Acta Aquatica Turcica

E-ISSN: 2651-5474 16(2), 238-245 (2020) DOI: https://doi.org/10.22392/actaquatr.644087

Fluoride Levels in Drinking Water and Assessment of Water Quality in Terms of Teeth Health in a Significant Watershed in Thrace Region

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Research Article

Received 07 November 2019; Accepted 21 April 2020; Release date 01 June 2020.

How to Cite: Tokatlı, C., & Güner, G. (2020). Fluoride levels in drinking water and assessment of water quality in terms of teeth health in a significant watershed in thrace region. *Acta Aquatica Turcica, 16*(2), 238-245. https://doi.org/10.22392/actaquatr.644087

Abstract

This study was carried out to determine the fluoride levels in the drinking water of Ergene River Basin, which is known as the lifeblood of the Thrace Region and one of the most contaminated river basins in Turkey. Drinking water samples were collected from 30 stations including residential areas located in the Ergene River Basin in dry (summer) season of 2018. Fluoride levels of water samples were determined by using a spectrophotometer and Cluster Analysis (CA) was applied to detected fluoride data to classify the investigated residential areas according to fluoride contents. Geographic Information System (GIS) was also used to make a visual explanation by presenting a distribution map of fluoride accumulations and also the detected data were evaluated in terms of teeth health of local people, who constantly drinks this water. According to detected data, the fluoride accumulations in drinking water of Ergene River Basin were determined between 0.246 ppm (Velimeşe Village) – 1.460 ppm (Bayramlı Village). According to the results of CA, 3 statistically significant clusters were formed as “High Fluoride Cluster”, “Optimum Fluoride Cluster” and “Low Fluoride Cluster”.

Keywords: Ergene River Basin, Fluoride, Drinking water quality, Cluster Analysis, Teeth health

İçme Suyunda Florür Düzeyleri ve Su Kalitesinin Diş Sağlığı Açısından Değerlendirilmesi: Ergene Nehir Havzası

Özet

Bu çalışma, Trakya Bölgesi'nin en önemli ve Türkiye'nin en kirli nehir havzalarından biri olan Ergene Nehir Havzası içme sularında florür seviyelerinin belirlenmesi amacıyla yapılmıştır. Ergene Havzası'nda belirlenen 30 istasyondan, 2018 yılı yaz (kurak) sezonunda, içme suyu örnekleri toplandı. Su numunelerindeki florür seviyeleri spektrofotometre kullanılarak belirlendi ve incelenen yerleşim alanlarının florür içeriğine göre sınıflandırılması için tespit edilen verilere Cluster Analizi (CA) uygulandı. Havza içme sularındaki florür birikimlerinin görsel bir özetini sunmak için Coğrafi Bilgi Sistemi (CBS) kullanılmış ve havza florür dağılım haritası çizilmiştir. Ayrıca edilen veriler sürekli olarak bu suyu içen yöre halkının diş sağlığı açısından da değerlendirilmiştir. Çalışmamız sonuçlarında göre, Ergene Havzası içme suyunda florür birikimleri 0.246 ppm (Velimeşe Köyü) - 1.460 ppm (Bayramlı Köyü) arasında olarak tespit edilmiştir. CA sonuçlarına göre ise, istatistiksel olarak anlamlı 3 küme tespit edilmiş ve bunlar “Yüksek Florür Kümesi”, “Optimum Florür Kümesi” ve “Düşük Florür Kümesi” olarak isimlendirilmiştir.

Anahtar Kelimeler: Ergene Nehri Havzası, Florür, İçme suyu kalitesi, Kümeleme Analizi, Diş sağlığı

INTRODUCTION

Fluorine is one of the most reactive and electronegative element which has a strong tendency to obtain a negative charge and in solution forms F– ions. Fluorine in the environment is present as fluorides which represent about 0.06–0.09 percent of the earth’s crust. Fluoride ions have the same charge and nearly the same radius as hydroxide ions and can take place of each other in mineral structures (Fawell et al., 2006). Fluoride forms mineral complexes with many cations and some less common mineral species of low solubility consist of fluoride. Fluoride in the environment is found in the atmosphere, soil, and water. It gets into the soil through dissolving rocks, precipitation, or waste runoff. Fluorides present at important levels in a broad variety of minerals, including fluorspar, rock phosphate, cryolite, apatite, and others (Murray, 1986). Fluorite (CaF_2) is a common fluoride mineral of low solubility existing in both fused and sedimentary rocks. Fluoride is generally relatedto volcanic activity and fumarolic gases. Thermal waters, particularly the ones with high pH, also contain a lot of fluorides (Edmunds and Smedley, 1996).

