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FERDİ TANIR

BERİL AKÇİMEN

FATİH KÖKSAL

NECDET AYTAÇ

İBRAHİM CENGİZLER

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Dimensions of water contamination in the subprovinces of Adana province, Turkey

Ferdi TANIR[1], Beril AKÇİMEN[2], Fatih KÖKSAL[2], Necdet AYTAÇ[1], İbrahim CENGİZLER[3]

Aim: To determine the dimension of the contamination of the drinking and utility water in the touristic Bahçe district of the Karataş subprovince of Adana province, and to share our views on how to raise the quality of the water in the district.

Materials and methods: In 2007 and 2008, 80 samples were taken 8 times, on a seasonal basis, from the drinking water and sea water of the Bahçe district. Eleven organic and inorganic parameters were measured and presented following a comparison with criteria values

Results: Ni, Zn, Cu, Pb, NO_3-N, COD, and phenol contamination parameters were found to be high in the stations that provide drinking water and utility water for the Bahçe district.

Conclusion: This level of contamination was attributed to the extensive use of natural and artificial fertilizers and pesticide, agricultural contamination, and the fact that polluters were not at a safe distance from the stations and were particularly hazardous types of polluters. It is of the utmost importance that training be provided in order to ensure use of fertilizers and pesticides in standard amounts and at standard times. The training should be supported with warnings and inspections.

Key words: Water pollution, heavy metals, pesticides, contamination

Adana ili kırsalında su kirliliğinin boyutları

Amaç: Bu araştırmanın amacı, Adana ili Karataş ilçesi turistik Bahçe beldesineki içme ve kullanma sularındaki kirliliğin boyutlarını saptamak ve su kalitesini artırma konusundaki görüşlerimizi paylaşmaktır.

Yöntem ve gereç: 2007 ve 2008 yıllarında sezonluk dönemlerle sekiz kezde içme suyu ve denizden alınan 80 su örneği alındı. Ölçülen organik ve inorganik 11 parametrenin ölçümleri standart değerlerle karşılaştırıldı.

Bulgular: Ni, Zn, Cu, Pb, NO_3-N, kimyasal oksijen ihtiyacı ile fenol değerleri, içme ve kullanma sularında yüksek bulundu.

Sonuç: Bu yüksek değerler atıklara ve tarımsal ilaçlara atfedildi. Belli miktarlarda ve zamanlarda zirai ilaçların kullanılması konusunda eğitim en önemli hedeftir. Bu eğitimler, gözlem ve uyarılarla desteklenmelidir.

Anahtar sözcükler: Su kirliliği, ağır metaller, tarım ilaçları, bulaşma

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[1] Department of Public Health, Faculty of Medicine, Çukurova University, Adana - TURKEY
[2] Department of Microbiology, Faculty of Medicine, Çukurova University, Adana - TURKEY
[3] Faculty of Fisheries, Çukurova University, Adana - TURKEY
Correspondence: *Ferdi TANIR, Department of Public Health, Faculty of Medicine, Çukurova University, Adana - TURKEY*
E-mail: ftanir@cu.edu.tr

Introduction

Adana province is one of the most important provinces of the ancient Cilicia region. Many species that are about to become extinct in other parts of the world still exist in marshy places, fish garths, and lagoons on the Mediterranean coast of Adana (approximately 80 km), a region that has rich nature with endemic plant varieties. The primary source of income in the Bahçe district of Karataş subprovince, 47 km from Adana, is tourism. There is 1 hotel with 110 beds and a public resort for 5000 people, and there are summer houses with 1654 residents. The permanent population of Bahçe district is 2800, and the temporary population is approximately 10,000 people (1-3).

Drinking water is obtained by collecting the water extracted from deep bores of 20-40 m, chlorinating it in a depot, and distributing it through networks. In the center of the district, the water extracted from 3 active wells is stored in 1 depot and transported to the utility areas through network chlorination. While 79% of the population uses water from this network, approximately 15% lack sufficient water (4). Only 20% of the community has treated water, and 80% lacks healthy drinking water (5,6).

This study aimed to determine the dimension of contamination of the drinking and utility water in the touristic Bahçe district of Karataş subprovince in Adana province and to share suggestions on raising the quality of the water in the district.

