TURKISH JOURNAL OF
WATER SCIENCE & MANAGEMENT

Türkiye Su Bilimi ve Yönetimi Dergisi

July-August-September-October-November-December/Volume :3 Issue :2 Year : 2019

(ISSN 2536 474X / e-ISSN 2564-7334)

MAF

Contents

Aims and Scope

We, within Republic of Turkey Ministry of Agriculture and Forestry, General Directorate of Water Management, are committed to consistently provide access to the accurate, reliable and global information that are necessary for water education, research and public service regarding water management. We aim to become a well-known scientific journal, indexed and referred at both national and international level. Turkish Journal of Water Science and Management is a reliable, innovative and peer-reviewed scientific journal that is open to all kinds of up-to-date technological and scientific progress suitable for the future education and research needs on water, offering accurate scientific information to all the readers.

Submission of Manuscripts

Please kindly access to the main page of the Journal via “http://dergipark.gov.tr/tjwsm” to register as user and submit your papers through “Submit a Manuscript”. If you have any problems, please kindly see the related video via “http://forum.dergipark.gov.tr/t/uds-kullanim-videolari/488/10”. Manuscripts under review, accepted for publication or published elsewhere are not accepted. Please kindly go to “http://water journal.tarimorman.gov.tr” to see the instructions for manuscript preparation.

Disclaimer

Any statements expressed in these materials are those of the individual authors, and do not necessarily represent the views of MAF which takes no responsibility for any statements made herein. Therefore, no reference made in this publication to any specific method, product, process or service constitutes or implies an endorsement, recommendation or warranty by MAF. The materials are for general information only and do not represent a standart of MAF, nor are they intended as a reference in Turkish specifications, contracts, regulations, statutes, or any other legal document. MAF makes no represantation or warranty of any kind, whether expressed or implied, concerning the accuracy, completeness, suitability, or utility of any information, apparatus, product, or process discussed in this publication and therefore assumes no liability. This information should not be used without first securing competent advice with respect to its suitability for any general or specific application. Anyone utilizing this information assumes all liability arising from such use, including but not limited to infringement of any patent or patents.

REPUBLIC OF TURKEY
MINISTRY OF AGRICULTURE AND
FORESTRY

Turkish Journal of
Water Science and Management
is abstracted and indexed in Dergi Park,
in compliance with APA format.

Turkish Journal of
Water Science and Management
is published once every
six months in Jan., and Jul.
by The Ministry of Agriculture
And Forestry
General Directorate of
Water Management,

Beştepe District
Alparslan Turkeş Street N: 71
Yenimahalle /Ankara, Turkey 06510,
Tel: +90 312 207 63 30,
Fax: +90 312 207 51 87,
email: waterjournal@tarimorman.gov.tr.

Publishing Office

General Directorate of
State Hydraulic Works
Printing and Photo-Film
Branch Office
Etlik- Ankara.

The Cover is
designed by Ajans 46

Research Article

Cost Optimization of Hanoi Water Distribution Network with Meta-Heuristic Optimization Algorithms

Hanoi Su Dağıtım Şebekesinin Meta-Sezgisel Optimizasyon Algoritmaları ile Maliyet Optimizasyonu

Volkan YILMAZ[1], Meral BÜYÜKYILDIZ[1], Ömer Kaan BAYKAN[2]

[1]*Konya Technical University, Faculty of Engineering and Natural Sciences, Civil Engineering Department, Konya*
vyilmaz@ktun.edu.tr, mbuyukyildiz@ktun.edu.tr
[2]*Konya Technical University, Faculty of Engineering and Natural Sciences, Computer Engineering Department, Konya*
okbaykan@ktun.edu.tr
Received Date:31.07.2018, Accepted Date: 26.04.2019

Abstract

Water transfer and distribution systems have high-cost values in a process from the collection of required water to the delivery by end-users. Besides the existence of few options for water transmission systems, there are more possible solutions for water distribution systems which have to require necessary conditions. Defining the best system which has minimum cost value for a water distribution system has been an optimization problem in time. Different optimization algorithms have been revealed with the help of the innovation of computer technologies and these algorithms were used in cost optimization of water distribution network field and performance of algorithms have been evaluated nearly for 50 years. In this study, Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) methods, commonly used in the literature, and recently revealed Artificial Bee Colony (ABC) algorithm method were applied to Hanoi water distribution network for the purpose of cost optimization. To determine the best performing algorithm for this case study; the comparative performance analysis of convergence velocity, stability, and distribution of results were evaluated.

Keywords: *Optimization, water distribution network, artificial bee colony, genetic algorithm, particle swarm optimization algorithm*

Öz

Gerekli suyun toplanmasından kullanıcılara ulaştırılmasına kadar geçen bir süreç içerisinde su iletim ve dağıtım sistemlerinin yüksek maliyet değerleri içerdiği görülmektedir. Su iletim sistemlerinde daha az sayıda seçeneğin bulunmasına karşılık su dağıtım şebekeleri istenen şartları sağlayan daha fazla olası çözümü içermektedir. Zamanla, minimum maliyet değerine sahip olan en iyi sistemin tasarlanması bir optimizasyon problemi haline gelmiştir. Son 50 yıldır bilgisayar teknolojilerindeki gelişme ile birlikte çeşitli optimizason algoritmaları ortaya atılmış ve bu algoritmalar su dağıtım şebekelerinin maliyet optimizasyonu konusunda kullanılarak algoritmaların performansları değerlendirilmiştir. Bu çalışmada literatürde yaygın olarak kullanılmış olan Parçacık Sürü Optimizasyon ve Genetik Algoritma yöntemlerine ilave olarak diğer iki yönteme kıyasla daha yakın zamanda ortaya atılmış olan Yapay Arı Kolonisi algoritması ile Hanoi su dağıtım şebekesi üzerinde maliyet optimizasyonu yapılmıştır. Mevcut çalışma kapsamında en başarılı algoritmanın belirlenmesi için yakınsama hızı, tutarlılık ve sonuçların dağılımı karşılaştırmalı performans analizi kapsamında incelenmiştir.

Anahtar kelimeler:*Optimizasyon, su dağıtım şebekesi, yapay arı kolonisi, genetik algoritma, parçacık sürü optimizayon algoritması*

Introduction

Collecting, transporting and delivering the necessary water to the customers include different processes. These processes are both crucial for urban life and very expensive. When cost values which were occurred in these processes are investigated, it can be seen that the cost rate of water transmission and distribution systems over total cost is very high. Ozdaglar et al. (2006), asserted that cost rate of water transmission and distribution systems over total project cost is nearly 56%,Dandy & Engelhardt (2006) asserted that pipe cost in the Water Distribution Networks (WDNs) constitute nearly 70% of the total cost. On the other hand, some researchers claim that total project cost can be reduced by approximately 50% with the use of the suitable pipe diameters (Murphy et. al, 1993; Quindry et. al, 1981).

Presence of high-cost values over water transmission and distribution systems canalized the researchers to study in this field. Researchers have been interested in especially WDNs field in time. However, the presence of different design criteria about the WDNs, the multitude of nonlinear equation to determine the pipe diameter and large interval of the commercial pipe sizes made the design become harder.

