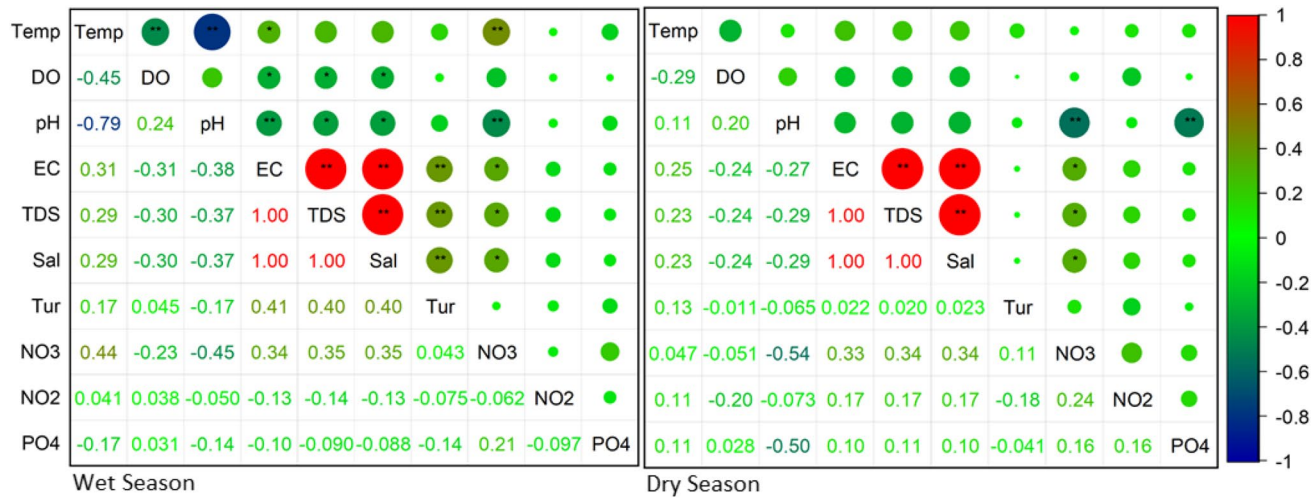

Fig. 4 Results of applied PCI for wet (pre-lockdown) and dry (lockdown) periods (* $p < 0.05$; ** $p < 0.01$)

and explained 16.51% of total variance. It was related to the variables of NO_3 and PO_4 (Fig. 5).

As a result of dry (lockdown) FA, 3 factors explained 78.91% of the total variance. Component 1 (F1, first factor) was named as "Salinity Factor" and explained 44.15% of total variance. It was related to the variables of salinity, TDS and EC. Component 2 (F2, second factor) was named as "Climatic Factor" and explained 18.52% of total variance. It was related to the variables of DO and temperature. Component 3 (F3, third factor) was named as "Agricultural Factor" and explained 16.22% of total variance. It was related to the variables of PO_4 and NO_3 (Fig. 5).

As a result of CA, 2 clusters were formed, which were named as "More Contaminated Zone – C1" and "Less Contaminated Zone – C2," for wet (pre-lockdown) and dry (lockdown) periods (Fig. 6). C1 was formed by the stations of Y4, Y5, Y6, Y9, Y15, and Y20; and C2 was formed by all the tap water stations and all the groundwater stations except the locations in cluster C1 both for the wet (pre-lockdown) and dry (lockdown) periods.