Materials and methods

Drinking water samples were taken from the summer houses, the hotel, and the settlements in Bahçe district (DWS-1, DWS-2, DWS-3), and seawater samples were taken from 2 stations on the touristic coast (SS-1, SS-2). Samples were taken 80 times in the course of 2 years, 10 times a month, twice each in January, April, July, and October in 2007 and 2008. The usage of pesticides and fertilizers was most commonly observed from April to September. The middle month (i.e. the second month) of each season was selected to determine the change in water pollution in relation to seasons and agricultural activities. This periodic sampling was intended to demonstrate the seasonal and agricultural differences among the months (5,7). These samples were analyzed and recorded. Chemical water and bacteriological water samples, which were taken in accordance with the regulations, were sent to the analysis center within 2 h. The samples were analyzed with a UV-Vis spectrophotometer for organic and inorganic contamination at the Work and Occupational Health Laboratory of the Department of Public Health in the Medical Faculty of Çukurova University.

Furthermore, bacteriological contamination was tested by using cultures in the Bacteriology Laboratories of the Department of Microbiology. Only 2 organic parameters of water contamination and 9 inorganic parameters were tested; other organic and inorganic parameters could not be measured due to the insufficient amount of chemicals (4).

Chemical oxygen demand (COD), phenol, inorganic water contamination, nickel (Ni), cyanide (CN), zinc (Zn), copper (Cu), lead (PB), total chromium (T-Cr), cadmium (Cd), nitrate-nitrogen (NO_3-N), and total phosphorus (T-P), which are among the criteria of organic water contamination, were measured (mg/L). Contamination measurements were conducted by using cultures of fecal coliforms, EMS/100 mL, and other reproducing bacteria (8). A team, comprising 2 physicians and 3 technicians, collected and analyzed the samples. The measurements were evaluated on the basis of the criteria set out in "Water Contamination Control Regulation" and "Turkish Standards Institute-TSI" (6). The findings were analyzed with variance analyses through repetitive measurements via the SPSS statistical program and presented.

Results

- It was found that the measurements of Ni, Cu, NO_3-N, T-P, phenol, and COD were higher than the normal values for both years on the basis of the annual average values (Table 1, Figures 1-10).
- It was found that the Pb values measured at the SS-1 station were normal for both years and higher than the standard values at the other stations (Table 1).
- It was found that all measurements of seawater from SS-1 and SS-2 were higher than normal values, although the Zn measurements at DWS-1, DWS-2, and DWS-3 were at normal levels for both years (Table 1).

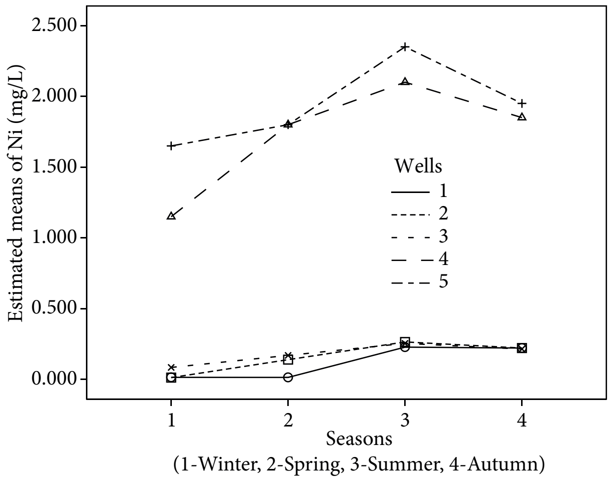

Figure 1. Seasonal distirubution of Ni measurements according to the Wells in 2007.