Groundwater is mostly affectedby fluoride accumulation through its association with the geologic substrate (Jha et al., 2011). High-fluoride regions occur in areas govern by crystalline basement rocks, alkaline volcanic rocks with associated geothermal activity, and sedimentary formations that consist of fluorapatite or fluoride-enriched clay minerals. The fluoride content of most rocks ranges from 100 to 1,300 mg/kg (Faure, 1991) and soil concentrations usually change between 20 and 500 mg/kg (Edmunds and Walton, 1983). However, much higher concentrations (>1,000 g/kg) can exist in soils that are derived from rocks with high fluorine contents (Cronin at al., 2003) or in soils affected by anthropogenic inputs, such as phosphate fertilizers (Kabata-Pendias and Pendias, 2001) and industrial contamination (Cronin et al., 2000). Surface waters generally do not contain more than 0.3 mg/L of fluoride unless they are polluted from external sources (Meenakshi at al., 2004) and fluoride is one of the very few chemicals that has been shown to cause significant effects in people through drinking-water (Fawell et al., 2006).

Human exposure to fluoride may occur from natural (drinking water) or industrial (fluoride emission) sources (Güner et al., 2016). The presence of fluoride in drinking water is a worldwide issue of concern since it has a considerable effect on human health (Ayenew, 2008). Drinking water with excess fluoride levels may result in fluorosis that is an important public health problem in many countries that lie in the geographical fluoride belt that extends from Turkey to China (Aoba and Fejerskov, 2002; Güner et al., 2016). When fluoride is ingested for a prolonged period, it accumulates mainly in calcifying tissues such as bone, cartilage, and dental tissues (Guissouma et al., 2007). Chronic ingestion of fluoride may result in dental fluorosis which is characterized by mottled teeth when the fluoride level in drinking water exceeds the optimal level (Sezgin et al., 2018; Buzalaf, 2018). Children are more susceptible to dental fluorosis during tooth development and drinking water with excess fluoride levels may result with different degrees of tooth mottling since pathological changes in dental fluorosis are time and dose-dependent (Buzalaf, 2018).

In addition to the intensive agricultural activities carried out in the Ergene River Basin, water pollution caused by industrial use is one of the important problems of the region. Ergene River is located in the Thrace region of Turkey and it is one of the most important river basins of this region. Ergene River, which has more than a thousand industrial enterprises in its basin, is known to be exposed to serious pollution due to rapid urbanization and industrialization. It is one of the most important branches of the Meriç River, which is the most important irrigation water source of the region (DSİ, 1997; Tokatlı and Baştatlı, 2016; Tokatlı, 2017; 2018). This study aimed to determine the fluoride accumulations in the drinking water of Ergene River Basin and evaluate the detected data in terms of teeth health of local people.

MATERIALS and METHODS

Study Area and Collection of Samples

Drinking water samples were collected in dry (summer) season of 2018 from 30 stations from the drill fountains of the villages located in the Ergene River Basin. Drinking water samples were then collected at the outflow of drill pump in polyethylene bottles. Coordinate information, station codes, and localities of selected stations are given in Table 1. The map of Ergene River Basin and the selected stations are given in Figure 1.

