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Research Article

Water Quality Assessment of Simav River (Susurluk Basin/Turkey) According to Seasons and Stations

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Abstract:

Susurluk Basin is under intense pressure from domestic, industrial wastes and agricultural activities. In this study, the effect of environmental factors on Simav Stream, one of the important rivers of the Susurluk Basin, was tried to be determined. In this purpose water samples were taken from 13 station seasonally in 2014-2015, and water quality parameters including dissolved oxygen, oxygen saturation, temperature, pH, electrical conductivity, salinty, turbidty, calcium, magnesium, total hardness, nitrite nitrogen, nitrate nitrogen, ammonium nitrogen, phosphate phosphorus, total phosphor, chloride, bicarbonate, carbonate, were determined in this samples. The results were compared with the limit values specified in the national and international quality criteria. According to the Surface Water Quality Regulation (SWQR), the upper parts of the river were less polluted (II. quality) and the middle and lower parts were polluted water (III. quality). As a result of the research, it has been observed that the middle and lower reaches of the Simav Stream are under the pressure of intense agricultural, animal livestock and pollution from domestic and industrial waste waters. It was determined that the pollution pressure started to increase in the upper part as well.

1. Introduction

Water is an essential natural resource essential for sustainable of life. While sea water is about %98 on earth water, approximately %2 fresh water and only 0,036 percent of it is found in lakes and rivers. Nowadays many the fresh water resources are polluted industrial, domestic and agricultural activities. Therefore, these polluted resources are not been suitable for human health and activities (drinking, agricultural etc.). In addition, the increasing contamination of freshwaters with this pollution resources is one the most important of the environmental problems in present-day [1-5].

Water quality which affect utility of water resource is the most important factor more than the amount of water. For this reason, monitoring and management of freshwater resources in terms of surface water quality and pollution is one of the most important issues. Evaluation of water quality parameters and pollution control are essential for effective water quality management [6-9]. When the water source becomes polluted, it is very difficult to restore water quality even if it is protected from polluting sources. Water pollution affects firstly physicochemical parameters of water. Due to the water pollution, life of aquatic organisms are damaged. Therefore, it is very important to determine the water quality of the river and to take the necessary measures for the protection of water resources [6,10,11]. In recent years, as a result of gradually unplanned urbanization, industrialization and rapid population growth in Turkey, the water pollution has become an important problem. Simav Stream, one of the important streams of the Susurluk Basin, is one of the main sources used as irrigation water in the region. There are many industrial enterprises/plant (Susurluk Sugar Factory, Oil, Cement, Marble Factories, Meat and Milk Integrated Facilities, chicken farms, fish and chicken processing plants etc.) and agricultural areas in the basin where Bursa, Balıkesir and Kütahya provinces and districts are located [12, 13]. It is known that Simav Stream is under intense pollution pressure. The purpose of in this research; To determine the simav river water quality and how environmental factors affect the stream, to comparing the results (river water quality parameter values) with national and international water quality criteria, is to provide resources for future studies in the river.

2. Material and Methods

2.1 Study area and sampling

The river are poured to Simav Lake after its first sources are taked from Şaphane mountains, east of Simav Lake. The River passes through some settlements and reaches Marmara Sea after passing Karacabey. During this time, it is fed from the excess waters of Uluabat and Kuşgöl lakes and anyway also many the other large and small streams such as Orhaneli Stream, Mustafakemalpaşa Stream, Kocaçay ve Nilüfer Stream. Simav Stream is known as Susurluk River after Balıkesir province. The length of the path followed by this river is 341 km. In this study, total 13 sampling stations were selected on the Simav River. The common features of these points are due to the fact that they are connected with the small streams around them, the fields on which agricultural activities are carried out, and the residential areas (Figure 1, Tablo 1). Water samples were collected seasonally between the dates of May 2014 – February 2015. The names of these places where experimental studies were carried out at the stations briefly denoted as (ST1, ST2, ST3, ST14, ST5, ST6, ST7, ST8, ST9, ST10, ST11, ST12, and ST13 as seen in Table 1).

2.2 Physicochemical analysis

Measurements of dissolved oxygen (DO), oxygen saturation (%) and temperature (T), electrical conductivity (EC, 25 °C µS/cm) and salinity, pH in water of Simav River were performed in situ. For this purpose was used WTW Oxi 320 meter, YSI EcoSense EC300A, YSI EcoSense pH100A measurement devidaces during the field studies. Water samples, taken from stations have been analyzed within 24 hours after sampling.

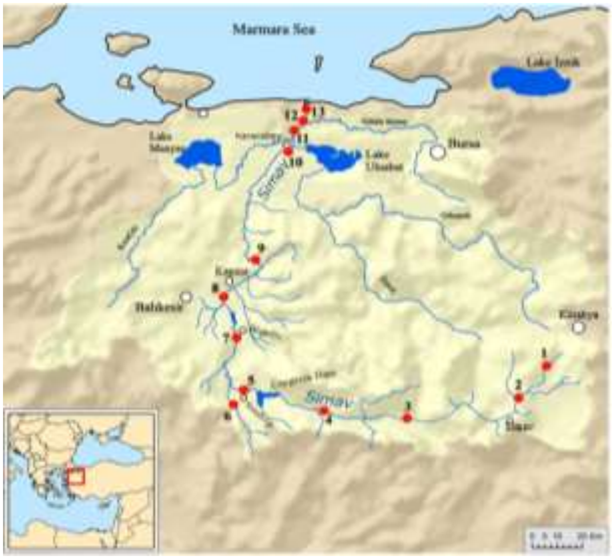

Figure 1. *Simav River and Sampling stations*

Table 1. *Sampling points and coordinate*

Station No	Sampling points	Location	Latitude Longitude
ST1	Şırla Stream	Simav-Kütahya (Rahimler)	39° 06′ 760″ K 29° 09′ 438″ D
ST2	Kalkan Pond exit	Simav-Kütahya	39° 05′ 286″ K 29° 05′ 642″ D
ST3	Çay Kasabası	Simav-Kütahya	39° 07′ 257″ K 28° 52′ 505″ D
ST4	Binmurt Bridge	Sındırgı-Balıkesir	39° 12′ 167″ K 28° 29′ 436″ D
ST5	Sındırgı Bridge (Çaygören Dam exit)	Sındırgı-Balıkesir	39° 17′ 061″ K 28° 11′ 497″ D
ST6	Cüneyt Bridge	Sındırgı-Balıkesir	39° 13′ 614″ K 28° 07′ 394″ D
ST7	Bigadiç Bridge	Balıkesir	39° 24′ 799″ K 28° 05′ 655″ D
ST8	Mahmudiye Bridge	Kepsut-Balıkesir	39° 36′ 247″ K 28° 05′ 122″ D
ST9	Yıldızköy Bridge	Susurluk-Balıkesir	39° 48′ 973″ K 28° 10′ 714″ D
ST10	Harmanlı Bridge	Karacabey-Bursa	40° 14′ 417″ K 28° 24′ 321″ D
ST11	Hayırlar Bridge (Lake Uluabat exit)	Karacabey-Bursa	40° 17′ 818″ K 28° 27′ 534″ D
ST12	Nilüfer Çayı joint point	Karacabey-Bursa	40° 18′ 382″ K 28° 26′ 891″ D
ST13	Estuary	Estuary	40° 23′ 348″ K 28° 30′ 332″ D