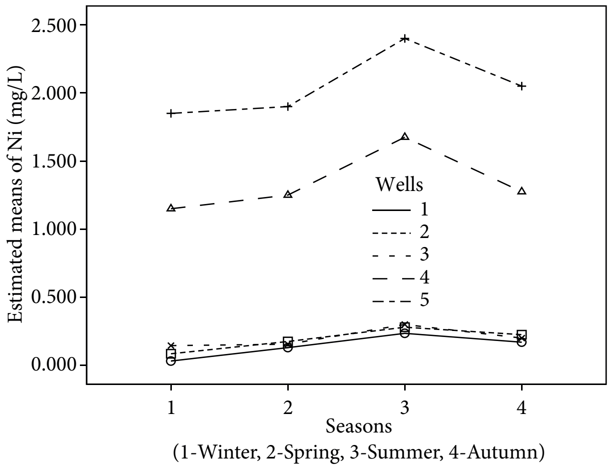

Figure 2. Seasonal distirubution of Ni measurements according to the Wells in 2008.

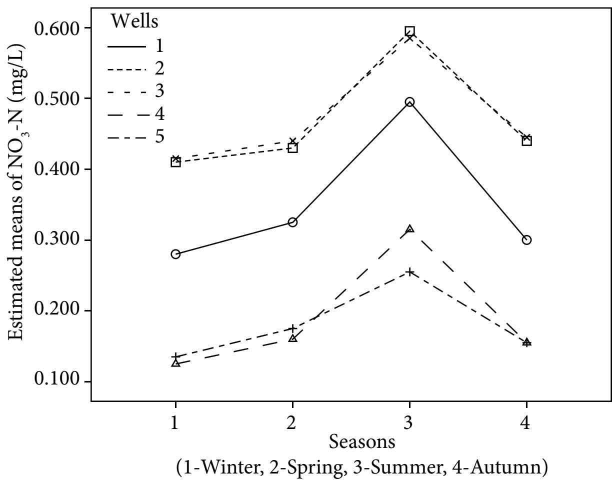

Figure 3. Seasonal distirubution of NO_3-N measurements according to the Wells in 2007.

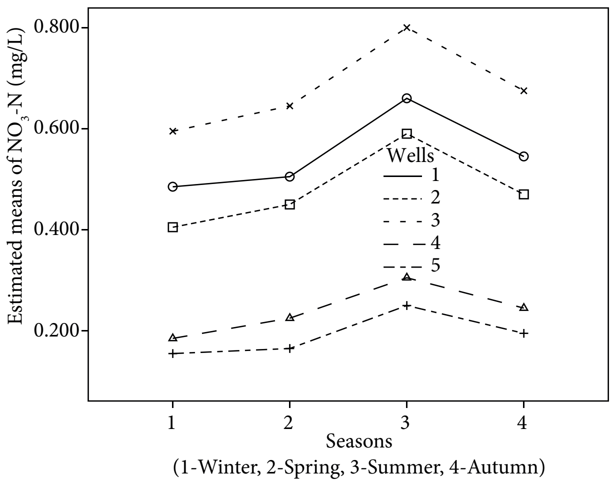

Figure 4. Seasonal distirubution of NO_3-N measurements according to the Wells in 2008.

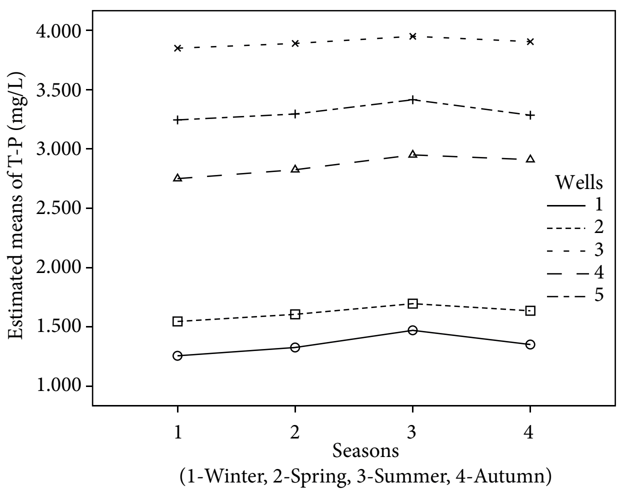

Figure 5. Seasonal distirubution of T-P measurements according to the Wells in 2007.