In this way, it has become an optimization problem with the minimum cost value and at the same time determining the best system, that meets the necessary conditions. Cost optimization has become a necessity both in designing a new system and in the rehabilitation of an existing system.

Initially, traditional optimization algorithms like linear and non-linear programming were used in this field in the literature. Particularly linear programming method has been preferred and accepted by many researchers for a long time (Tospornsampan et. al, 2007). In the 1990s, stochastic optimization algorithms like Tabu Search, Genetic Algorithms (GA) and Simulated Annealing methods were used for determining the optimum system. Recently, Meta-Heuristic optimization algorithms like Particle Swarm Optimization (PSO) and Shuffled Frog Leaping optimization algorithms that modeling the behavior of different creatures, which live in a flock format, were used to determine the optimum system.

In the literature, performance of algorithms was compared with using different algorithms from some benchmark networks like Alperovits and Shamir (Alperovits& Shamir, 1977) network, NewYork WDN (Schaake& Lai, 1969), Hanoi WDN (Fujiwara &Khang, 1990) and Two-Loop network (Kadu et. al, 2008). Minimum cost values, evaluation numbers, convergence velocities and stability of algorithms were compared.

In this study, Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) methods, commonly used in the literature, and recently revealed Artificial Bee Colony (ABC) algorithm method were applied to Hanoi water distribution network for the purpose of cost optimization. To determine the best performing algorithm for this case study; the comparative performance analysis of convergence velocity, stability, and distribution of results was examined.

Main objective of this study is to test the performance of ABC algorithm, which was revealed recently in the literature. In order to compare results of ABC algorithm, GA and PSO algorithms were also used for Hanoi WDN. Algorithms were run under equal conditions as much as possible to control the performance metrics properly in comparative performance analysis.

Material and Methods

Study Area: Hanoi WDN

Hanoi WDN which was first presented by Fujiwara & Khang (1990) became a benchmark network (Figure 1). Numerous researchers (Kadu et. al, 2008; Afshar & Marino, 2005; Babu & Vijayalakshmi, 2013; Cisty, 2010; Cunha & Ribeiro, 2004; Cunha & Sousa, 1999; Geem, 2009; Perelman & Ostfeld, 2007; Vasan & Simonovic, 2010) preferred to study this network in the literature. This network has one source, 31 joints and 34 pipes. All joints in the network have 0m elevations. The minimum pressure value is assumed as 30m. Detailed numeric information about Hanoi WDN can be found in Cunha & Sousa (1999).

Optimum Design of WDNs

There are some criteria for the design of WDNs. These criteria must be satisfied for all nodes and all pipes of a WDN. At first, the diameter of pipes is determined and head loses for all pipes are calculated by using Hazen-Williams formula in Eq. (1).

$$Hk_j = \left[\frac{Q_j}{0.2785 C_{HW} D_j^{2.63}} \right]^{1.852} L_j \tag{1}$$

where Hk_j shows the head loss in pipe j., Q_j expresses the flow running through the pipe j., C_{HW} expresses the Hazen-Williams roughness coefficient, which varies depending on the type of the pipe, and D_j expresses the diameter of the respective pipe. Head loss values are calculated by using this formula. A head loss in any pipe is extracted from the previous node's hydraulic head value along the flow directions to determine the P_i pressure values for each joint. Pressure condition in Eq. (2) must be satisfied for each joint.

$$P_{min} \leq P_i \leq P_{max} \quad \forall_i = 1,2,3,........, N \tag{2}$$

Herein P_{min} and P_{max} show the minimum and maximum pressure values in joint i respectively for N nodes. In addition, while the flow coming into a node is shown by Q_i^{in}, the flow going out of a node is shown by Q_i^{out} and if any, the flow drained from a node is shown by Q_i^{demand}, the continuity condition given in Eq. (3) should be met.

$$Q_i^{in} - Q_i^{out} - Q_i^{demand} = 0 \quad \forall_i = 1,2,3,........, N \tag{3}$$

In the energy conditions given in Eq. (4), sum of the head losses through m pipes in any flow direction must be equal to the sum of the head losses which occurred in other flow direction through n pipes. γ_{min} parameter in Eq.(4) is defined in related codes.

$$\sum_{i=1}^{m} Hk_i - \sum_{j=1}^{n} Hk_j = \gamma \cong 0 \leq \gamma_{min} \tag{4}$$

Eventually objective function that is given in Eq. (5) is run with last pipe sizes. Herein Z shows objective function, D_j the diameter of the pipe no j, $C(D_j)$ the unit cost for diameter D_j and L_j the length of pipe no j. δ parameter in Eq. (5) shows the penalty cost. When a pipe system doesn't satisfy any criteria, a penalty cost value occurs and total cost of the system is increased artificially. In this way, unwanted solutions can be eliminated.

$$Z = \sum_{i=1}^{M} C(D_j) \cdot L_j + \delta \tag{5}$$

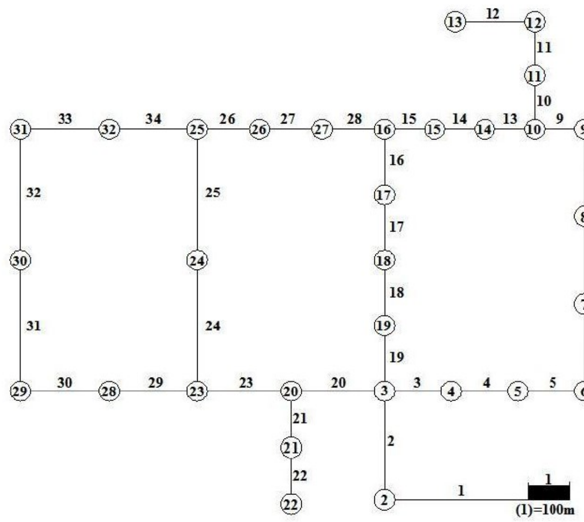

Figure 1. Hanoi WDN (Cunha & Sousa, 1999).

Artificial Bee Colony (ABC) algorithms were firstly asserted by Karaboga (2005) and behavior of food seeking of bees are modeled in this method. In the ABC method, certain bees leave from the hive and start to search for sources of food places. These bees come back to their hive for informing other bees about the food places. Then, bees search for better food sources near the previous food places. In this way, bees try to find the best food places, which represents the best solution points for any problem. PSO method, which was firstly proposed by Kennedy & Eberhart (1995),was inspired by the food searching behavior of birds and fishes in a flock format. GA method uses evaluations of new generations to reach the best solution points.

ABC, PSO and GA methods start and complete the solution in a similar way like the other optimization algorithms. At first X_{ij} initial solution points are defined with Eq. (6) in the range of x_j^{min} and x_j^{max} limit values.

$$x_{ij}=x_j^{min}+rand(0,1)(x_j^{max}-x_j^{min}) \qquad i = 1\ldots\ldots PN,\ j = 1\ldots\ldots\ldots D_p \qquad (6)$$

Herein PN means the population number, which is the number of bees for ABC method, number of particles for PSO method and number of chromosomes for GA method. PN can take different values for different problems. D_p parameter expresses the dimension of the problem. For example,D_p can be defined as a pipe number for a WDN problem.