In water samples brought to the laboratory Mg^{+2} (mg/l), Ca^{+2} (mg/l), total hardness (mg /l $CaCO_3$), HCO_3^- (mg/l), CO^-_3 (mg/l), Cl^- (mg/l), NH_4-N (mg/l), NO_3^--N (mg/l), NO_2^--N (mg/l), PO_4^{-3}-P (mg/l), ∑P (mg/l) and turbidity (NTU) have been measured. Total hardness ($CaCO_3$) were determined by EDTA titrimetric method and alkalinity (HCO_3 and CO_3 mg/l $CaCO_3$) by titration with acid (Sulfiric acid). Cl- determine by titrating of AgNO3 according to Mohr method. In addition, the amount of the substances, NH_4-N, NO_3^--N, NO_2^--N, PO_4^{-3}-P, ∑P, were determined with CECİL CE4003 brand spectrophotometer associated with photometric test kits [14].

3. Results and Discussions

Range (minimum, maximum) and mean values of some water quality parameters of Simav River were given Table 2-4, and Figure 2-4, also seasonal variatons of these parameters were given Table 5-8. Physichochemical values of Simav River were show change acoocrding to stations and seasonal. Accordingly, in the river the lowest and the highest values; for temperature 6.4-23.4 C^0; for dissolved oxygen 0,3-18,1 mg/l; for pH 7.65-9.3; for electrical conductivity 254-2198 µS/cm; for turbidity 0.3-141.5 NTU; for Ca^{+2} 11.2-80.2 mg/l; for Mg^{+2} 6.8-68.04 mg/l; for total hardness 72.6-304.1; for NO_3^--N 0,015-3,2 mg/l; for NO_2^--N 0.008-0.96 mg/l; for NH_4-N 0.01-3.6 mg/l; for PO_4^{-3}-P 0.02-2.63 mg/l; for ∑P 0.08-6.68 mg/l; for Cl^- 8.8-536.9 mg/l; for HCO_3^- 112,5-530,7 mg/l have been found.

For easy of analysis, the data of the parameters of the Simav River water obtained from experimental measurements, we have, first, divided these parameters into two groups such as Group-1(Table 5-6) and Group-2 (Table 7-8). Due to the stations 2 and 3 (ST2, ST3) river were dried, water samples were not taken in this period.

The pH value of the river water changes very little depending on the stations and seasons, this change maybe expressed with the the width of the river changing from place to place. It is very difficult to determine the direct or indirect effect of pH on water quality [15]. The geological structure of the region is one of the most important factors affecting the pH of the waters, and it is closely related to the dissolved CO_2 in the water. The presence of free CO_2, carbonate and bicarbonate in water can be determined by measuring the pH of the water. As a result of photosynthesis, phytoplankton consume the CO_2 and increase the pH in the environment [16]. Aquatic organisms are tolerant to a certain pH range and can generally develop at pH 6.4-8.6 limit values [17]. pH, which deviates from the value range specified for the development of living things, negatively affects the life of aquatic organisms [7]. In decleration of human use purpose waters of the Turkish Standards Institute [18], the recommended value is 6.5<pH<8.5, while the maximum allowed value is reported as 6.5<pH<9.5 range [18]. During the research, pH values varied between 7.6 and 9.3, and the highest average value was found to be 8.84. pH values were measured seasonally above the upper limit value recommended in Drinking Water Standards (TS266) [18] and Surface Water Quality Regulation (SWQR) [19] in rivers. However, in terms of average values, recommended limit values were not exceeded, and Simav River water has alkaline property along the year (Table 2).

Water temperature changes the concentration of many variables by affecting biological, chemical and physical activities in water. By affecting all vital activities of aquatic organisms, it causes a change in their physiology and affects their distribution in water. Becouse of increase metabolic and respiratory rate of organisms as the temperature in water, dissolved oxygen value is decrease [20, 21]. During our research, the water temperature values at the sampling points changed within normal limits depending on the seasons. The average temperature values were show a change between 9,42-17,63 C^0 in the river. While the lowest temperature (6.4 C^0/November) was measured at the source point, the highest temperature (23 C^0/August) was measured at the point of the stream close to the sea. It was observed that especially at the river bed expanded and the sampling points close to the sea, temperature values were higher than the other sampling points. In [12], reported that the water temperature is high in the sub-region of Simav Stream during the summer months. In similar studies, it was stated that the water temperature increased with the expansion of the river bed and proximity to the sea, and while the water temperature in the river reached the highest value in the summer period and decreased in the winter period [1, 11, 22, 23, 24, 25]. It is stated that the optimal conditions in terms of water temperature are between 7-18°C in trout farming and between 16-26°C in carp farming [26, 27] reported that in the upper basin of the Simav River (from the source point to the Binmurt bridge), there are members of Cyprinidae that prefer the fast-flowing upper reaches of the stream.

Electrical conductivity of the water, EC, shows that the capacity of the ions included by the river water and whether this water allows the current to pass or not. Since conductivity can be considered as an indicator of dissolved substances in water, it is monitoring parameter.

An increase in conductivity in drinking water may indicate that the water is polluted or that sea water is mixed [16, 25]. From the point of view of fisheries, it becomes dangerous especially for fish if the EC value is greater than $^{10}00$ µmhos/cm [1, 8, 28]. Acceptable value for aquatic organisms is 250-500 µmhosx10/cm. The electrical conductivity values in the stream changed according to the stations, and high values were measured in the lower basin during the summer (2198 µmhos/cm in ST11) and autumn (956 µmhos/cm in ST12) periods. It can be said that the climatic conditions, intensive agricultural and livestock activities in the river region, and the pollution load brought to the Simav Stream by other important streams of the basin affect the measurement of high electrical

Table 2. *Range, mean and S.E. of physicochemical parameters at the stations of the Simav River*