Table 1. Location properties of selected stations

Station Code	Location	Coordinate North	Coordinate East	Station Code	Location	Coordinate North	Coordinate East
S1	Muratlı	41.17275	27.49570	**S16**	Karakavak	41.32615	27.07046
S2	Sarılar	41.14440	27.66180	**S17**	Kadriye	41.34883	26.99870
S3	Çorlu	41.15593	27.81326	**S18**	Çerkezmüsellim	41.27186	27.02568
S4	Velimeşe	41.24793	27.88046	**S19**	Hayrabolu	41.21345	27.10629
S5	Çerkezköy	41.28212	28.00176	**S20**	Pehlivanköy	41.34710	26.92391
S6	Saray	41.44099	27.92175	**S21**	Danişment	41.30453	26.90137
S7	Karlı	41.36929	27.86502	**S22**	Çöpköy	41.21846	26.82429
S8	Marmaracık	41.20692	27.75227	**S23**	Bayramlı	41.30688	26.82262
S9	Vakıflar	41.26342	27.64992	**S24**	Uzunköprü	41.26693	26.68699
S10	Karamusul	41.30349	27.44734	**S25**	Salarlı	41.22682	26.62626
S11	Müsellim	41.34041	27.37037	**S26**	Kurtbey	41.14380	26.57977
S12	Düğüncübaşı	41.33248	27.27715	**S27**	Yenicegörece	41.13088	26.46713
S13	Lüleburgaz	41.40263	27.36572	**S28**	Meriç	41.19106	26.41824
S14	Babaeski	41.43123	27.09134	**S29**	Adasarhanlı	41.08398	26.35818
S15	Alpullu	41.37195	27.14307	**S30**	İpsala	40.92896	26.39274

Chemical Analysis

Fluoride parameter was determined by using the spectrophotometric method during the laboratory studies with a "Hach Lange DR 3900 Spectrophotometer" device (wavelength range 320 – 1100 nm). Cuvette Test LCK 323 was used in spectral photometer. This method provides fluoride ions to react with zirconium to form a colorless zirconium fluoride complex. This causes the red zirconium lake which is present to lose color (https://tr.hach.com/).

Statistical Analysis and GIS Maps

Cluster Analysis (CA) was applied to detected data to classify the investigated villages according to fluoride levels by using the "PAST" statistical package program. The distribution map (GIS Map) of the fluoride parameter was made by using the "MapInfo" package program.