After the definition of x_{ij} solution points, initial solution matrix occurs. Row and column number can be defined as PN and D_p respectively. Every row of the solution matrix describes a different WDN solution. Then, the objective function in Eq. (5) run and total cost values are calculated for each WDN solutions. The best solution that has a minimum total cost value is saved as a global optimum value. After this step, ABC, PSO and GA methods search for better global optimum solutions and better global optimum values with different operators.

ABC algorithm searches for better solutions around previous solutions. In the PSO algorithm; solution points, which were previously found out, are updated to the new best solution points. GA method uses crossover and mutation operators to change genes' location. Best solution points and cost values are saved after each iteration. If an algorithm reaches a better result during optimization, the location of the solution points and cost values are replaced. When determined iteration number is obtained or predefined cost value is reached, the algorithm is stopped.

Results

In order to determine the differences between three methodologies; ABC, PSO and GA methods were run with the same objective function, discharge values and individual numbers (number of bees for ABC method, number of particles for PSO method and number of chromosomes for GA method). Individual numbers were defined as 2, 5, 10 and 20 times of dimension number that was 34 for Hanoi WDN to observe the relations between the individual number and results. Eventually, individual numbers were accepted as 68, 170, 340 and 680. Iteration number was accepted as 1000 for all study. In all methods, 30 trials were carried out to observe the stability. Coefficient of C_{HW} for Hazen-Williams formula was accepted as 130 for all pipes. Diameter values were identified in a continuous manner and the results were discretized by rounding to new (nearest) diameter values.

In PSO method, acceleration parameters were accepted as 2.0 for c_1 and c_2. Inertia weights were accepted as 0.9 for w_{max} and 0.4 for w_{min}. The limit value for acceleration parameters was sustained as 0.20m for PSO study (v_{max}=0.20 m, v_{min}=-0.20 m). In GA method, crossover rate was0.15 and the mutation rate was0.40. Tournament selection was used from the selection operators for GA method.

At the end of the study, statistical parameters about cost values for 30 trials and box plot graph for these results were shown in Table 1 and Figure 2 respectively. In order to show the stability properly, the variation of standard deviation was given in Figure 3.

When the optimization results were observed it was seen that the ABC method reached better results in spite of PSO and GA in terms of all statistical parameters. The ABC method obtained lower minimum, average, maximum cost values as shown in Table 1 and lower standard deviation value as shown in Figure. 3. Furthermore, results of the ABC method have more stable behavior as shown in Figure 2. On the other hand, it was observed that PSO results had a lower performance metrics than ABC and GA methods. PSO method obtained higher minimum, average and maximum cost values as shown in Table 1.

Generally, the relation between the performance of the method and the individual number was not revealed clearly. However, it was seen that the average cost values were decreased with the increasing individual numbers as shown in Table 1. In this context most stable behavior was obtained with the PSO method. PSO method reached better solutions while the individual number increased (Table 1).

Convergence graphs give information about the convergence velocity of the algorithms. In this mean, convergence graphs of the best results for each method are shown in Figure 4 for the individual numbers of 2D, 5D, 10D and 20D. As a summary, it was observed that even though the PSO algorithm reached the optimum cost value earlier than the other methods, it obtained higher cost values than GA and ABC ultimately.

Table 1
Statistical Parameters of Optimum Cost Values for ABC, PSO and GA

Parameters	ABC (x10^6)			
	Number of Bees			
	2D (68)	5D (170)	10D (340)	20D (680)
Min.	6.240	6.112	6.120	6.120
Ave.	6.342	6.270	6.245	6.225
Max.	6.507	6.434	6.355	6.330
Std.*	0.058	0.067	0.064	0.056
Parameters	**PSO (x10^6)**			
	Number of Particles			
	2D (68)	5D (170)	10D (340)	20D (680)
Min.	6.926	6.576	6.543	6.417
Ave.	7.386	7.116	6.865	6.749
Max.	7.737	7.493	7.161	7.060
Std.	0.237	0.262	0.184	0.176
Parameters	**GA (x10^6)**			
	Number of Chromosomes			
	2D (68)	5D (170)	10D (340)	20D (680)
Min.	6.380	6.192	6.183	6.250
Ave.	6.829	6.719	6.569	6.522
Max.	7.653	7.874	6.988	6.913
Std.	0.268	0.339	0.187	0.151

Note. Std. = Standard Deviation

Furthermore, it was observed that the PSO algorithm caught the local minimum points. The GA method reached the optimum cost values later than the PSO and ABC methods. On the other hand, a correlation between convergence performance and individual numbers was observed for the GA method. As the individual numbers increased, the GA method gave the optimum value faster.

As a result of this study, the ABC algorithm showed a better performance than PSO and GA for Hanoi WDN. ABC algorithm obtained the lower cost values (Table 1) with a more stable structure (Figure 2 and Figure 3).

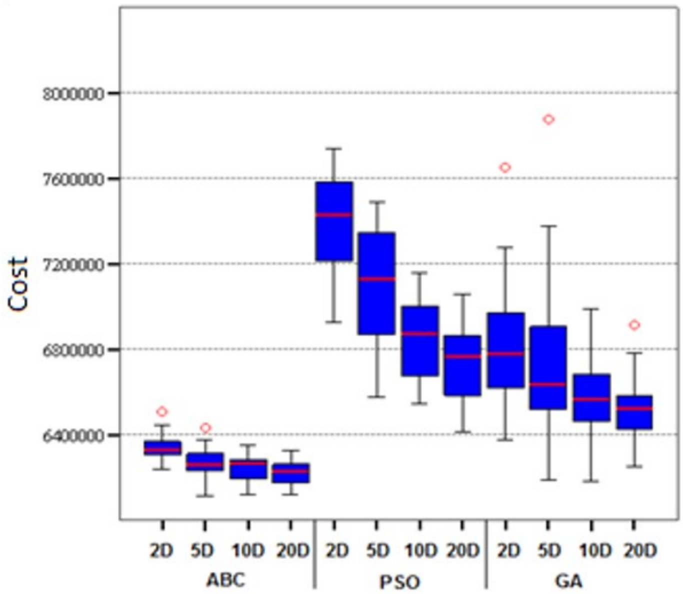

Figure 2. The Box Plot graph of optimization results for Hanoi WDN.