Parameters		Water Temp. (C^0)	DO (mgl-1)	Oxygen Saturation(%)	pH	E.C (25C^0 µS/cm)	Salinity	Turbidity
ST1	Range Mean±SE	13,1-6,4 9,42±1,66	16,5-11,41 14,10±1,13	153,4-93 129,93±14,06	9,34-7,65 8,52±0,12	562-492,4 530,35±14,497	0,2-0,3 0,25±0,028	8,55-0,97 3,46±1,73
ST2	Range Mean±SE	15,2-6,9 10,26±2,52	10-18,15 13,18±2,50	178-82,3 117,37±30,4	8,74-8,16 8,46±0,16	607-400,1 477,43±65,187	0,3-0,2 0,2±0,081	2,12-1,38 2,22±0,51
ST3	Range Mean±SE	14,2-7,2 10,7±3,5	11,84-5,68 13,76±1,92	143,6-97,7 120,65±22,9	8,93-8,59 8,76±0,17	254,4-267,9 261,15±6,75	0,1 0,1±0,00	1,39-0,5 0,94±0,44
ST4	Range Mean±SE	22,1-11,8 16,45±2,690	7,67-11,02 8,79±0,76	100,9-78,7 89,2±4,54	9,03-8,62 8,842±0,08	865-375,4 586,87±106,81	0,3-0,2 0,057±0,041	8,08-1,16 4,16±1,46
ST5	Range Mean±SE	20,4-8,2 14,45±8,49	6,96-11,84 8,65±1,15	100,4-68,8 84,5±9,06	8,78-8,41 8,535±0,08	564-356,9 476,22±52,288	0,3-0,2 0,25±0,029	13,69-1,7 6,1±2,61
ST6	Range Mean±SE	20,3-9,8 3,8±2,47	6,03-11,23 8,22±1,23	99-53,4 76,42±9,63	9,14-7,82 8,575±0,28	561-379,7 457,55±39,309	0,3-0,2 0,225±0,025	3,21-0,35 1,82±0,73
ST7	Range Mean±SE	23-11,4 17,15±2,41	5,54-17,4 10,01±2,79	203,20-58,2 107,3±33,50	9,3-8,35 8,775±0,20	637-390,5 520,12±50,95	0,3-0,2 0,25±0,029	14,08-2,34 5,96±2,73
ST8	Range Mean±SE	21,1-13,8 16,4±2,74	5,7-11,7 8,96±1,27	124-65,3 93,45±12,8	9,34-8,07 8,565±0,27	592-438,9 594,22±66,75	0,4-0,2 0,275±0,048	12,31-3,04 7,80±2,51
ST9	Range Mean±SE	22-10,7 17,07±2,78	5,71-10,61 7,45±1,11	95,4-59,1 76,22±8,64	8,98-7,97 8,314±0,23	744-435 608,5±78,79	0,2-0,4 0,3±0,058	11,51-2,23 6,14±2,07
ST10	Range Mean±SE	21,5-12 15,4±2,09	4,8-11,7 9,11±1,54	107,7-54,3 86,4±11,72	8,96-7,84 8,422±0,23	656-488,7 567,42±44,48	0,3-0,2 0,25±0,029	22,07-8,45 15,06±3,12
ST11	Range Mean±SE	23,4-12,2 15,97±2,58	0,32-7,12 4,95±1,56	66,7-23,4 53,8±10,28	8,16-7,87 8,03±0,06	2198-513 1309,75±389,49	1,1-0,4 0,775±0,149	141,5-17,98 59,68±28,43
ST12	Range Mean±SE	21,6-10,5 16,82±2,82	0,44-10,57 4,46±2,47	94,5-10,4 45,13±20,92	8,65-7,65 8,017±0,23	956-523 826,5±102,42	0,5-0,3 0,45±0,05	22,07-14,38 21,25±2,56
ST13	Range Mean±SE	22,7-12,3 17,63±2,88	21,61-6,64 11,25±3,50	88,2-28,00 64,33±12,83	9,1-7,71 8,471±0,33	924-480 752,5±102,95	0,5-0,3 0,4±0,057	7,4-1,64 5,83±1,40

Table 3. *Range, mean and S.E. of physicochemical parameters at the stations of the Simav River*

Parameters		Ca^+ (mgl-1)	Mg^{++} (mgl-1)	Total Hardness ($CaCO_3$ mgl^{-1})	Cl^- (mgl-1)	HCO^-_3 (mgl-1)	CO^{-2}_3 (mgl-1)
ST1	Range Mean±SE	64,16-52,93 58,94±2,65	45,68-35,02 38,4±2,45	290,84-261,87 280,61±6,40	39,93-13,31 22,18±6,27	268,4-186,05 231,5±20,73	60-12 27,57±10,94
ST2	Range Mean±SE	80,2-17,64 38,895±21,14	40,82-10,69 18,952±10,18	237,59-185,75 163,02±64,08	35,5-26,63 29,58±2,95	423,95-213,5 320,25±60,77	30,1-6 16±7,21
ST3	Range Mean±SE	38,49 38,49±0,00	17,49 17,49±0,00	156,94 156,94±0,00	8,87 8,87±0,00	152,5-106,75 129,62±22,87	60-3 31,5±28,5
ST4	Range Mean±SE	65,76-11,23 39,29±12,92	54,43-16,52 35,72±9,301	245,36-72,66 190,94±39,85	35,5-17,75 26,62±5,12	280,6-155,55 232,56±30,15	45-9 17,25±9,75
ST5	Range Mean±SE	70,58-22,46 45,71±9,98	24,3-6,8 17,98±3,83	183,24-140,17 172,40±10,74	35,5-8,87 22,18±5,43	204,35-122 167,75±20,72	60-6 20,25±13,60
ST6	Range Mean±SE	41,7-11,23 23,66±6,42	59,29-37,91 44,22±5,04	235,8-190,41 212,79±12,92	17,75-8,88 13,31±1,81	347,7-198,25 257,72±32,24	15,1-6 5,25±3,54
ST7	Range Mean±SE	56,14-19,25 38,89±8,24	68,04-23,33 41,79±9,39	304,13-179,68 229,21±26,51	22,19-13,31 19,96±2,21	283,65-179,95 244,76±22,52	24,1-3 11,25±5,79
ST8	Range Mean±SE	59,35-17,64 39,29±8,52	49,57-23,33 33,53±6,17	276,55-181,2 214,60±22,09	39,94-22,19 26,62±4,43	314,15-176,9 273,73±32,62	24,1-9 13,5±5,54
ST9	Range Mean±SE	67,37-28,87 49,32±7,95	62,21-34,99 45,19±6,35	293,21-253,75 280,14±8,94	62,13-31,06 43,26±6,62	344,65-158,6 270,68±43,21	15,1-6 5,25±3,54
ST10	Range Mean±SE	48,12-26,66 32,33±5,26	54,43-40,82 48,81±3,36	261,95-226,69 249,58±7,86	102,06-48,81 53,25±24,13	305-15,25 250,1±34,06	30,1-9 9±14,28
ST11	Range Mean±SE	56,14-35,28 40,5±5,21	55,4-43,74 50,05±2,87	292,13-250,1 274,95±8,88	536,94-221,88 369,425±64,569	530,7-280,6 420,9±52,04	0,00 0,00
ST12	Range Mean±SE	48,12-12,83 33,682±7,43	43,74-30,13 39,607±3,233	261,95-136,62 221,647±28,65	199,68-102,06 137,56±23,198	396,5-240,95 336,26±33,69	0,00 0,00
ST13	Range Mean±SE	48,12-19,25 34,887±6,15	59,29-29,16 43,982±8,560	260,69-201,43 234,367±13,91	366-112,5 285,08±58,150	366-112,3 285,08±58,15	12,1-6 4,5±2,872

Table 4. *Range, mean and S.E. of physicochemical parameters at the stations of the Simav River*