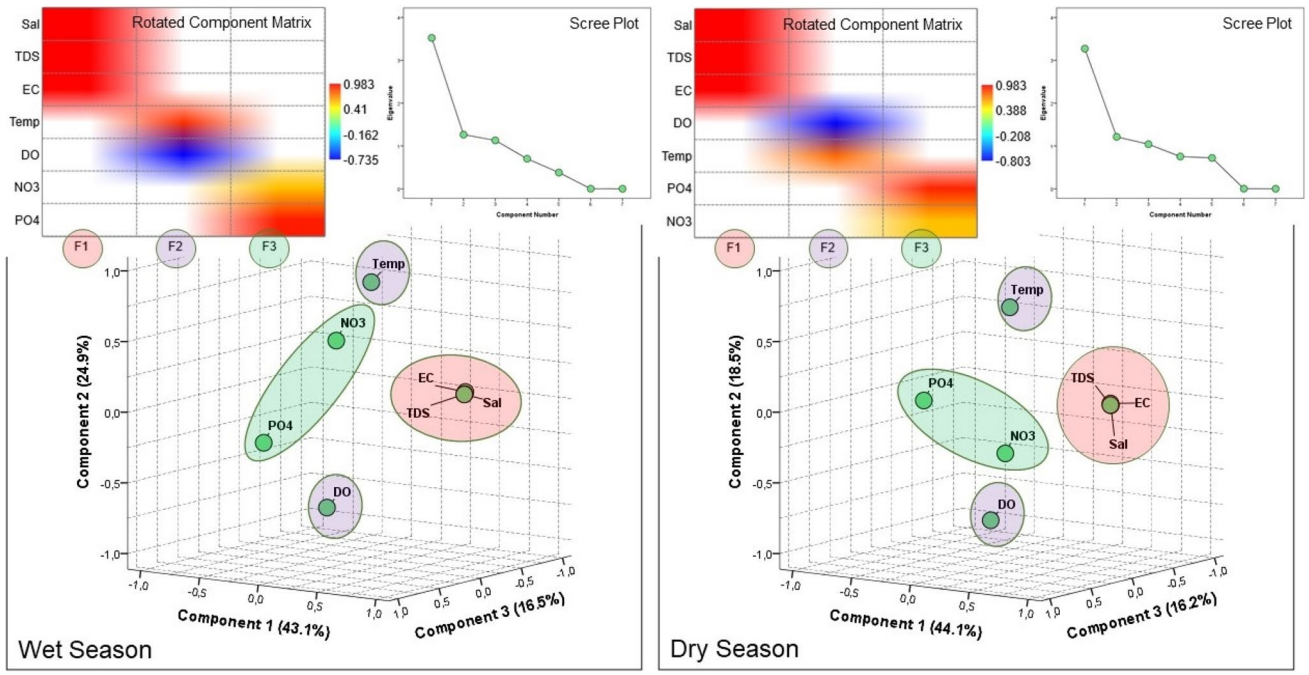

Fig. 5 Component plots with the factor loads of rotated component matrix for wet (pre-lockdown) and dry (lockdown) periods