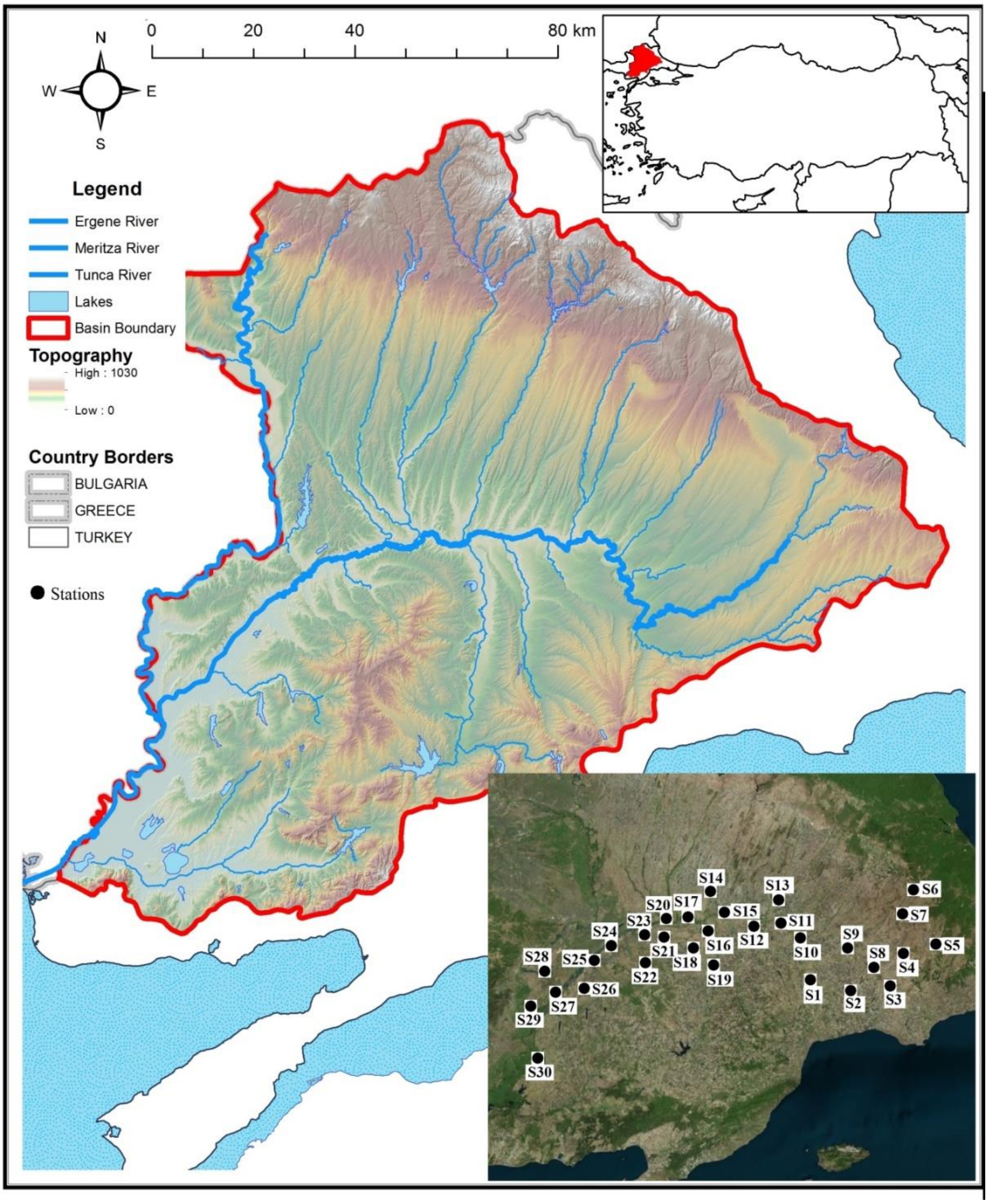

Figure 1. Map of Ergene River Basin and selected stations

RESULTS and DISCUSSION

Results of investigated fluoride parameter in Ergene River Basin with a minimum, maximum and mean values and some national and international water quality standards are given in Table 2. The distribution map of fluoride levels in drinking water of the basin is given in Figure 2.

According to the result of this study, although fluoride accumulations recorded in some villages of Ergene River Basin (especially in Bayramlı and Salarlı Villages) were determined as quite high levels, fluoride levels in the drinking water resources of the basin have been found to be in the range of human consumption standards specified by Turkish Standards Institute (TS266, 2005), European Communities (EC, 2007) and World Health Organization (WHO, 2011), in general. It was also determined that Ergene River Basin has I. – II. Class water quality in terms of fluoride parameter, according to the Water Pollution Control Regulation criteria in Turkey (SKKY, 2015).

Table 2. Results of detected data and some limit values

Limit Values and the Results of Present Study		F^- (mg/L)
Water Quality Classes (SKKY, 2015)	I. Class (Very Clean)	1
	II. Class (Less Contaminated)	1.5
	III. Class (Much Contaminated)	2
	IV. Class (Extremely Contaminated)	>2
Drinking Water Standards	TS266 (2005)	1.5
	EC (2007)	1.5
	WHO (2011)	1.5
Ergene River Basin	Minimum	**0.246**
	Maximum	**1.460**
	Mean	**0.494**
	SD	**0.275**

TS266 – Turkish Standards Institute; EC – European Communities;
WHO – World Health Organization