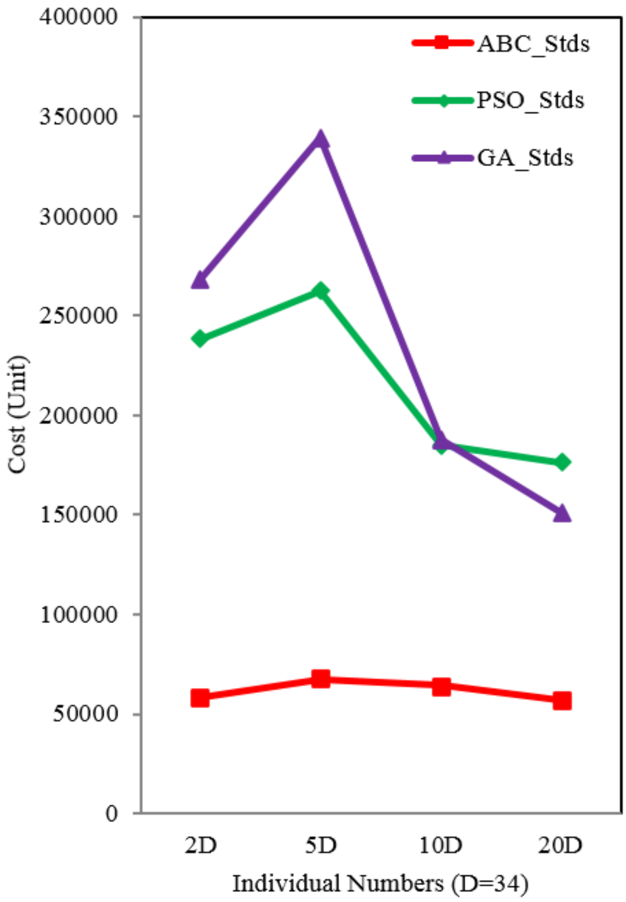

Figure 3. Variation of standard deviation values for Hanoi WDN.

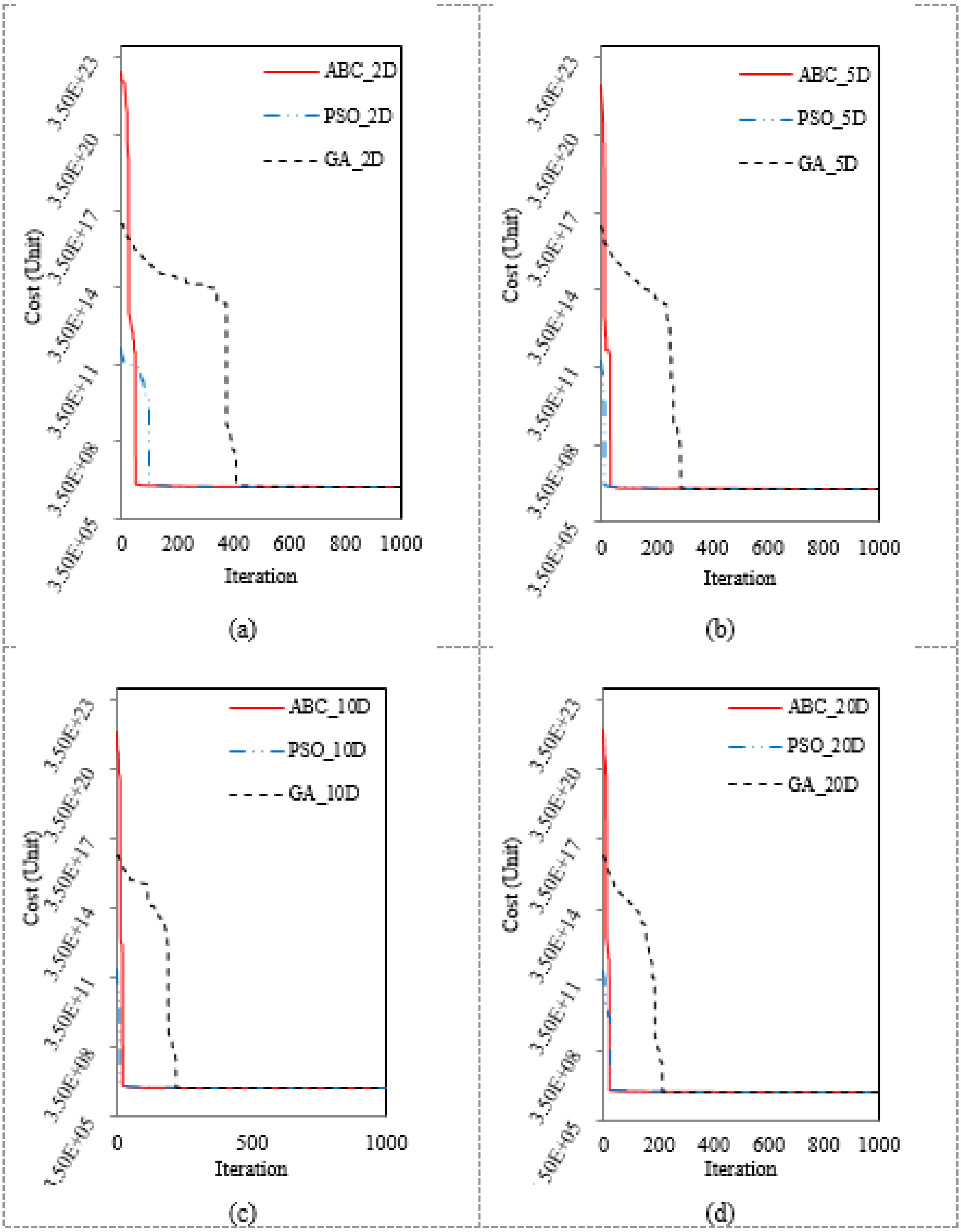

Figure 4. Convergence graphs of each method for the individual numbers of2D=64 (a), 5D=170 (b), 10D=340 (c) and 20D=680(d).

Discussion and Conclusion

The main purpose of this study is to search the performance of the ABC optimization algorithm for the WDN problem. Therefore, the GA and PSO algorithms were preferred as a reference method for the comparison of each method. All of the three methods ran with the same initial conditions. Three optimization algorithms analyzed by using comparative performance analysis for Hanoi WDN. At the end of the study, it was observed that the ABC algorithm obtained minimum cost values with a more stable behavior than the PSO and GA methods. Furthermore, the ABC method reached the optimum cost value faster than the other two methods' general convergence patterns. Finally, it was revealed that the ABC algorithm performed better than the PSO and GA methods for Hanoi WDN.

Consequently, the optimization process has been a necessity nowadays especially for the WDN problems which are so expensive structures. Since, the structure of the optimization methods are so different that it cannot be claimed a certain optimization method performs well for a certain optimization problem (Yilmaz, 2015). Therefore, different optimization methods should be tried and the results of these methods should be compared with each other. In this way, engineering functions can be serviced with fewer costs.

Acknowledgment

This study was conducted as a part of Ph.D. dissertation, namely Optimization of Water Distribution Networks Using Metaheuristic Methods, written by the author in 2015 for Selcuk University.

References

Afshar, M. H.,& Marino, M. A. (2005). A Convergent Genetic Algorithm for Pipe Network Optimization.*Scientia Iranica*, 12 (4), 392-401.

Alperovits E.,& Shamir, U. (1977). Design of optimal water distribution systems.*Water Resources Research*, 13(6), 885-900.

Babu, K. S. J.,& Vijayalakshmi, D. P. (2013). Self-Adaptive PSO-GA Hybrid Model for Combinatorial Water Distribution Network Design.*Journal of Pipeline Systems Engineering and Practise*, 4, 57-67.

Cisty, M. (2010). Hybrid Genetic Algorithm and Linear Programming Method for Least-Cost Design of Water Distribution Systems.*Water Resources Management*, 24, 1-24.

Cunha, M. C., Ribeiro, L. (2004).Tabu search algorithms for water network optimization.*European Journal of Operational Research*, 157, 746-758.