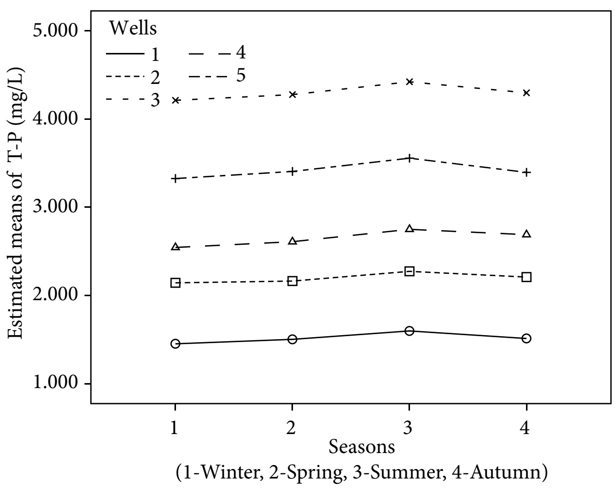

Figure 6. Seasonal distirubution of T-P measurements according to the Wells in 2008.

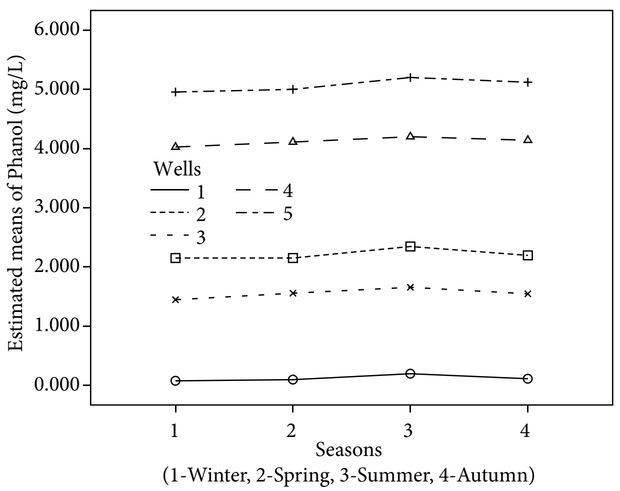

Figure 7. Seasonal distirubution of Phenol measurements according to the Wells in 2007.

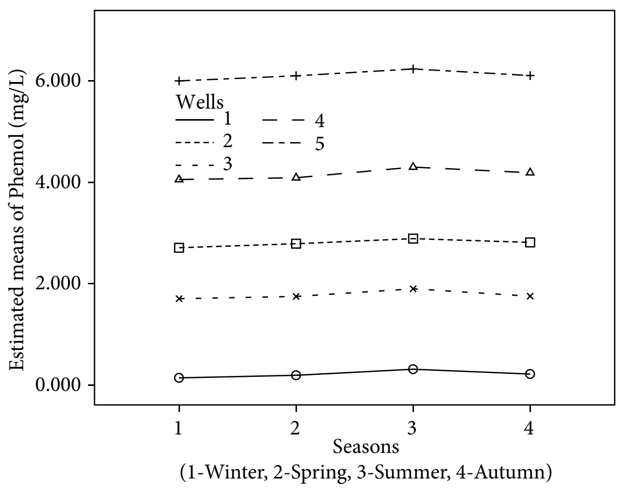

Figure 8. Seasonal distirubution of Phenol measurements according to the Wells in 2008.

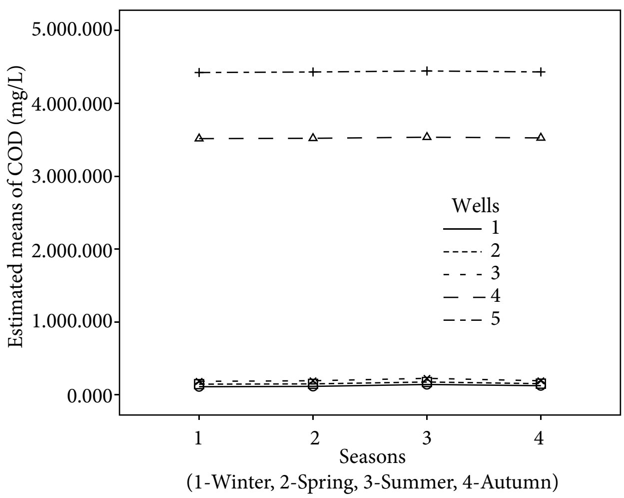

Figure 9. Seasonal distirubution of COD measurements according to the Well in 2007.