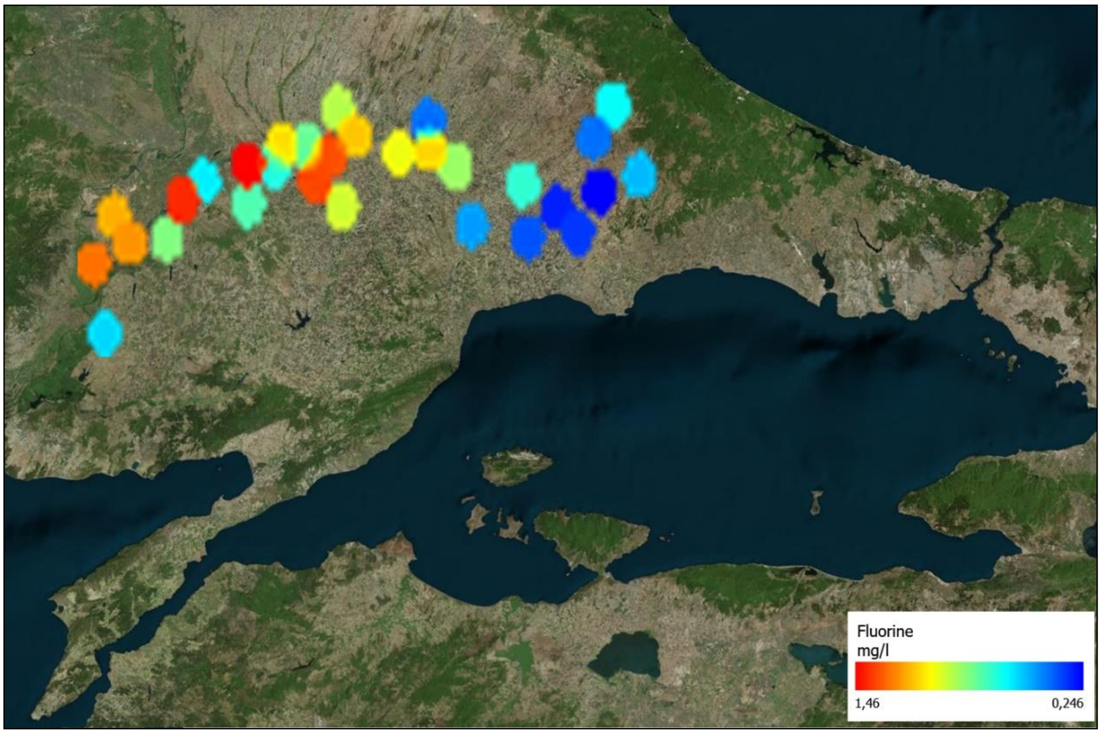

Figure 2. Fluoride distribution map of Ergene River Basin

The diagram of Cluster Analysis (CA) calculated by using fluoride levels of villages located in the Ergene River Basin is given in Figure 3. According to results of CA, 3 statistically significant clusters were formed: Cluster 1 named as “High Fluoride Cluster” with higher fluoride accumulations corresponded to Bayramlı and Salarlı villages; Cluster 2 named as “Optimum Fluoride Cluster” with optimum fluoride accumulations corresponded to Müsellim, Pehlivanköy, Alpullu, Yenicegörece, Meriç, Karakavak, Çerkezmüsellim, and Adasarhanlı Villages; Cluster 3 named as “Low Fluoride Cluster” with lower fluoride accumulations corresponded Çerkezköy, Saray, Danişment, Vakıflar, Uzunköprü, İpsala, Kadriye, Çöpköy, Karamusul, Babaeski, Hayrabolu, Düğüncübaba, Kurtbey, Çorlu, Velimeşe, Marmaracık, Sarılar, Karlı, Lüleburgaz, and Muratlı Villages.