Cunha, M. C.,& Sousa, J. (1999). Water Distribution Network Design Optimization: Simulated Annealing Approach. *Journal of Water Resources Planning and Management*, 125 (4), 215-221.

Dandy, G. C.,& Engelhardt, M. O. (2006).Multi-objective trade-offs between cost and reliability in the replacement of water mains.*Journal of Water Resources Planning and Management*, 132 (2), 79–88.

Fujiwara, O.,& Khang, D. B. (1990). A two-phase decomposition method for optimal design of looped water distribution networks.*Water Resources Research*, 26 (4), 539-549.

Geem, Z. W. (2009). Particle –swarm harmony search for water network design.*Engineering Optimization*, 4, 297-311.

Kadu, M. S., Gupta R.,& Bhave, P. R. (2008). Optimal Design of Water Networks Using a Modified Genetic Algorithm with Reduction in Search Space.*Journal of Water Resources Planning and Management*, 147-160.

Karaboğa, D. (2004).*Yapay Zeka Optimizasyon Algoritmaları* (1st ed.),.Ankara: Noble Basımevi.

Karaboğa, D. (2005). An Idea on Honey Bee Swarm for Numerical Optimization.*Erciyes University Engineering Faculty Computer Engineering Department Technical Report* – TR06. Kayseri.Kennedy, J.,& Eberhart, R. (1995). Particle Swarm Optimization.Proceedings of *IEEE International Conference on Neural Networks,*4, 1942-1948.Perth: Australia.http://dx.doi.org/10.1109/ICNN.1995.488968

Murphy, L. J., Simpson, A. R.,& Dandy, G. C. (1993).Design of a pipe network using genetic algorithms. *Water*, 20 (4), 40–42.

Ozdağlar, D., Benzeden E., &Kahraman, A. M. (2006). Kompleks Su Dağıtım Şebekelerinin Genetik Algoritma ile Optimizasyonu. *The Turkish Chamber of Civil EngineersTechnical Journal*, 3851-3867..

Perelman, L.,& Ostfeld, A. (2007). An adaptive heuristic cross-entropy for optimal design of water distribution systems.*Engineering Optimization*, 39 (4), 413-428.

Quindry, G. E., Brill, E. D.,&Liebman, J. C. (1981). Optimization of looped water distribution systems.*Journal of the Environmental Engineering Division ASCE*, 107 (4), 665-679.

Schaake, J.,& Lai, D. (1969*). Linear Programming and Dynamic Programming Application of Water Distribution Network Design, Report 116.*Cambridge, MA:MIT Press..

Tospornsampan, J., Kıta, I., Ishii, M., &Kitamura, Y. (2007). Split-Pipe Design of Water Distribution Network Using Simulated Annealing.*International Journal of Computer and Information Engineering*, 1 (3), .154-164.

Vasan, A., &Simonovic, S. P. (2010). Optimization of Water Distribution Network Design Using Differential Evolution.*Journal of Water Resources Planning and Management*, 136 (2), 279-287.

Yilmaz, V. (2015). Optimization of Water Distribution Networks Using Metaheuristic Methods(Doctoral dissertation). Retrieved from http://acikerisim.selcuk.edu.tr:8080/xmlui/bitstream/handle/123456789/4579/409834.pdf?sequence=1;tc

Extended Turkish Abstract
(Genişletilmiş Türkçe Özet)

Hanoi Su Dağıtım Şebekesinin Meta-Sezgisel Optimizasyon Algoritmaları ile Maliyet Optimizasyonu

Suyun kaynağından toplanmasıyla başlayıp iletilmesi ve biriktirilmesiyle devam eden ve su dağıtım şebekeleri aracılığıyla son kullanıcıya ulaştırılmasıyla son bulan süreç bir dizi yüksek maliyetli aşamayı içermektedir. Bu süreçlerin toplam maliyetleri içerisinde su iletim ve dağıtım sistemlerinin oranı oldukça yüksektir. Bu konuda yapılmış olan bazı çalışmalar, su dağıtım şebekelerinin toplam proje maliyeti içerisindeki oranının yaklaşık %70'e kadar çıkabildiğini göstermiştir. Su dağıtım şebekelerinin yüksek maliyet değerleri içermesinin yanısıra hidrolik hesaplamalarındaki lineer olmayan ifadelerin çokluğu, şebeke sistemlerinde istenilen bir takım kısıtlar ve kullanılan ticari boru tip ve çap seçeneklerinin oldukça fazla olması bir şebeke sisteminin istenilen şekilde tasarlanmasını güçleştirmektedir.

Bir su dağıtım şebekesininhem minimum maliyet değerine hemde istenilen diğer şartlara sahip olarak tasarlanması zaman içerisinde bir optimizasyon problemi haline gelmiştir. Bilgisayar teknolojilerindeki gelişime paralel olarak optimizasyon alanında sürekli yeni yöntemler ortaya atılmıştır. Araştırmacılar ortaya atılan bu optimizasyon tekniklerini kullanarak en uygun şebeke sisteminin belirlenmesi konusunda yaklaşık son 50 yıldır çalışmalar yürütmektedirler.

Bu konuda yapılmış olan çalışmalara ilişkin literatür incelendiğinde:Özellikle bazı Benchmark (Örnek) şebekelerinin tercih edildiği ve araştırmacıların kullandıkları algoritmaları bu Benchmark şebekeler üzerinde deneyerek yöntemlerinin başarılarını test ettikleri görülmektedir. Yaygın olarak kullanılan Bencmark şebekelerinin bazıları Alperovits ve Shamir Şebekesi. Hanoi su dağıtım şebekesi, New York su dağıtım şebekesi ve İki Gözlü şebeke olarak ifade edilebilir.

Mevcut çalışmada Benchmark şebeke olarak Hanoi su dağıtım şebekesi seçilmiştir. Bu şebeke üzerinde literatürde yaygın olarak kullanılan Parçacık Sürü Optimizasyon (PSO) ve Genetik Algoritma (GA) yöntemlerine ilave olarak bu konuda yeni bir yöntem olması bakımından önemli olan Yapay Arı Kolonisi (YAK) optimizasyon algoritması kullanılmıştır. Hanoi su dağıtım şebekesi üzerinde kullanılan bu üç yöntemin sonuca ulaşma hızları, kararlılıkları ve minimum maliyet değeri üretebilmedeki başarıları karşılaştırmalı olarak incelenerek mevcut şebeke üzerinde yöntemlerin karşılaştırmalı performans analizi gerçekleştirilmiştir.

Mevcut çalışmada yöntemler arasındaki değerlendirmenin objektif olarak yapılabilmesi amacıyla PSO, GA ve YAK olmak üzere her üç optimizasyon algoritmasıda aynı amaç fonksiyonu ile çalıştırılmış ve her üç yöntem içinde borulardan geçen debi miktarı gibi hidrolik değişkenler aynı olacak şekilde optimizasyon modeli kurulmuştur. Hanoi su dağıtım şebekesi 34 adet borudan oluştuğu için problem 34 boyutlu olarak tasarlanmıştır. Optimizasyon algoritmalarının başarısında önemli bir değişken olan birey sayısı yani YAK için arı sayısı, PSO için parçacık sayısı ve GA için kromozom sayısı, yöntemin başarısının birey sayısı ile değişip değişmediğinin gözlemlenebilmesi amacıyla problemin boyut sayısı olan 34' ün 2, 5, 10 ve 20 katı olacak şekilde 68, 170, 340 ve 680 olarak belirlenmiştir. Yapılan bütün çalışmalarda iterasyon sayısı 1000 olarak kabul edilmiştir. Algoritmaların kararlılıklarının belirlenebilmesi amacıyla her yöntem 30 kere çalıştırılmış ve elde edilen sonuçlara göre yöntemlerin performansları karşılaştırılmıştır.