Parameters		NO_3-N (mgl-1)	NO_2^--N (mgl-1)	NH_4-N (mgl-1)	PO_4^{-3}-P (mgl-1)	∑P (mgl-1)
ST1	Range Mean±SE	0,91-0,12 0,447±0,18	0,017-0,01 0,013±0,001	0,12-0,02 0,07±0,02	0,11-0,02 0,061±0,021	0,37-0,11 0,22±0,063
ST2	Range Mean±SE	0,5-0,1 0,26±0,12	0,063-0,008 0,026±0,018	0,54-0,13 0,27±0,135	0,24-0,04 0,116±0,062	0,35-0,08 0,18±0,085
ST3	Range Mean±SE	0,5-0,015 0,25±0,24	0,033-0,014 0,024±0,009	0,87-0,14 0,50±0,36	0,07-0,022 0,046±0,024	0,35-0,08 0,215±0,135
ST4	Range Mean±SE	1-0,18 0,49±0,19	0,02-0,01 0,015±0,002	0,21-0,02 0,12±0,03	1,57-0,07 0,565±0,347	1,42-0,17 0,742±0,259
ST5	Range Mean±SE	0,72-0,15 0,54±0,13	0,034-0,01 0,018±0,005	0,13-0,024 0,06±0,02	0,14-0,02 0,105±0,040	0,27-0,21 0,247±0,014
ST6	Range Mean±SE	0,74-0,2 0,47±0,11	0,017-0,011 0,014±0,001	0,94-0,025 0,33±0,20	0,08-0,025 0,05±0,012	0,24-0,08 0,138±0,034
ST7	Range Mean±SE	0,15-1,34 0,85±0,26	0,034-0,028 0,031±0,0015	0,16-0,025 0,08±0,03	0,39-0,04 0,197±0,072	0,95-0,39 0,6±0,122
ST8	Range Mean±SE	3,2-0,35 1,2±0,679	0,071-0,032 0,051±0,011	0,56-0,025 0,193±0,124	0,75-0,13 0,36±0,139	1,32-0,46 0,842±0,202
ST9	Range Mean±SE	1,99-0,35 1,09±0,42	0,22-0,044 0,141±0,039	0,38-0,025 0,19±0,07	1,79-0,25 0,802±0,338	1,82-0,65 1,482±0,278
ST10	Range Mean±SE	0,92-0,02 0,48±0,18	0,13-0,015 0,063±0,027	3,66-0,04 1,01±0,88	0,86-0,28 0,517±0,122	2,2-0,57 1,277±0,383
ST11	Range Mean±SE	0,68-0,2 0,32±0,12	0,104-0,073 0,301±0,219	2,9-0,22 1,12±0,61	2,63-0,36 1,367±0,551	6,68-1,65 3,623±1,091
ST12	Range Mean±SE	0,8-0,2 0,57±0,13	0,38-0,019 0,133±0,083	1,86-0,18 1,067±0,451	1,63-0,25 0,745±0,306	2,78-0,81 1,725±0,404
ST13	Range Mean±SE	0,2-0,2 0,2±0,00	0,1-0,01 0,056±0,018	1,28-0,11 0,64±0,30	1,29-0,03 0,612±0,264	4,55-0,12 2,41±0,96

Table 5. *The values of the parameters included in Group-1 measured in May and August at 13 stations*

		pH	E.C. (25 ^{0}C µS/cm)	D.O. (mg/l)	Satur. (%)	T (^{0}C)	Salin (ppt)	Turb. (NTU)	Total Hardness ($CaCO_3$ mg/l)
ST1	May	8,8	528	13,14	150,2	11,4	0,2	0,97	261,87
	August	8,23	539	16,5	153,4	13,1	0,3	8,55	290,84
ST2	May	8,74	425,2	18,15	178	15,2	0,3	1,38	185,75
	August	-*	-*	-*	-*	-*	-*	-*	-*
ST3	May	8,93	267,9	15,68	143,6	14,2	0,1	0,5	156,94
	August	-*	-*	-*	-*	-*	-*	-*	-*
ST4	May	9,03	474,1	7,94	89	20	0,2	8,08	72,66
	August	8,62	633	7,67	88,2	22,1	0,3	2,99	216,95
ST5	May	8,78	420	8,85	100	20,4	0,2	1,7	183,24
	August	8,41	564	6,96	68,8	14,6	0,3	4,53	140,17
ST6	May	9,14	417,8	9,25	83	15	0,2	3,21	235,8
	August	7,82	561	6,4	70,3	20,3	0,3	0,78	234,54
ST7	May	9,3	509	17,4	203,2	18,2	0,2	4,28	304,13
	August	8,35	544	5,54	64,3	23	0,3	2,34	179,68
ST8	May	9,34	592	10,04	124	20,8	0,2	3,87	276,55
	August	8,07	581	5,7	65,3	21,1	0,3	12,31	216,11
ST9	May	8,98	515	7,41	86	22	0,2	7,22	253,75
	August	7,97	744	5,71	64,4	21,5	0,4	3,63	288,05
ST10	May	8,62	488,7	11,7	107,7	13,8	0,2	22,07	261,95
	August	7,84	632	4,8	54,3	21,5	0,3	11,4	226,69
ST11	May	8,11	513	7,12	66,7	12,7	0,7	54,92	292,13
	August	7,98	2198	0,32	23,4	23,4	1,1	141,5	280,47
ST12	May	9,25	730	6,23	72	20,3	0,4	22,07	261,95
	August	7,65	944	0,44	10,4	21,6	0,5	26,8	136,62
ST13	May	8,86	707	6,64	73	22,54	0,3	7,4	221,48
	August	7,71	899	2,61	28	22,7	0,5	7,03	260,69

Table 6. *The values of the parameters included in Group-1 measured in May and August at 13 stations*

		pH	E.C. (25 ^{0}C µS/cm)	D.O. (mg/l)	Satur. (%)	T (^{0}C)	Salin (ppt)	Turb. (NTU)	Total Hardness ($CaCO_3$ mg/l)
ST1	November	8,43	562	15,38	123,1	6,4	0,3	2,7	284,58
	February	8,63	492,4	11,41	93	6,8	0,2	1,64	285,18
ST2	November	8,16	607	10,2	82,3	8,7	0,3	2,12	228,67
	February	8,49	400,1	11,2	91,8	6,9	0,2	3,17	237,59
ST3	November	-*	-*	-*	-*	-*	-*	-*	-*
	February	8,59	254,4	11,84	97,7	7,2	0,1	1,39	156,94