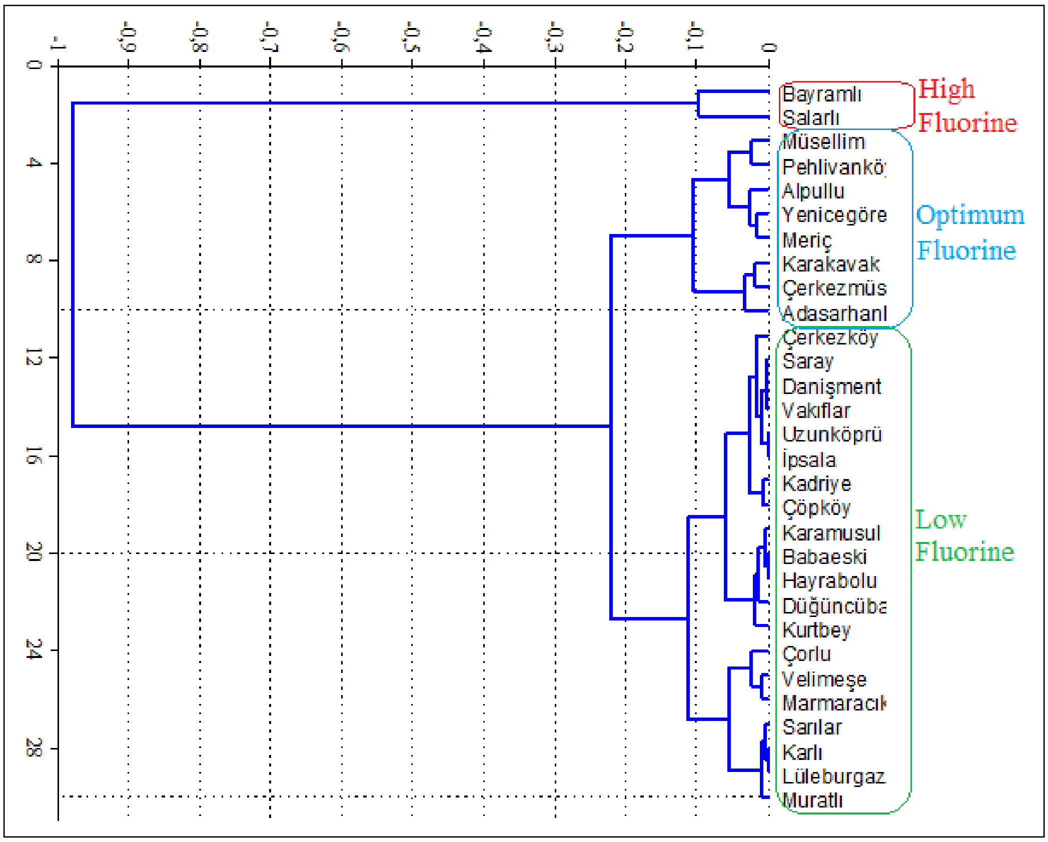

Figure 3. Diagram of CA

Groundwater plays such an essential role in the existence of human population therefore its availability and safety has become an issue of concern across the globe (Howard et al., 2006). It is the main source of drinking water and there are many contaminants in groundwater which may have an adverse effect on human health (Villholth et al., 2010). Among these contaminants, nitrate and fluoride are the more widespread. Drinking water is a direct source of fluoride exposure and depending on the concentration and daily consumption, it can be either beneficial or detrimental on human health (Ayoob and Gupta, 2006). Drinking water with optimal fluoride levels has a preventive effect on dental caries. Recommended and permitted level of fluoride in drinking water for preventing dental caries ranges from 0.7 to 1.2 mg/L. In this range of limit, fluoride provides protection against dental caries in children besides minimizing risk of dental fluorosis (Iheozor-Ejiofor et al., 2013; O'Mullane et al., 2016). However, health may be adversely affected if excessive amounts are ingested through drinking water. Exposure to fluoride concentrations more than the optimal level may result in fluorosis (Ayoob and Gupta, 2006; Güner et al., 2016; Sezgin et al., 2018).

Endemic fluorosis that is related to high fluoride levels in drinking water has been observed in some regions of Turkey for more than 50 years. Surface and groundwater samples had fluoride concentrations between 1.5 and 13.70 ppm in different areas in Turkey. High levels of fluoride were mostly associated with geochemical formations. Most severe dental and skeletal fluorosis cases were reported in villages around Tendurek Volcano where high levels of fluoride were found in drinking water. There were other regions like Isparta city center, Kizilcaoren village, Gullu village, and 45 villages of Dogubeyazit region, where different degrees of dental and skeletal fluorosis were observed. Most of these areas have been supplied with drinking water containing fewer fluoride concentrations, in recent decades (Oruç, 2008).

In a recent study, which was performed in Edirne region, Havsa and Suloglu towns were evaluated in terms of oral health. The prevalence of dental caries and dental fluorosis in children was investigated. According to the results of this study, it was found that dental caries levels were lower in the optimal fluoride area (0.703 ppm in Havsa District) than below-optimal fluoride area (0.357 ppm in Süloğlu District). Furthermore, it was indicated that optimal fluoride concentrations may have a positive effect on reducing dental caries among children in that study population (Güner et al., 2017).

In another study, Onur et al. (2019) investigated fluoride levels in drinking water in 3 districts of Edirne and assessed children in terms of oral health and dental fluorosis. According to the fluoride levels in drinking water, the region was divided into 3 groups; group 1: <0.5 ppm, group 2: 0.5-1.2 ppm, and group 3: 2.39 ppm. It was reported that an increase in fluoride level in drinking water increased the severity of dental fluorosis. Children living in the area with high fluoride concentration in drinking had less dental caries on their permanent teeth and high dental fluorosis scores compared to children living in areas with low and optimal fluoride concentrations in drinking water.