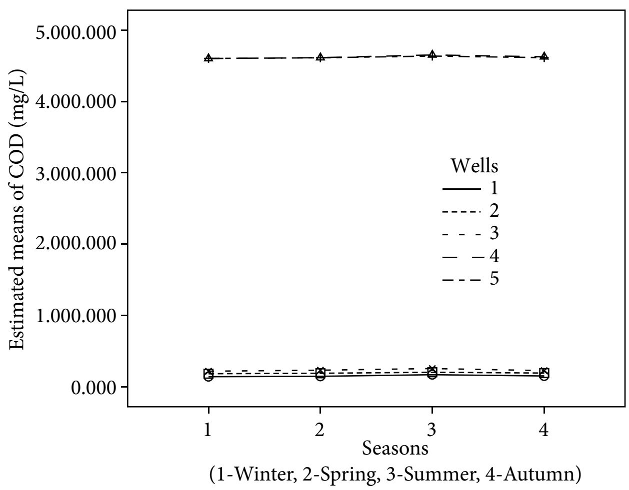

Figure 10. Seasonal distirubution of COD measurements according to the Well in 2008.

- During the T-Cr measurements, only the average value of 2008 at the DWS-2 station was higher than the normal values, and the average values at the other stations were normal for both years (Table 1).
- Measurements of CN and Cd, which are inorganic chemicals, were at normal levels for both years at all stations. These chemicals were not subject to statistical analyses as they were at constant levels (Table 1).
- In the seasonal distribution of measurements of the samples from the stations, it was seen that the Zn level was normal at DWS-1, DWS-2, and DWS-3, and above normal at SS-1 and SS-2; T-Cr was normal at all stations; and other chemicals (Ni, Cu, Pb, NO_3-N, T-P, phenol, and COD) were above normal at all stations (Table 2).
- In the spring, T-Cr was above normal only at DWS-2 and at normal levels at all other stations; other chemicals (Ni, Zn, Cu, Pb, NO_3-N, T-P, phenol, and COD) were above normal at all other stations (Table 2).
- In the summer, T-Cr was above normal at DWS-2 and normal at all other stations, Zn was normal only at DWS-1, and all other chemicals (Ni, Cu,

Table 1. Annual average measures of chemicals in water, by stations.

Stations	Years	**Measurements of chemicals (mg/L) and P-values**										
		Ni **P = 0.1**	**CN**	**Zn** **P < 0.001**	**Cu** **P < 0.001**	**Pb** **P < 0.001**	**T-Cr** **P < 0.001**	**Cd**	**NO_3-N** **P < 0.001**	**T-P** **P < 0.001**	**Phenol** **P < 0.001**	**COD** **P < 0.001**
DWS-1	2007	**0.12**	<0.01	0.32	**0.51**	**0.15**	0.02	<0.01	**0.35**	**1.35**	**0.12**	**123**
	2008	**0.14**	<0.01	0.36	**0.92**	**0.13**	0.02	<0.01	**0.55**	**1.52**	**0.22**	**154**
	Av.	**0.13**	<0.01	0.34	**0.72**	**0.14**	0.02	<0.01	**0.45**	**1.44**	**0.17**	**138**
DWS-2	2007	**0.16**	<0.01	0.40	**0.69**	**0.14**	0.02	<0.01	**0.47**	**1.62**	**2.20**	**156**
	2008	**0.19**	<0.01	0.38	**0.91**	**0.16**	**0.12**	<0.01	**0.48**	**2.20**	**2.80**	**194**
	Av.	**0.18**	<0.01	0.39	**0.80**	**0.15**	0.07	<0.01	**0.48**	**1.96**	**2.50**	**175**
DWS-3	2007	**0.18**	<0.01	0.35	**0.66**	**0.23**	0.02	<0.01	**0.47**	**3.90**	**1.55**	**199**
	2008	**0.20**	<0.01	0.37	**0.98**	**0.34**	0.03	<0.01	**0.68**	**4.30**	**1.78**	**235**
	Av.	**0.19**	<0.01	0.36	**0.82**	**0.28**	0.03	<0.01	**0.58**	**4.10**	**1.67**	**217**
SS-1	2007	**1.72**	<0.01	**3.03**	**0.39**	0.07	0.03	<0.01	**0.19**	**2.86**	**4.12**	**3524**
	2008	**1.34**	<0.01	**2.68**	**0.42**	0.08	0.03	<0.01	**0.24**	**2.65**	**4.16**	**4622**
	Av.	**1.53**	<0.01	**2.86**	**0.41**	0.08	0.03	<0.01	**0.22**	**2.76**	**4.14**	**4073**
SS-2	2007	**1.94**	<0.01	**2.31**	**1.01**	**0.26**	0.04	<0.01	**0.18**	**3.31**	**5.07**	**4432**
	2008	**2.05**	<0.01	**3.30**	**0.96**	**0.27**	0.05	<0.01	**0.19**	**3.42**	**6.11**	**4615**
	Av.	**2.00**	<0.01	**2.81**	**0.99**	**0.27**	0.05	<0.01	**0.19**	**3.37**	**5.60**	**4524**