ST4	November	8,93	865	8,56	78,7	11,8	0,3	1,16	228,79
	February	8,79	375,4	11,02	100,9	11,9	0,2	4,41	245,36
ST5	November	8,41	564	6,96	68,8	14,6	0,3	4,48	183,1
	February	8,54	356,9	11,84	100,4	8,2	0,2	13,69	183,1
ST6	November	8,54	471,7	6,03	53,4	10,1	0,2	0,35	190,41
	February	8,8	379,7	11,23	99	9,8	0,2	2,97	190,41
ST7	November	8,84	637	5,8	58,2	16	0,3	3,17	211,75
	February	8,61	390,5	11,33	103,5	11,4	0,2	14,08	221,3
ST8	November	8,38	765	8,4	80,8	13,8	0,4	3,04	184,57
	February	8,47	438,9	11,7	103,7	9,9	0,2	12,01	181,2
ST9	November	8	740	6,1	59,1	14,1	0,4	2,23	285,58
	February	8,32	435	10,61	95,4	10,7	0,2	11,51	293,21
ST10	November	8,27	656	9,05	84,5	14,3	0,3	8,45	257,05
	February	8,96	493	10,89	99,1	12	0,2	18,33	252,65
ST11	November	7,87	1707	6,46	66,2	15,6	0,9	17,98	277,1
	February	8,16	821	5,9	58,9	12,2	0,4	24,33	250,1
ST12	November	8,12	956	6,4	65,2	13,6	0,5	14,38	244,01
	February	8,65	523	10,57	94,5	10,5	0,3	21,76	244,01
ST13	November	8	924	7,31	68,3	13	0,5	7,27	253,87
	February	9,1	480	9,43	88,2	12,3	0,3	1,64	201,43

conductivity values in the lower basin. It has been reported that the pollution of Nilüfer Stream increases gradually towards the lower region where it joins with Simav Stream [29]. In the upper river basin, the electrical conductivity values were measured at 561 µmhos/cm and above, and it was measured below this value only in ST2. It is thought that the periodic drying of the second station is effective in measuring this value. In [30] reported that there is an increase in the pollution of the middle part of the stream due to the mixing of wastes from Sındırgı and Bigadiç sewage systems, dairy farms and slaughterhouses into the Simav Stream without any treatment. According to SWQR, the upper and middle course of the river II. in quality class (medium), lower grade III. in the quality class.

Dissolved oxygen, DO, is one of the most important parameters used in monitoring water quality change. The amount of dissolved oxygen in a river is very important especially for the fish living in a river [7, 31]. The amount of dissolved oxygen determined in the water at any time in the water changes depending on the current temperature of the water, the partial pressure of the atmospheric gas on the water surface, the water flow rate, the dissolved salt concentration and biological events. The amount of dissolved oxygen in water decreases with decreasing temperature. While the amount of dissolved oxygen in water increases with photosynthesis and current velocity, it decreases as salt density, temperature, organic matter degradation and respiration activities increase [17,32,33] As seen from Table 5 and 6, the amount of the DO in river water decreases gradually from May to August in time and increases slowly from November to February in time. It may be due to heavy rainfall in May and December and less rainfall in August and February. The mean dissolved oxygen values of Simav Stream were measured between 4.95-14.10 mg/l (Table 2). Especially in the lower regions of the stream (ST10;ST11; ST12; ST13), it was observed that the dissolved oxygen value decreased very much (respectively 4.8; 0.3; 0.44; 2.61 mg/l) during the summer period. Due to the expansion of the river bed the decrease in the flow rate, weather conditions and increased pollution load are tought to be effective in the decrease of dissolved oxygen in these stations. The river subdivision (ST10, ST11, ST12, ST13) is exposed to agricultural, industrial, and domestic wastes while passing through the settlements where intensive agriculture and livestock are made. At the 10th sampling point (ST10), Kocasu emerged from Lake Uluabat, and at the 12th sampling point (ST12) Nilüfer Stream are join the stream. It was reported that Uluabat Lake was under intense pollution pressure and could not be used as drinking or irrigation water, and also stated that pollutant limits should be introduced on the basis of basin [34]. It is stated that the water quality of the Nilüfer Stream is an open sewer at the exit of the Bursa city center and is heavily polluted due to domestic and industrial discharges in the city center [35]. According to the EC directive declared by the European Union Commission on the purpose of the protection of fish health in fresh waters, a decrease in the dissolved oxygen level below 4 mg/L in the water poses a threat to Cyprinid species [36]. Dissolved oxygen values should be between 9.20–11.50 mg/L for trout and 5.00–9.00 mg/L for carp [26]. Oxygen below 5mg/l produces harmful effects and sensitivity to low levels varies by species; however, most species experience stress between 2 and 4 mg/L. Fish deaths occur especially at oxygen levels below 2 mg/l [37, 38]. It has been stated that in the lower basin of the river (in the region where Nilüfer Stream mixes), the majority of the species that prefer clean, oxygen-soluble, slow-flowing regions of the rivers have disappeared [27]. According to SWQR (Surface Water Quality Regulation), the upper part of the stream is II. quality (very good), and subgrade III. quality (medium) class.

Turbidity is due to particles dissolved or suspended in water. Since turbidity is inversely proportional to the penetration of light into water, it is an important parameter for aquatic organisms [1, 39]. Excessive turbidity may adversely affect the food sources, spawning areas and gill functions of fish and other aquatic organisms. Simav Stream turbidity values have exceeded the limit values specified in TS266 along the stream. It was observed that turbidity values increased especially in the summer period. The highest turbidity values were measured in the stream sub-region (ST10, ST11, ST12) (Table 2). The decreasing amount of water in the summer period and the amount of suspended matter coming from the side arms and upper region may be effective formed of the high turbidity. The increase in turbidity values have been remarkable after Uluabat Lake outlet waters and the mixing of Nilüfer Stream.

Generally, the hardness for water is understood as the precipitation property of the soap in water. In practice, the hardness of the water is expressed with the amount of Ca^{+2} ve Mg^{+2} ions dissolving in water passing through the soil [40, 41, 42]. One of the water quality parameters that increase the effect of toxic substances in water is total hardness and hard water increases this effect. Therefore, hard water is not suitable for aquaculture [42].
$CaCO_3$ is one of the water quality parameters. Hardness in water is given as $CaCO_3$ equivalent in mg/l unit; soft water (0-50 mg/l $CaCO_3$), medium hard (150-250 mg/l $CaCO_3$), hard water (250-350 mg/l $CaCO_3$), very hard (brackish) water (>350 mg/l $CaCO_3$) classified as [16]. According to the measured data seen in Table 5 and 6, as it is seen that the total hardness values show variations along the river, calculated average values show that the river takes a place among the rivers classified with medium hard. Ca^{+2} and Mg^{+2} are the most found metal ions dissolved in streams and rivers. Among these, calcium is the one much more found than those. These two ions play a vital role on the formation of cobonate salts which are necessary especially for aquatic animals, and for the elimination of the toxic effects of some substances [17, 43, 44, 45, 46,]. The normal the least and maximum amounts of Ca^{+2} and Mg^{+2} are 1-150 and 5-10 mg/l, respectively [47, 48]. In Table 7 and 8, Fig. 3, it is seen that the amount of the value of Ca^{+2} ve Mg^{+2} in Simav Çayı valley do not vary prominently. Mg^{+2} can be derived from igneous and metamorphic rocks and magnesium carbonate (dolomite) in sedimentary rock. Some researchers have suggested that the sources of magnesium are due to the rains bringing magnesium from different regions with volanic, karstic and calcareous structures [13, 50, 49]. In [50] reported that the Simav Stream valley is over volcanic materials. According to the determined calcium and magnesium values, it can be said that the river rock structure has a karstic structure. Chloride anion is found in all of the natural waters, and it is the one of the minerals effecting on the diversity of livings. Since the solubility of chloride salts is high, it is one of the important indicators of healthy water. A water is called very salty water if its chloride concentration is higher than 250 mg/L [51]. Its concentration is usually low but it is high concentrations in polluted waters. The source of chloride in natural water may be domestic, industrial wastes, agricultural activities, as well as it may be of mineral origin. Chloride content may vary according to the distance of freshwater to the sea and the rock structure. The sudden increase in chloride suggests that industrial wastes are mixed with water [11, 32, 40, 49, 52,]. Chloride values of the Simav River water at upper basins are close to each other varying from 8,87-29,58 m/l as seen in Table 7 and 8. It is thought that the lowest value was determined at the 3rd sampling point because the river dries up periodically. The required value of chloride in natural is between 0 and 30 mg/L. So, the chloride concentration value of the river at the mentioned basins may be said that it is suitable. It was observed that the chloride values increased after the Kepsut region.