Yapılan çalışmadan elde edilen sonuçlar incelendiğinde bütün istatistiki parametrelere göre YAK yönteminin PSO ve GA yöntemlerine kıyasla daha başarılı sonuçlar ürettiği görülmektedir. YAK yöntemi diğer iki yönteme göre daha düşük maliyet değerleri üretmiş ve bunun yanında daha düşük standart sapma değeri elde ederek diğer iki yönteme kıyasla daha kararlı bir yapı sergilemiştir.

Genel olarak yöntemlerin başarısı ile birey sayısı arasında net olarak bir ilişki tespit edilememiş olsa da yöntemlerin üretmiş olduğu ortalama maliyet değerlerinin birey sayısı arttıkça azalmış olduğu görülmüştür. Bu kapsamda en belirgin davranış PSO yönteminden elde edilen sonuçlarda görülmektedir. PSO yöntemi birey sayısı arttıkça daha başarılı sonuçlar üretebilmiştir.

Yapılan çalışmalarda iterasyonlar boyunca maliyet değerlerinin değişimini gösteren yakınsama grafikleri yöntemlerin optimum maliyet değerine ulaşma hızlarını değerlendirme bakımından önemlidir. Yakınsama grafikleri incelendiğinde PSO yönteminin optimum maliyet değerine diğer iki yönteme kıyasla daha erken ulaştığı fakat diğer iki yönteme kıyasla daha yüksek maliyet değerlerinin elde edildiği görülmektedir.Bu sonuç PSO yönteminin yerel minimum noktalarına takılma konusunda diğer yöntemlere kıyasla daha hassas ve daha başarısız olduğunu düşündürmüştür. Bunun yanısıra GA yönteminin optimum maliyet değerine YAK ve PSO yöntemlerine kıyasla daha geç ulaştığıda yine yakınsama grafiklerinde görülebilmektedir.

Sonuç olarak bir Benchmark şebeke olan Hanoi su dağıtım şebekesi üzerinde YAK, PSO ve GA olmak üzere 3 adet Meta-Sezgisel optimizasyon algoritması ile yapılmış olan karşılaştırmalı performans analizinde YAK yönteminin diğer iki yönteme kıyasla daha düşük maliyet değerleri elde ettiği, daha düşük standart sapma değeri üreterek daha kararlı bir davranış sergilediği ve optimum maliyet değerine daha erken yakınsadığı sonuçlarına ulaşılmış ve özet olarak YAK yönteminin diğer iki yönteme kıyasla daha yüksek bir performans sergilediği görülmüştür.

Genel olarak optimizasyon algoritmalarının doğası gereği, belirli bir yöntemin her problemde üstün davranış sergileyeceğini iddia etmek doğru değildir. Herhangi bir yöntem bir problem üzerinde başarılı olurken başka bir problem üzerinde başarısız olabillir. Bu yüzden su dağıtım şebekeleri gibi optimizasyonun gerekli olduğu bir alanda belirli bir sistem tasarlanırken mutlaka farklı yöntemler denenmeli ve sonuçlar incelenerek istenilen sistem bu şekilde tasarlanmalıdır. Bu yolla kullanıcılara mühendislik hizmetinin daha kaliteli ve daha düşük maliyetlerle sunulması sağlanabilir.

Research Article

Drinking Water Treatment Plants in Turkey and Determination of Revision Needs

Türkiye'deki İçme Suyu Arıtma Tesisleri ile Revizyon İhtiyaçlarının Belirlenmesi

Esra GİRESUNLU[1], Arife ÖZÜDOĞRU[2], Fulya YAYCILI[2], Hilal UFLAZ[1], Cenk GÜMÜŞKAYA[1], Murat SARIOĞLU[1], Yakup KARAASLAN[2]

[1]*MWH now part of Stantec, Koşuyolu Mah., Salih Omurtak Sok., No:61, Kadıköy, İstanbul*
esra.giresunlu@stantec.com, hilal.uflaz@stantec.com, cenk.gumuskaya@stantec.com, murat.sarioglu@stantec.com
[2]*Republic of Turkey Ministry of Agriculture and Forestry, General Directorate of Water Management, 06510, Yenimahalle, Ankara*
arife.ozudogru@tarimorman.gov.tr, fulya.yaycili@tarimorman.gov.tr, yakup.karaaslan@tarimorman.gov.tr
Received Date: 04.04.2019, Accepted Date: 27.05.2019

Abstract

Drinking water quality is regulated by Regulation Concerning Water Intended for Human Consumption by Ministry of Health in Turkey. As in the process of becoming a member state of EU, Turkish regulation is compatible with EU Drinking Water Directive. This study revealed that there are 489 drinking water treatment plants, 397 of which are under operation. This work aims to deterrmine the inventory of the drinking water treaatment plants in Turkey, and evaluate the current status of the plants. Within this work, identity cards for these active plants were prepared. Process selection of these plants were specified. A GIS-based program called ISBIS was developed and all data collected within this work was uploaded to the database. Site-visits to 193 selected plants were conducted and site-visit reports focusing on operational and structural issues at these plants were issued. As a result of this work, it appeared that 37 drinking water treatment plants out of 193 site-visited need to be reconstructed. Also, it was observed that most of the drinking water treatment plants are not capable of removing micropollutants, and will need major revisions.

Keywords: *Drinking water treatment, water quality, regulation, operational issues, revision*

Öz

Türkiye'de içme suyu kalitesi, Sağlık Bakanlığı tarafından hazırlanan İnsani Tüketim Amaçlı Sular Hakkında Yönetmelik ile yönetilmektedir. Avrupa Birliği'ne tam üyelik sürecinde olan Türkiye'nin mevzuatı, AB İçme Suyu Direktifi değerlerine uygundur. Bu çalışma ile Türkiye'de 397'si çalışmakta olan 489 içme suyu arıtma tesisi tespit edilmiştir. Bu çalışma boyunca her bir aktif içme suyu arıtma tesisi için kimlik kartları hazırlanmıştır. Bu tesislerin proses seçimleri incelenmiştir. ISBIS isimli CBS-tabanlı bir yazılım geliştirilmiş, çalışma boyunca toplanan tüm veri bu programın veri tabanına yüklenmiştir. 193 adet seçilmiş içme suyu arıtma tesisine saha ziyaretleri düzenlenmiş, bu tesisler hakkında işletme ile ilgili ve yapısal sorunların değerlendirildiği saha ziyaret raporları düzenlenmiştir. Sonuç olarak, ziyaret edilen 193 içme suyu arıtma tesisinden 37'sinin yeniden inşa edilmesi gerektiği tespit edilmiştir. Ayrıca, mevcut içme suyu arıtma tesislerinin çoğunun mikrokirletici giderimi yapmasının mümkün olmadığı ve revizyona ihtiyaç duyacakları tespit edilmiştir.