Abbreviations: Drinking water station: DWS, sea station: SS, nickel: Ni, cyanide: CN, zinc: Zn, copper: Cu, lead: Pb, total chromium: T-Cr, cadmium: Cd, nitrogen-nitrate: $N0_3$-N, total phosphorus: T-P, chemical oxygen demand: COD, average: Av.

Note: Values above standard were highlighted in bold. As all measurements of CN and Cd were the same, analysis could not be performed.

Pb, NO_3-N, T-P, phenol, and COD) were above normal at all other stations (Table 2).

- In the autumn, Zn was normal at DWS-1 and DWS-3 and above normal at other stations, T-Cr was above normal at DWS-2, and other chemicals (Ni, Cu, Pb, NO_3-N, T-P, phenol, and COD) were above normal at all other stations (Table 2).
- During the analysis of all organic and inorganic chemicals in the water samples according to seasons, a significant difference was found between measurements. This difference was more obvious in the increase in the summer months, and it was at the lowest level in the winter months (Table 2, $P < 0.001$).
- The differences between the measurements of organic and inorganic chemicals in the water samples on the basis of the seasons were found to be significant (Table 2, $P < 0.001$).
- The differences in the water samples between the years on the basis of seasons were found to be significant, at $P < 0.001$ for Ni, T-Cr, NO_3-N, and COD, and at $P = 0.016$ for T-P. It was found to be insignificant for Zn ($P = 0.48$), Pb ($P = 0.72$), and phenol ($P = 0.313$) (Table 2).
- The difference between the stations in terms of seasons within a year was significant at $P < 0.001$ for Ni, Pb, T-Cr, NO_3-N, T-P, phenol, and COD, and insignificant for Zn ($P = 0.052$) and Cu ($P = 0.108$) (Table 2).
- In analysis of the differences between stations irrespective of the year and season, no significant difference was found in the water samples taken from DWS-1, DWS-2, and DWS-3 for Ni and Zn ($P = 1.0$). However, the difference between the drinking water (DWS-1, DWS-2, DWS-3) and seawater (SS-1 and SS-2) was found to be

Table 2. Annual average measures of chemicals in water, by season.