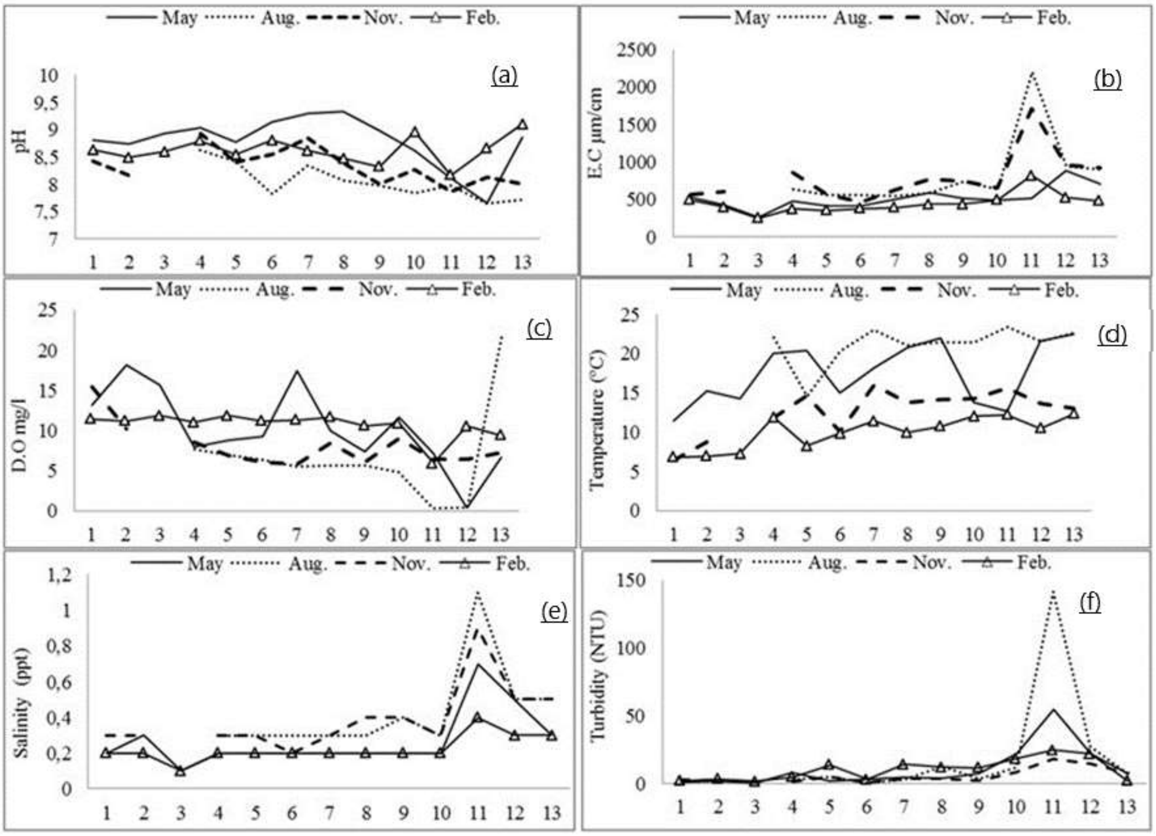

Figure 2. *Variations of water quality parameters the Simav River corresponding to seasonally of of (a) pH, (b) E.C, (c) DO, (d) temperature, (e) salinity and (f) turbidity*

Table 7. *The values of the parameters included in Group-2 measured in May and August at 13 stations*

		NH_4-N (mg/l)	NO_3-N (mg/l)	NO_2-N (mg/l)	PO_4-P (mg/l)	ΣP (mg/l)	Ca (mg/l)	Mg (mg/l)	Cl (mg/l)	HCO_3 (mg/l)	CO_3 (mg/l)
ST1	May	0,05	0,6	0,01	0,11	0,37	56,14	35,02	13,31	186,05	60
	August	0,01	0,91	0,017	0,02	0,28	52,93	45,68	39,93	207,4	12
ST2	May	0,54	0,5	0,063	0,07	0,35	17,64	40,82	26,63	213,5	30
	August	0,27	0,25	0,027	0,12	0,18	51,86	25,27	29,586	320,25	16
ST3	May	0,87	0,5	0,033	0,07	0,35	38,49	17,49	8,87	152,5	60
	August	0,505	0,257	0,023	0,046	0,215	38,49	17,49	8,87	129,625	31,5
ST4	May	0,21	1	0,02	0,49	0,78	56,14	16,52	17,75	213,5	15
	August	0,024	0,59	0,012	0,13	0,6	11,23	54,43	17,75	280,6	9
ST5	May	0,09	0,7	0,01	0,06	0,24	70,58	6,8	35,5	122	60
	August	0,02	0,72	0,034	0,02	0,21	22,46	24,3	8,87	201,3	6
ST6	May	0,94	0,5	0,017	0,08	0,24	41,7	37,91	17,75	228,75	15
	August	0,025	0,45	0,011	0,025	0,11	11,23	59,29	8,88	347,7	0
ST7	May	0,05	1,2	0,028	0,2	0,95	48,12	68,04	22,18	225,7	24
	August	0,025	1,34	0,034	0,04	0,39	19,25	37,91	13,31	253,15	3
ST8	May	0,56	0,35	0,071	0,37	1,32	59,35	36,94	22,19	311,1	24
	August	0,025	0,91	0,032	0,13	0,46	17,64	49,57	22,19	292,8	0
ST9	May	0,13	0,35	0,11	0,56	1,72	52,93	34,99	31,06	247,05	15
	August	0,025	1,64	0,22	0,61	1,74	28,87	62,21	62,13	332,45	0
ST10	May	3,66	0,6	0,083	0,45	1,61	48,12	40,82	102,06	150,25	0
	August	0,04	0,92	0,13	0,48	2,2	27,27	45,68	66,56	271,45	0
ST11	May	0,93	0,2	0,073	0,53	2,6	56,14	43,74	221,88	448,35	0
	August	0,43	0,2	0,96	1,95	6,68	35,29	55,4	536,94	530,7	0
ST12	May	1,83	0,6	0,083	0,45	1,61	48,12	40,82	102,06	366	0
	August	0,18	0,8	0,38	0,65	2,78	12,83	30,13	199,68	396,5	0
ST13	May	1,06	0,2	0,1	0,43	3,31	48,12	29,16	159,75	335,5	6
	August	0,14	0,2	0,06	0,7	4,55	32,08	58,32	181,94	366	0