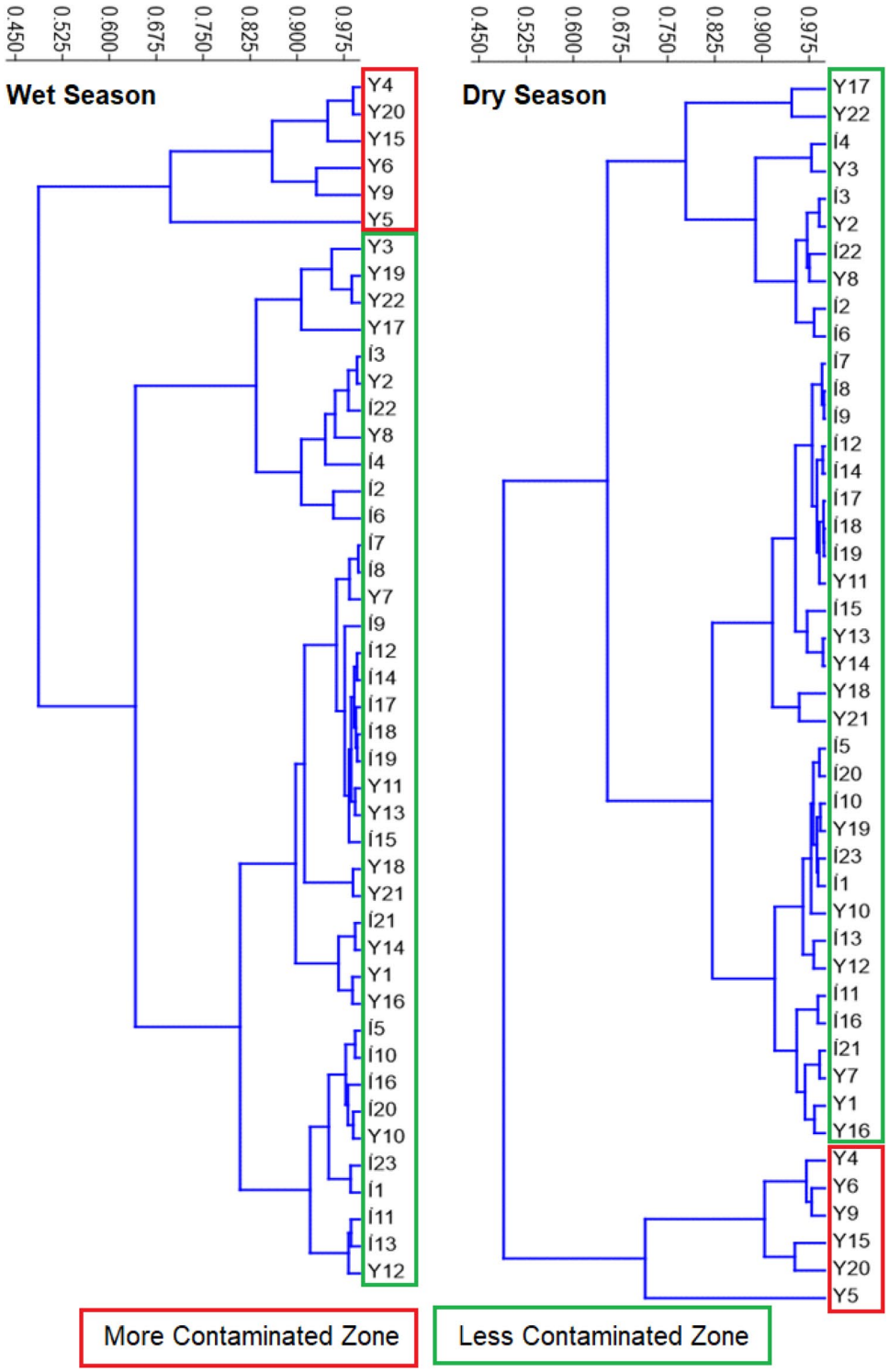

Fig. 6 Hierarchical Dendogram of CA for wet (pre-lockdown) and dry (lockdown) periods

Discussion

Nitrate and phosphate levels in the tap and groundwater samples were recorded as quite high levels in both investigated seasons. According to the Water Quality Control Regulations in Türkiye (WQCR 2015), in terms of nitrate contents of tap water, 21.7% of samples were 1. Class (clean), 34.7% of samples were 2. Class (slightly polluted), 34.7% of samples were 3. Class (polluted) and 8.7% of samples were 4. Class (highly polluted) water quality in the wet (pre-lockdown) period, while 21.7% of samples were 1. Class, 26.1% of samples were 2. Class, 30.4% of

samples were 3. Class and 21.7% of samples were 4. Class water quality in the dry (lockdown) period. Nitrate concentrations in groundwater resources were quite higher than detected in the tap water and only 9.1% of samples were 1. Class, while 9.1% of samples were 3. Class and 81.8% of samples were 4. Class water quality in the wet season. It was also determined that the nitrate content of groundwater increased even more in the dry season and 4.5% of samples were 2. Class, 9.1% of samples were 3. Class and 86.3% of samples were 4. Class water quality in this season (WQCR 2015). According to the Water Quality Control Regulations in Türkiye (WQCR 2015), in terms of phosphate contents of tap water, 17.4% of samples were 1.–2. Class and 82.6% of samples were 3.–4. Class water quality in the wet (pre-lockdown) period, while 69.6% of samples were 3. Class and 30.4% of samples were 4. Class water quality in the dry (lockdown) period. Phosphate accumulations in groundwater resources were quite higher than detected in the tap water and 4.5% of samples were 2. Class, 95.6% of samples were 3.– 4. Class water quality in the wet season, while 4.5% of samples were 1. Class and 95.6% of samples were 3.–4. Class water quality in the dry season (WQCR 2015).

It is clearly known that nitrate and phosphate are significant organic pollutants, and their values may reach quite high concentrations in drinking water in especially rural areas, where intensive agricultural, fertilization, and livestock activities are carried out (Çiçek et al. 2013; Peiyue et al. 2019). In addition, these significant organic pollution indicator parameters may reach quite high levels in groundwater and drinking waters, especially in areas such as the present study area of İpsala District and connected villages, where there is no sewage system and septic tanks are still being used (Tokatlı 2014, 2019).

In the investigated region, industrial wastewater discharges declined during the lockdown period; however, the agricultural applications increased since the early-spring and according to the data of two recent researches conducted in the surface waters and sediments of the same region in the COVID-19 lockdown period, significant reductions were detected in especially industrial pollutants during the lockdown period, while the increases in water and sediment qualities were observed much less in terms of agricultural origin pollutants (Tokatlı and Varol 2021; Tokatlı 2022; Ezewudo et al. 2021). Therefore, ongoing agricultural activities and domestic discharges during the lockdown period may have caused an increase in agricultural–domestic origin pollutants such as nitrogenous and phosphorus compounds. In the present research, EC, NO_3, and PO_4 contents of the investigated tap (drinking) and groundwater resources of the Lower Meriç Plain were recorded as increased significantly, while DO parameter was determined as quite decreased during the dry (lockdown) period in general.