Anahtar kelimeler: *İçme suyu arıtımı, su kalitesi, mevzuat, işletme sorunları, revizyon ihtiyacı*

Introduction

It is estimated that over 1.1 billion people do not have access to safe water (UNICEF Handbook on Water Quality, 2008). Keeping in mind that water scarcity is often a problem of water quality as well as quality is important (Bauer, 2004). One of the major challenges humanity is facing is related to the uncertainties in spatial and temporal variations in quality and quantity of water resources (Schwarzenbach et al., 2010). The increase in population, agricultural and industrial activities leads to the introduction of a wide variety of chemicals to the environment, and hence result in significant deterioration in water quality. Contamination of drinking water resources by anthropogenic chemicals is a problem particularly experienced in industrialized countries (Benner et. al., 2013). As a result, degradation trends in drinking water quality lead to adverse health impacts (Delpla et. al., 2009).

Water treatment technologies have evolved over the past few centuries to protect public health from pathogens and chemicals (Ray and Jain, 2011). The goal of all water treatment technologies is to remove turbidity as well as chemical and pathogenic contaminants from water sources in the most affordable and expedient manner possible. A typical water treatment plant treats lake or river water (turbid surface water with organics) and processes the raw water using various unit processes, including screening, aeration, coagulation, flocculation, sedimentation or settling, filtration, hardness treatment, disinfection, and fluoridation (Spellman and Drinan, 2012).

Drinking Water Quality in Turkey is regulated by Regulation Concerning Water Intended for Human Consumption by Ministry of Health (2005), which is compatible to the EU Drinking Water Directive (1998). However, a complete inventory of the surface water resources used for drinking water supply and drinking water treatment plants are not available. Also, the problems being experienced at the drinking water treatment plants in terms of water quality and operation are not recorded.

This work aims to make a complete inventory of the drinking water treatment plants in Turkey. Doing this, also the treatment process selections were researched and included in the inventory. Site-visits were conducted to selected drinking water treatment plants for determination of the problems experienced by the operators, and possible revision needs that is required at the plants.

Method

An inventory work has been undertaken all around Turkey to deteminate the surface water resources and drinking water treatment plants. A total of 193 drinking water treatment plants were site-visited and evaluated in terms of process, operational issues and treated water quality. A site-visit report was issued for each drinking water treatment plant site-visited. The reports included information on the water resource of the plant, water quality, existance of an on-site laboratory and analysis capability, the process and equipment used, occupational health and security issues and energy efficiency. Revision needs were determined for each drinking water treatment plant site-visited in terms of both increasing treated water quality and EU harmonisation process. Also, a study was conducted to determine the costs to adopt necessary revisions at the drinking water treatment plants.

An identity card (ID card) was prepared to include general information on the plant, process details, all the supporting documents to be supplied by the operators and operational issues detected during site-visits. These ID cards were filled with relevant information during site-visits where site-visits were conducted. For plants that were not visited, the ID cards were sent to the plant operators for their contributions and collected back once ready.

A GIS based drinking water information system, namely ISBIS (İçme Suyu Bilgi Sistemi in Turkish) was developed, which uses the information on the ID cards as input. Only using the information on the ID cards, seven different reports can be generated using ISBIS, which are per capita consumption, per capita production, day vs. year ratio, banded population, deployable yield, source yield vs. production, and banded capacity. ISBIS also includes information on surface water resources used for drinking water supply. All data is available as a map, where all the coordinates for water resources and drinking water treatment plants are marked. Also, water quality data is available for both the resources and drinking water treatment plant inlet and outlet. Reports regarding water quality can be generated through using ISBIS.

Results and Discussions

The work carried out in terms of inventory of the drinking water treatment plants in Turkey revealed that there are 489 plants. Among these, 397 are in operation while the other 92 are out of operation. Out of 489, 229 drinking water treatment plants were large scale, 158 of which are in operation and all site-visited. The other 260 were package treatment plants and 239 were in operation, while the rest were inactive. Site visits were conducted to 35 of these package plants.

The process distribution of the treatment plants are given in Table 1. Also the number of drinking water treatment plants in operation and the ones that were site-visited are listed. According to the data given, most of the large scale plants do conventional treatment, while the selected process is advanced treatment for only 12 active large scale plants. On the other hand, most of the package treatment plants are employed for arsenic removal, while similar to large scale plants, the number of conventional treatment systems are also high. Table 1 is visualized in Figure 1 to make the comparison clear.

Table 1

Drinking Water Treatment Plants' Process Distribution and Counts

Type	Process	Count	In operation	Site-visited
Large scale	Physical treatment	28	28	28
Large scale	Conventional treatment	187	118	118
Large scale	Advanced treatment	14	12	12
Package*	Conventional treatment	109	90	20
Package	As removal	115	113	15
Package	As(1), Fe(2) and Mn(3) removal	2	2	-
Package	Fe and Mn removal	29	29	-
Package	Br removal(4)	1	1	-
Package	Softening	4	4	-

*Note.*Package drinking water treatment plants are those with treatment capacity below 4000 m^3/day.*

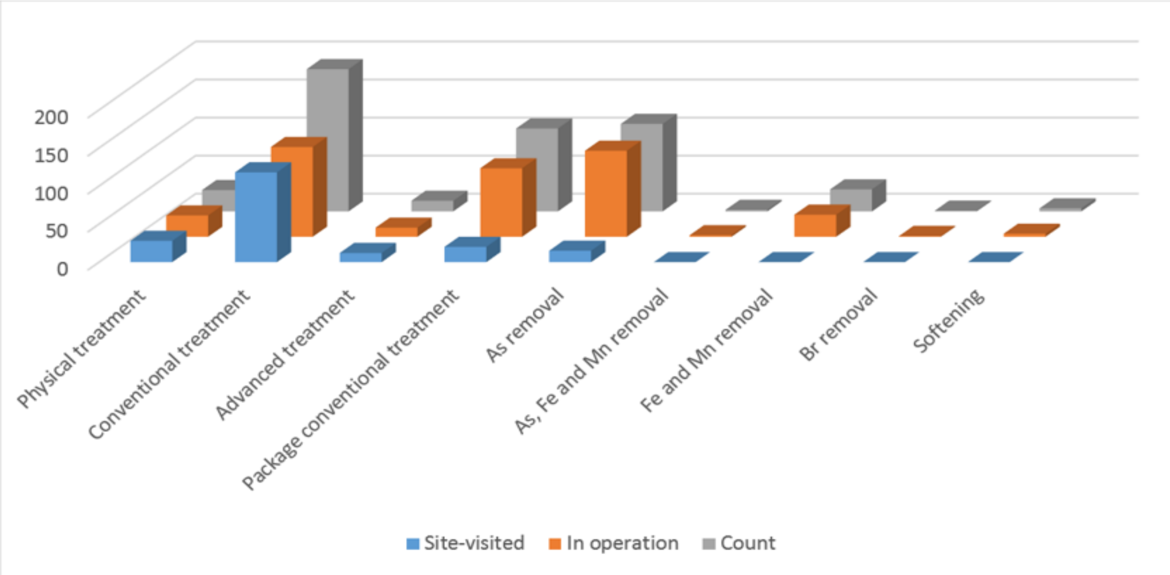

Figure 1. Process distribution and counts of drinking water treatment plants in Turkey (prepared by author).