Table 8*. The values of the parameters included in Group-2 measured in November and February at 13 stations*

		NH_4-N (mg/l)	NO_3-N (mg/l)	NO_2-N (mg/l)	PO_4-P (mg/l)	ΣP (mg/l)	Ca (mg/l)	Mg (mg/l)	Cl (mg/l)	HCO_3 (mg/l)	CO_3 (mg/)l
ST1	November	0,12	0,16	0,014	0,07	0,11	62,56	36,94	22,19	268,4	18,3
	February	0,11	0,04	0,01	0,03	0,12	64,16	35,96	13,31	265,4	20
ST2	November	0,13	0,15	0,008	0,24	0,08	57,74	24,3	26,63	323,3	6
	February	0,14	0,1	0,009	0,04	0,11	80,2	10,69	35,5	423,95	12

ST3	November	0,505	0,2575	0,0235	0,046	0,215	38,49	17,49	8,87	129,625	31,5
	February	0,14	0,015	0,014	0,022	0,08	38,49	17,49	8,87	106,75	3
ST4	November	0,11	0,2	0,011	1,57	1,42	24,06	48,6	35,5	280,6	45
	February	0,15	0,18	0,018	0,07	0,17	65,76	23,33	35,5	155,55	0
ST5	November	0,03	0,6	0,01	0,2	0,27	44,91	20,41	22,19	204,35	15
	February	0,13	0,15	0,021	0,14	0,27	44,91	20,41	22,19	143,35	0
ST6	November	0,26	0,2	0,014	0,055	0,085	20,88	39,85	13,31	256,2	6
	February	0,12	0,74	0,014	0,04	0,12	20,85	39,85	13,31	198,25	0
ST7	November	0,11	0,73	0,028	0,39	0,56	32,08	37,91	22,19	283,65	18
	February	0,16	0,15	0,032	0,16	0,5	56,14	23,33	22,19	179,95	0
ST8	November	0,06	3,2	0,068	0,75	1,03	40,1	24,3	39,94	314,15	21
	February	0,13	0,34	0,034	0,19	0,56	40,1	23,33	22,19	176,9	9
ST9	November	0,38	1,99	0,19	1,79	1,82	48,12	47,63	39,94	344,65	0
	February	0,23	0,39	0,044	0,25	0,65	67,37	35,96	39,94	158,6	6
ST10	November	0,07	0,02	0,015	0,86	0,73	27,27	54,43	48,81	305	6
	February	0,25	0,38	0,025	0,28	0,57	26,66	54,32	53,25	173,85	30
ST11	November	0,22	0,2	0,065	2,63	3,56	35,29	54,43	359,44	423,95	0
	February	2,9	0,68	0,104	0,36	1,65	35,28	46,66	359,44	280,6	0
ST12	November	1,86	0,7	0,05	1,63	1,7	36,89	43,74	146,44	341,6	0
	February	0,4	0,2	0,019	0,25	0,81	36,89	43,74	102,06	240,95	0
ST13	November	1,28	0,2	0,055	1,29	1,66	19,25	59,29	124,25	326,35	0
	February	0,11	0,2	0,01	0,03	0,12	40,1	29,16	88,75	112,5	12

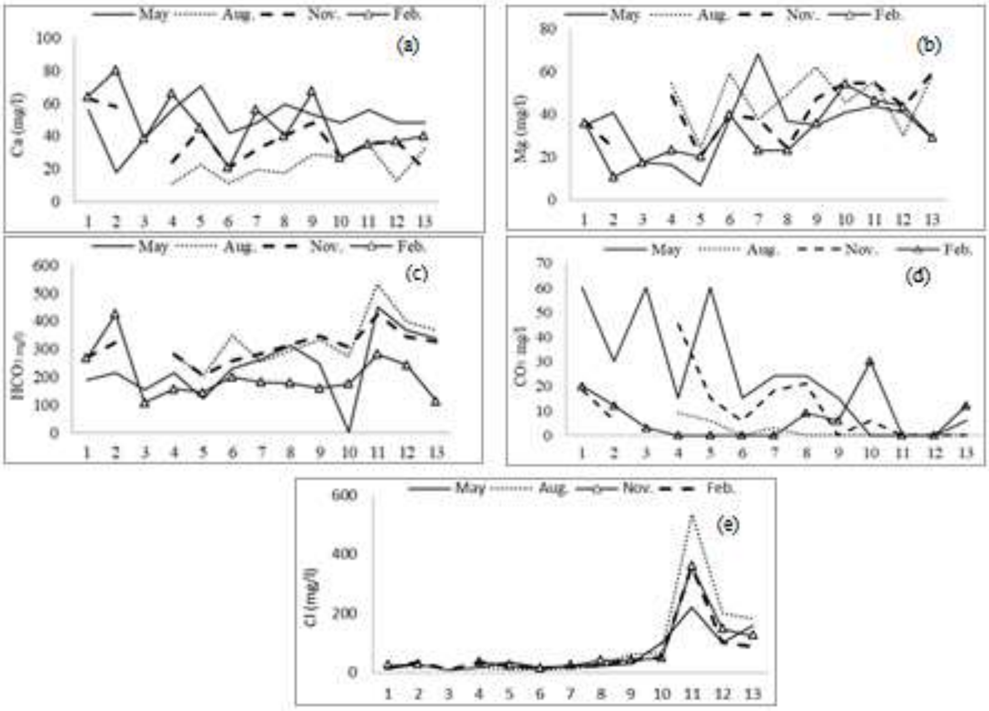

Figure 3. *Variations of water quality parameters the Simav River corresponding to seasonally of (a) Ca, (b) Mg, (c) HCO_3, (d) CO_3, (e) Cl^-*

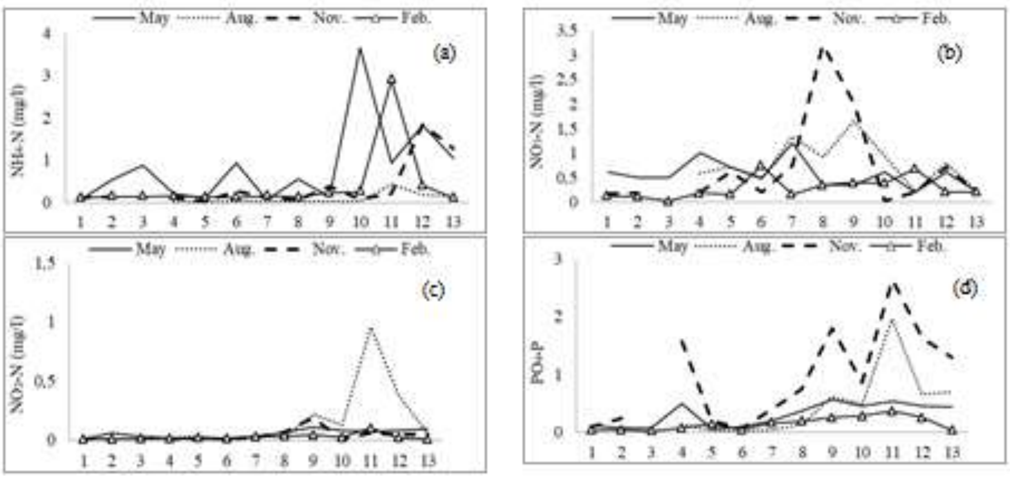

Figure 4. *Variations of water quality parameters the Simav River corresponding to seasonally of (a) NH_4-N, (b) NO_3-N, (c) NO_2-N, (d) PO_4-P*

The highest mean value (369.42 mg/l) was determined at the 11th sampling point (Uluabat Lake outlet) (Table 3, Figure 3).