Agricultural applications and domestic wastes, which continue intensively in the lockdown period (summer season) in the region, are thought to be the reason for these significant increases of nutrients in groundwater resources of the region. In addition, the detected significant water quality changes within winter (wet) pre-lockdown and summer (dry) lockdown seasons were influenced mainly by seasons not the impact of COVID-19 pandemic, since our current study was tap and groundwater and it is an expected and normal situation that they are not being affected by instantaneous changes as much as surface waters in a quite short time as COVID-19 lockdown period. Also, the pressure of agricultural practice, which is one of the non-point sources of pollution mainly effective on the rural groundwater, has been continued during the lockdown. Therefore, there has been a general decrease in groundwater quality in this process, rather than an increase as observed in the surface water and sediments (Tokatlı and Varol 2021; Tokatlı 2022).

According to the results of numbers of investigations conducted in the lockdown period of COVID-19, serious improvements in the qualities of surface water resources were reported due to reduced industrial effluents during the lockdown period (Yunus et al. 2020; Dutta et al. 2020; Arif et al. 2020). However, point pollution sources such as industrial effluents are more effective on the quality of surface waters than groundwater resources. Therefore, many studies regarding the impact of COVID-19 pandemic on water resources and the data of the current research show that the lockdown period has improved the quality of surface waters more than groundwater. In a research on the impacts of COVID-19 pandemic in the water qualities of riverine habitats of the same watershed (Meriç River Basin, Thrace Region, Türkiye), in contrast to the current study, significant reductions between the rates of 54–94% were recorded in the industrial origin toxic metal contents of the surface water resources during the lockdown period (Tokatlı and Varol 2021).

Conclusions

Although many restrictions and implementations applied during the lockdown period limited the industrial applications and thus reduced the anthropogenic pressure on the lots of environmental components, the data of this research show that the tap (drinking) and groundwater quality of the Lower Meriç Plain, Türkiye has decreased during this period. Nutrient contents of waters and the values of applied WQI and NPI have increased significantly during the lockdown period. According to the results FA, no significant parametric differences were recorded between the investigated pre-lockdown and lockdown periods. Three statistically significant factors both for

the applied pre-lockdown and lockdown FAs explained 84.53 and 78.91% of the total variance respectively, which were named as "Salinity Factor," "Climatic Factor," and "Agricultural Factor." According to the results of CA, no significant locational differences were recorded between the investigated pre-lockdown and lockdown periods. Two clusters were formed both for the applied pre-lockdown and lockdown CAs, which were named as "More contaminated zone" and "Less contaminated zone."

The agricultural production area of the Meriç Plain, which has almost the highest and most fertile soils of the Thrace Region, is approximately 500,000 decares. The majority of agricultural lands in the plain consists of paddy fields requiring the use of quite high amounts of agricultural fertilizers and pesticides because of monocultural agrogenic approaches. Agricultural applications (mainly rice production) were continued even more intensely in the lockdown period (because it was in the summer season) in the region. Consequently, despite many industrial production restrictions applied during the lockdown period, monoculture agricultural activities are thought to be the main reason for the significant decreases in the qualities and the significant increases in the organic contents of tap (groundwater) resources in the Meriç Plain.

The COVID-19 pandemic has shown that nature might return to its former state in a short time if the pressure on the environment is released. On the other hand, the sustainability of the agricultural applications is the main key to the protection of soil, water, and the environment, especially in rural lands. Even at a time when industrial activities and industrial origin pollutants have been significantly reduced, such as the COVID-19 pandemic lockdown, the fact that organic pollutants in the tap and underground resources of the Meriç Plain increased rather than decreased, once again demonstrating the importance of the sustainability in agricultural activities in the region and in line with the data obtained, it can be suggested that monocultural applications in agricultural activities should be given up and the local people should be encouraged to polycultural applications.

In conclusion, the present research provides to become aware of the effects of agricultural pressure on the groundwater resources and also reflects the necessity of the polycultural approaches and sustainability in agrogenic applications.

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