Seasons	Stations	Measurements of chemicals (mg/L)										
		Ni **P < 0.001**	**CN**	**Zn** **P < 0.001**	**Cu** **P = 0.01**	**Pb** **P < 0.001**	**T-Cr** **P < 0.001**	**Cd**	**$N0_3$-N** **P < 0.001**	**T-P** **P < 0.001**	**Phenol** **P < 0.001**	**COD** **P < 0.001**
Winter	**DWS-1**	**0.11**	<0.01	0.28	**0.52**	**0.13**	0.02	<0.01	**0.38**	**1.33**	**0.12**	**122**
	DWS-2	**0.16**	<0.01	0.75	**0.73**	**0.15**	0.05	<0.01	**0.41**	**1.81**	**2.08**	**152**
	DWS-3	**0.18**	<0.01	0.79	**0.81**	**0.25**	0.02	<0.01	**0.54**	**3.95**	**1.51**	**204**
	SS-1	**1.61**	<0.01	**2.78**	**0.31**	0.05	0.02	<0.01	**0.18**	**2.66**	**4.09**	**3656**
	SS-2	**1.90**	<0.01	**2.71**	**1.01**	**0.17**	0.04	<0.01	**0.16**	**3.17**	**5.06**	**4330**
Spring	**DWS-1**	**0.13**	<0.01	**0.32**	**0.74**	**0.12**	0.02	<0.01	**0.42**	**1.41**	**0.13**	**135**
	DWS-2	**0.18**	<0.01	**0.85**	**0.84**	**0.13**	**0.07**	<0.01	**0.46**	**1.90**	**2.56**	**166**
	DWS-3	**0.19**	<0.01	**0.79**	**0.79**	**0.30**	0.04	<0.01	**0.55**	**3.99**	**1.62**	**213**
	SS-1	**1.49**	<0.01	**2.84**	**0.38**	0.06	0.04	<0.01	**0.24**	**2.70**	**4.16**	**3874**
	SS-2	**1.95**	<0.01	**2.82**	**1.02**	**0.28**	0.05	<0.01	**0.18**	**3.35**	**5.61**	**4435**
Summer	**DWS-1**	**0.14**	<0.01	0.38	**0.85**	**0.16**	0.02	<0.01	**0.56**	**1.57**	**0.23**	**156**
	DWS-2	**0.19**	<0.01	**0.80**	**0.98**	**0.17**	**0.08**	<0.01	**0.54**	**2.09**	**2.87**	**199**
	DWS-3	**0.20**	<0.01	**0.42**	**0.84**	**0.35**	0.04	<0.01	**0.61**	**4.35**	**1.85**	**229**
	SS-1	**1.54**	<0.01	**2.96**	**0.48**	**0.12**	0.03	<0.01	**0.25**	**2.87**	**4.20**	**4657**
	SS-2	**2.12**	<0.01	**2.90**	**1.01**	**0.32**	0.05	<0.01	**0.22**	**3.52**	**6.01**	**4842**
Autumn	**DWS-1**	**0.14**	<0.01	0.36	**0.76**	**0.14**	0.02	<0.01	**0.44**	**1.45**	**0.21**	**139**
	DWS-2	**0.19**	<0.01	**0.79**	**0.65**	**0.16**	**0.07**	<0.01	**0.51**	**2.03**	**2.48**	**184**
	DWS-3	**0.20**	<0.01	0.32	**0.82**	**0.22**	0.02	<0.01	**0.60**	**4.12**	**1.70**	**222**
	SS-1	**1.48**	<0.01	**2.85**	**0.46**	**0.09**	0.03	<0.01	**0.21**	**2.80**	**4.12**	**4105**
	SS-2	**2.02**	<0.01	**2.82**	**0.91**	**0.31**	0.05	<0.01	**0.19**	**3.44**	**5.73**	**4490**

Abbreviations: Drinking water station: DWS, sea station: SS, nickel: Ni, cyanide: CN, zinc: Zn, copper: Cu, lead: Pb, total chromium: T-Cr, cadmium: Cd, nitrogen-nitrate: $N0_3$-N, total phosphorus: T-P, chemical oxygen demand: COD, average: Av.

Note: Values above standard were highlighted in bold. As all measurements of CN and Cd were the same, analysis could not be performed.

significant (P < 0.001). Measurement differences were found to be significant (P < 0.001) in terms of Pb, Cu, NO_3-N, T-P, phenol, and COD. It was also found that the difference (P = 0.328) between the T-Cr values measured at DWS-1 and DWS-3 and the difference (P = 0.428) between the Cu values at DWS-2 and DWS-3 were insignificant, while the difference between the values measured at the other stations was significant (P < 0.001, Tables 1 and 2).

Table 3. Annual average bacteriological measures in water, according to stations.

Bacteriological Parameter (mg/L)	**DWS-1* 2007**	**DWS-1* 2008**	**DWS-2* 2007**	**DWS-2* 2008**	**DWS-3* 2007**	**DWS-3* 2008**	**SS-1* 2007**	**SS-1* 2008**	**SS-2* 2007**	**SS-2* 2008**
Fecal Coliform (EMS/100 mL)	0	0	0	0	0	0	**600**	**600**	**600**	**600**
Pseudomonas aeruginosa (in 250 mL)	**1500**	0	**1500**	0	**1500**	0	0	**2500**	0	**2500**

*Water contamination control regulation (5).
Note: Values above standard were highlighted in bold.