In [53] stated that chloride creates a pollution load together with some the other parameters in the Lake Uluabat and domestic and agricultural drainage waters pollute the lake. It could be said that especially in Kepsut region and afterwards (ST8, 9, 10, 11, 12, 13), the increase in chloride values was caused by intense domestic and industrial wastes and agricultural activities. The large agricultural lands have been expressed quite close to the stream in the Kepsut region [13]. In this research, it has been observed that the agricultural lands of the region were flooded in the autumn period and the surface waters from these lands mixed with the stream.

Phosphorus is found in natural waters either in the form of dissolved organic phosphorus or in the form of organic phosphorus suspended in water. Therefore, it indirectly affects the development of heterotrophic organisms negatively. Lack of phosphorus limits the growth of autotrophs organisms [44, 17]. Domestic wastes (especially detergents), industrial wastes, sewage water are constitute 91% of the phosphorus source. Agricultural fields, volcanic rocks, meteorites and soil constitute 9% of the phosphorus source. Phosphates mixed with surface waters from these sources creates eutrophication as they cause excessive growth of algae and other aquatic plants. Some researchers sudgested that the amount of phophorous may vary from 0,05 to 0,3 mg/l in stream and river waters [17, 32, 40, 44]. Phosphorus values increased along the river in Kepsut and afterwards. In the upper region of Simav Stream did not show much change at stations, but its value at station 4 (1.57 mg/l PO4-P and 1.42 mg/l total P in autumn) was remarkable (Figure 4). It was detected in the 9th sampling point (1.79 mg/l, 1.82 mg/l) between Kepsut and Susurluk settlements in the central region. It is thought that intensive agricultural activities and direct discharge of domestic wastes into streams in these regions caused an increase in phosphorus values. Phosphorus values were determined above the limit values in the summer and autumn periods seasonally. We can said that due to the decreased in stream flow caused in summer and due to the runoff from agriculturel areas in autumn phosporus values were incresead (Figure 4). It has been reported that phosphorus values increase in the middle region of Simav Stream in summer, and it was a receiving body for domestic and industrial wastewater, especially after Çaygören Dam. For this reason, it have been stated that the water pollution of Simav Stream increases towards the north [30]. The highest phosphorus values of Simav Stream (in summer and autumn) were determined in the river sub-region. It is thought that the reason for this increase as the mixing of the side branches carrying the pollution load into the river and is also caused by the environmental factors mentioned above. According to SWQR (the Surface Water Quality Regulation), the stream III. quality (medium) class.

One of the important elements found in natural waters is nitrogen (N) and it is also found in stream and river waters in the form of dissolved gas (N_2), inorganic nitrogen (NH_4, NO_2, NO_3) and dissolved or organic compound.

Inorganic nitrogen is only nutritive element taking place among these nitrogen compounds. These nutritive elements are very important for the microorganisms to survay their lives. There are many nitrogen sources are due to the interaction between water and atmosphere, natural decomposition of organic matter, the metabolic by-product of protein catabolism that provides NH4-N, the nitrogen bound by microorganisms from the soil and the biological degradation of domestic, agricultural and industrial wastes. In recent years, the increase in these nitrogenous compounds with human influence affects the distribution and physiology of aquatic organisms. Therefore, nitrogen compounds are one of the important parameters in the determination of water pollution [42, 44, 54, 55, 56]. In natural waters, ammonia is 0.1 mg/l and ammonium compounds are 1 mg/l or less [17,57]. Nitrite, nitrate and ammonium nitrogen levels, which are nitrogen derivatives, showed differences according to stations and seasons in Simav Stream. The values increasing from the upper course of the stream to the lower course were measured. The values increasingly from the upper region of the river to the lower region were measured. The highest nitrate nitrogen (1.99 mg/l, autumn) and nitrite nitrogen (0.96 mg/l, spring) values were determined in the sub-region stream (Table 4). According to SWQR, it was in the I. quality class in terms of NO3-N value. The lower and middle region of the stream heve been in I. quality (good) class according to the average value of NH4-N value, but the middle region, only around Karacabey, and the lower region II. have been determined in the quality class. Seasonally, the highest ammonium nitrogen (3.66 mg/l) was detected in ST10 (in the lower part of the stream) in the spring period (Figure 4). It can be said that it was caused by the increasing domestic and industrial wastes, as well as the intensive livestock activities. It was emphasized that the discharge of slaughterhouse and factory wastes, sewage water in the river basin to the Simav Stream created intense pollution pressure, and it have been stated that especially the Nitrate values were high [13].

4. Conclusions

In this research, it was aimed to determine the water quality of Simav River which one of the most important river of the Turkey. As a result of rapid population growth, unplanned urbanization and industrialization in Turkey, water pollution has been occurring in recent years. Simav River is under pressure of pollotion from spring point to sea. Especially upper catchment is affected from the agricultural activies and middle/down catchment from the both agriculturel and livestock, endustrial activities. It is thought that, all of thesese man-made activities cause pollution in Simav river. Periodic floods and wastes from the food industry (especially from meat, milk production and industrial facilities) are thought to be effective in the formation of pollution. In the region both the main stream and its tributaries are used for irrigation, and Çaygören Dam Lake on the river is also that purpose. Relatively cleaner areas of the stream have been the sections passing through high mountain areas and low population areas.

In order to increase the quality of Simav Stream and provide its sustainability;

- By raising awareness of the people of the region, excessive use of chemical fertilizers and pesticides in agricultural activities should be prevented.
- In order to prevent the mixing of the rivers due to the flood from the agricultural areas, a flood prevention plan should be prepared and the surrounding people should be informed.
- The industrial facilities in the basin should be inspected frequently, and the facilities whose treatment systems do not work or that operate irregularly should be prevented from continuing their activities.
- The people of the environment, one of the most important livelihoods of which is livestock, should be informed about the sustainability of waters. In addition, other pollution sources (Integrated meat plant, poultry farm etc) should be inspected frequently.
- For the sustainability of the stream, the water quality should be constantly monitored physically, chemically and biologically. Necessary measures should be taken according to the data obtained.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
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