In this study, the concentrations of fluoride range from 0.246 to 1.46 mg/L with a mean of 0.46 mg/L. It was found that samples from Optimum Fluoride Cluster which consist of 8 villages have fluoride concentrations within the recommended limits. In this area, these concentrations may have a positive effect on reducing dental caries among children. Whereas samples from Bayramlı and Salarlı villages from "High Fluoride" Cluster slightly exceed the permissible limits (1.46 and 1.36 mg/L), respectively. These fluoride concentrations in drinking water may reduce the incidence of dental caries. However, the risk of dental fluorosis may increase_in children living in this area. Therefore, improvement of fluoride levels in drinking water in High Fluoride Cluster is important to avoid possible health effects like dental fluorosis.

These findings in the present study can provide a real insight into drinking water safety at Ergene River Basin but further investigation is still needed. Residents living in this area should be evaluated in terms of tooth decay and dental fluorosis.

Acknowledgements: The author would like to thank for the financial and technical supports supplied by Trakya University, Turkey. This investigation has been supported by the project numbered as 2017/211 accepted by Trakya University, Commission of Scientific Research Projects. Also the authors would like to thank Environmental Engineer Alper Uğurluoğlu for his contributions on this manuscript.

REFERENCES

Aoba, T., & Fejerskov, O. (2002). Dental fluorosis: Chemistry and biology. *Critical Reviews in Oral Biology and Medicine*, *13* (2), 155–170.

Ayenew, T. (2008). The distribution and hydrogeological controls of fluoride in the groundwater of central Ethiopian rift and adjacent highlands. *Environmental Geology*, *54* (6), 1313-1324.

Ayoob, S., & Gupta, A. K. (2006). Fluoride in drinking water: a review on the status and stress effects. *Critical Reviews in Environmental Science and Technology*, *36* (6), 433-487.

Buzalaf, M. A. R. (2018). Review of fluoride intake and appropriateness of current guidelines. *Advances in Dental Research*, *29* (2), 157-166.

Cronin, S. J., Manoharan, V., Hedley, M. J., & Loganathan, P. (2000). Fluoride: a review of its fate, bioavailability, and risks of fluorosis in grazed-pasture systems in New Zealand. *New Zealand Journal of Agricultural Research*, *43*, 295–321.

Cronin, S. J., Neall, V. E., Lecointre, J. A., Hedley, M. J., & Loganathan, P. (2003). Environmental hazards of fluoride in volcanic ash: a case study from Ruapehu Volcano, New Zealand. *Journal of Volcanology and Geothermal Research*, *121*, 295–321.

DSİ (State Water Works) (1997). *Ergene Nehri Kirliliği Değerlendirme Raporu*. Türkiye Devlet Su İşleri Genel Müdürü, Ankara, Türkiye.

EC (European Communities) (2007). *European Communities (drinking water) (no. 2), Regulatıons 2007, S.I. No. 278 of 2007.*

Edmunds, W. M., & Walton, N. (1983). The Lincolnshire limestone—hydrogeochemical evolution over a ten-year period. *Journal of Hydrology*, *61*(1–3), 201–211.

Edmunds, W. M., & Smedley, P. L. (1996). *Groundwater geochemistry and health: an overview*. Environmental Geochemistry and Health, British Geological Society special publication, no: 113, pp. 91-105.

Faure, G. (1991). *Principles and applications of inorganic geochemistry*. Macmillan Publication Co., New York, pp. 626.

Fawell, J., Bailey, K., Chilton, J., Dahi, E., & Magara, Y. (2006). *Fluoride in drinking-water*. IWA publishing.

Guissouma, W., Hakami, O., Al-Rajab, A. J., & Tarhouni, J. (2017). Risk assessment of fluoride exposure in drinking water of Tunisia. *Chemosphere*, *177*, 102-108

Güner, Ş., Haznedaroğlu, E., Sezgin, B. I., Okutan, A. E., & Menteş, A. (2017). Prevalence of dental caries and fluorosis in two towns of Edirne, Turkey. *Caries Research*, *51*, 290–385.