- The difference between the measured averages of 2007 and 2008 irrespective of station and season was insignificant only for Ni ($P = 0.1$) and significant for all other chemicals. The value in 2008 was the highest one ($P < 0.001$, Table 1 and Figures 1 and 2).
- During the analysis of the bacteriological contamination in the samples, it was detected that the fecal coliform values measured in 2007 were at normal levels for DWS-1, DWS-2, and DWS-3, and at the level of contamination at the other stations and at other times. *Pseudomonas aeruginosa* (in 250 mL) was detected in the drinking water samples taken from DWS-1, DWS-2, and DWS-3 in 2007 and the seawater taken from SS-1 and SS-2 in 2008. This contamination was considered to be attributable to the location of the sewerage system, which was nearer to the stations than the normal distance (Table 3).

Discussion

Ammonium nitrate (NH_4NO_3), phosphorus pentoxide (P_4O_{10}), and potassium sulfate (K_2SO_4) are the most commonly used fertilizer components in the Adana region of Turkey, which is also the area most exposed to pesticides in Turkey, at a rate of 40%. The most preferred pesticides are methamidophos, parathion-methyl, dichlorvos (DDVP), azinphos-methyl, chlorpyrifos-ethyl, and carbaryl. This high usage rate of both fertilizers and pesticides in the agricultural areas of Adana province has been reported to cause water, soil, air, and food contamination (5,7,9,10).

The contamination at the drinking water stations, very clear at DWS-2 and particularly in the agricultural areas in our study, is in line with previous studies, and thus previous studies support our findings (7,9,11-13).

The contamination level, which was above the contamination parameters in the district, can be attributed to the unconscious use of natural and/or artificial fertilizers in the subprovince and the location of water wells nearer to the sources of pollution than the distances set out in regulations. The findings of studies conducted in Bornova in 1981, Bursa in 1981, and Çukurova in 1979, which reported fertilizer and pesticide contamination in underground waters, and the similar findings of some other studies in the literature are supportive of our findings (10,14-16).

Detection of herbicide-type pesticides used for cultivated fields on the surface and in underground water, such as garden soil and water and river water, was found in a study conducted in the Salamanca and Zamora regions of Spain (17). Detection of contamination of insecticide-type pesticides with organophosphate in the water of rivers and creeks in a study conducted on water louse in Tokyo (18), detection of phosphorus and nitrogen in the watershed of Pennsylvania (19), and the reporting of high levels of Zn, Cu, and Pb concentrations in the riverbed of the Guadiamar in Spain (20) all support our findings, but the high level of Cd in the same place was defined as a different finding. In a contamination study conducted on *Cyperus alternifolius* and *Villarsia exaltata* plants living in water, Zn and Pb values similar to ours were found. However, that study was different than ours as the presence of Al and Cd was also reported (21).

Conclusions

The distance of one drinking water station (33.3%) from a stable and the distance of one (33.3%) from fields and/or gardens meant that 2 drinking water stations (66.6%) were below the criteria values. It was reported that the use of natural and/or artificial fertilizers according to the types of soil in the district was much higher than the recommended level. It was found that the content of fertilizers and pesticides included inorganic substances with values surpassing the criteria values.

In light of these observations, it was concluded that the high level of organic and inorganic parameters in the drinking and utility water of Bahçe district is attributable to the excessive use of natural and artificial fertilizers, causing agricultural contamination, and the fact that the distance of the pollution sources from the water stations is less than is allowed, as well as the structure of these polluters (4,8,9,14,22). It is of the utmost importance that people be trained in order to ensure that fertilizers and pesticides are used in the amounts and at the periods and places advised by the relevant authorities. Furthermore, warnings should be given and inspections should be conducted in order to ensure compliance. Also needed is coordination among formal and informal education and training institutions, health organizations, and agricultural institutions to raise environmental consciousness in each section of the public.

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