Güner, Ş., Uyar-Bozkurt, S., Haznedaroğlu, E., & Menteş, A. (2016). Dental fluorosis and catalase immunoreactivity of the brain tissues in rats exposed to high fluoride pre-and postnatally. *Biological Trace Element Research*, *174* (1), 150-157.

Howard, G. J. B., Pedley, S., Schmoll, O., Chorus, I., & Berger, P. (2006). *Groundwater and public health*. IWA Publishing, London.

Iheozor-Ejiofor, Z., O'Malley, L, A., Glenny, A. M., Macey, R., Alam, R., Tugwell, P., Walsh, T., Welch, V., & Worthington, H. V. (2013). Water fluoridation for the prevention of dental caries. *Cochrane Database of Systematic Reviews*, Issue 12. Art. No.: CD010856.

Jha, S. K., Mishra, V. K., Sharma, D. K., & Damodaran, T. (2011). Fluoride in the environment and its metabolism in humans. *In Reviews of Environmental Contamination and Toxicology*, *211*, 121-142.

Kabata-Pendias, A., & Pendias, H. (2001). *Trace elements in soils and plants*. CRC Press, Boca Raton, FL, 3rd edition, pp. 413.

Meenakshi, Garg, V. K., Kavita, Renuka, & Malik, A. (2004). Ground water quality in some villages of Haryana, India: focus on fluoride and fluorosis. *Journal of Hazardous Materials*, *106*, 85-97.

Murray, J. J. (1986). *Appropriate use of fluorides for human health*. World Health Organization, Geneva.

O'Mullane, D. M., Baez, R. J., Jones, S., Lennon, M. A., Petersen, P. E., & Rugg-Gunn, A. J. (2016). Whelton H, Whitford GM. Fluoride and oral health. *Community Dental Health*, *33* (2), 69-99.

Onur, Ş. G., Sezgin, B, I., Tokatlı, C., Haznedaroğlu, E., Okutan, A. E., İldeş, G. Ç., Kalaoğlu, E. E., Yazıcı, B., & Menteş, A. (2019). Prevalence of dental fluorosis and dental caries in 3 districts of Edirne with different water fluoride levels. *Yeditepe Üniversitesi Diş Hekimliği Fakültesi Dergisi*, *15* (2), 219-223.

Oruc, N. (2008). Occurrence and problems of high fluoride waters in Turkey: an overview. *Environmental Geochemistry and Health*, *30*, 315–323.

Sezgin, B. I., Onur, Ş. G., Menteş, A., Okutan, A. E., Haznedaroğlu, E., & Vieira, A. R. (2018). Two-fold excess of fluoride in the drinking water has no obvious health effects other than dental fluorosis. *Journal of Trace Elements in Medicine and Biology*, *50*, 216-222.

SKKY (Su Kirliliği Kontrol Yönetmeliği) (2015). *Yüzeysel Su Kalitesi Yönetimi Yönetmeliğinde Değişiklik Yapılmasına Dair Yönetmelik. Yayımlandığı Resmi Gazete: Tarih 15 Nisan 2015, Resmi Gazete No: 29327*.

Tokatlı, C., & Baştatlı, Y. (2016). Trace and toxic element levels in river sediments. *Polish Journal of Environmental Studies*, *25*(4), 1715-1720.

Tokatlı, C. (2017). Bio – ecological and statistical risk assessment of toxic metals in sediments of a worldwide important wetland: Gala Lake National Park (Turkey). *Archives of Environmental Protection*, *43* (1), 34-47.

Tokatlı, C. (2018). Essential and toxic element bioaccumulations in fishes of Gala and Siğirci Lakes (Meriç River Delta, Turkey). *Acta Alimentaria*, *47*(4), 470-478.

TS 266 (Türk Standartları Enstitüsü) (2005). *Sular-İnsani tüketim amaçlı sular. Türk Standartları Enstitüsü, ICS 13.060.20*.

Villholth, K. G., & Rajasooriyar, L. D. (2010). Groundwater resources and management challenges in Sri Lanka–an overview. *Water Resources Management*, *24* (8), 1489-1513.

WHO (World Health Organization) (2011). *Guidelines for Drinking-water Quality. World Health Organization Library Cataloguing-in-Publication Data, NLM classification: WA 675*.