Figure 2 shows the distribution of large scale drinking water treatment plants among Turkey. As expected, the plants are mostly located where the population is higher and where the water needs to be treated prior to supply. Table 2 shows how the site-visited drinking water treatment plants distributed among the 25 water basins of Turkey. According to the information given, most of the large scale drinking water treatment plants are located in Marmara Basin, where more than 20% of the total population of Turkey is living. On the other hand, there are no large scale plants located in Antalya, Batı Akdeniz and Burdur Basins.

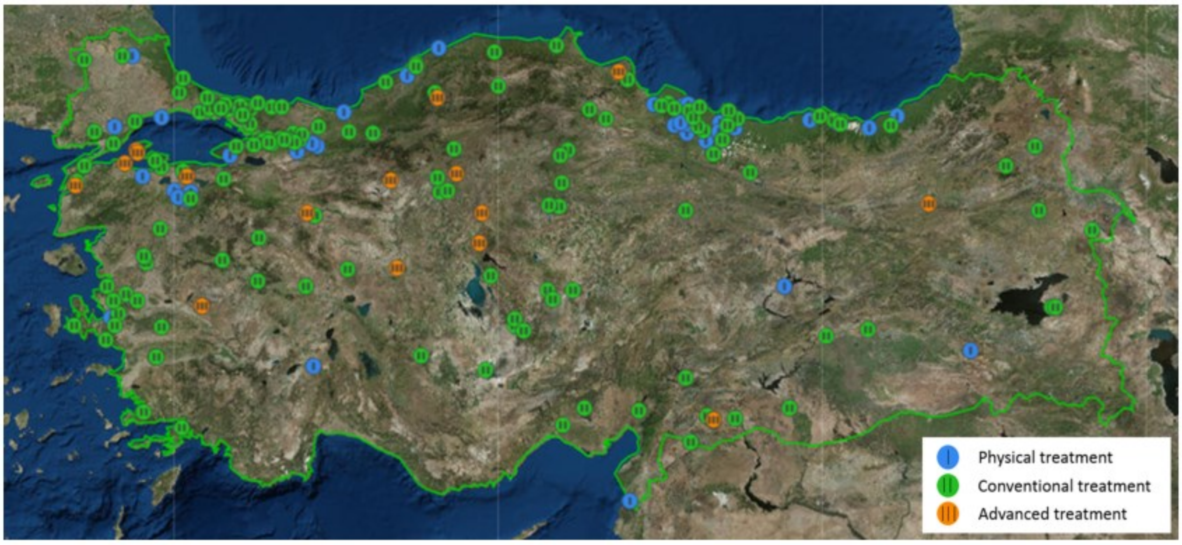

Figure 2. Distribution of large scale drinking water treatment plants among Turkey (prepared by author).

Table 2

Distribution of Site-Visited Drinking Water Treatment Plants Among Water Basins of Turkey

No	Basin	Physical treatment	Conventional treatment	Advanced treatment	Package treatment	Total
1	Akarçay	0	1	0	0	1
2	Antalya	0	0	0	0	0
3	Aras	0	2	0	0	2
4	Asi	0	0	0	0	0
5	Batı Akdeniz	0	4	0	0	4
6	Batı Karadeniz	3	3	1	4	11
7	Burdur	0	0	0	0	0
8	Büyük Menderes	0	2	0	0	2
9	Ceyhan	0	1	0	0	1
10	Çoruh	0	1	0	0	1
11	Doğu Akdeniz	1	3	0	0	4
12	Doğu Karadeniz	6	17	0	2	25
13	Fırat – Dicle	1	9	1	1	12
14	Gediz	0	1	1	4	6
15	Kızılırmak	1	6	4	3	14
16	Konya Kapalı	0	2	0	3	5
17	Kuzey Ege	0	1	0	0	1
18	Küçük Menderes	0	5	0	3	5
19	Marmara	5	29	2	5	41
20	Meriç – Ergene	1	3	0	0	4
21	Sakarya	0	14	3	3	20
22	Seyhan	0	1	0	0	1
23	Susurluk	5	5	0	3	13
24	Van Gölü	0	0	0	2	2
25	Yeşilırmak	5	8	0	2	15
	TOPLAM	28	118	12	35	193

The evaluation carried out at the site-visited drinking water treatment plants revealed that there are several major problems regarding the raw water quality, the process selection at the plants and operation. First, the water intake structures were not selected appropriately. Some dams supplying water to drinking water treatment plants were constructed to supply water for irrigational purposes, and the water intake structure was constructed to take water from one level only. On the other hand, these structures should be constructed to take water from different levels, depending on the water level at the dams and water quality at different levels depending on trophic status.

Secondly, process selection of drinking water treatment plants were not done considering the water quality at the water resource. The main reason for this is lack of data regarding water quality at the dams and other water resources. Prior to process selection, long term monitoring should be done at the water resources and the changes in water quality should be followed carefully. The monitoring should be done at least for five years. Different locations and levels of water should be included in the sampling work. Seasonally, cyanobacteria, cyanotoxin and other toxins should be included in the monitoring. If taste and odor problems are being observed, the source of this should be defined. Especially, total organic carbon, turbidity and microbiological parameters should be taken into consideration while treatment process selection is done.

The site-visits revealed that the incoming flow cannot be distributed equally to independent treatment lines, resulting in different and deteriorated water quality at the outflow. Also, the incoming flow is changing in a wide range and suddenly, as mentioned by the operators. Operational conditions are not changed according to inlet water flow and quality. At some treatment plants, inflow water quality is not determined, hence there is no valve to do sampling.

General approach followed in Turkey is to drain the sedimentation tanks occasionally and to clean the sludge accumulated manually. However, mechanical equipment should be employed for this, and the sludge cleaning process should be done periodically and automatically.

Algae formations and solid matter accumulation in aeration and oxidation tanks were observed at many of the site-visited drinking water treatment plants. As mentioned by the operators, manganese and iron peaks are observed frequently and it was observed that the operators are not capable of handling these situations.

Powdered and/or granular activated carbon is used at some drinking water treatment plants. However, it was understood that there was no selection criteria while selecting these activated carbons, resulting in low removal rates for targeted pollutants. Not every type of activated carbon solves the target problems. While selecting the one that is to be used, the target pollutants and the water chemistry should be taken into consideration for successful treatment. Also, the steps to dose powdered activated carbon should be determined. Dosage also needs to be adjusted, as overdosing may result in detection of powdered activated carbon in the drinking water to be supplied. Regeneration need of granular activated carbon is not considered and many of the treatment plants have not done regeneration even once. The granular activated carbon filters' inflow and outflow and head losses are not tracked.

In terms of coagulation and flocculation process, Jar-Test is the most important step of successful removal of pollutants. However, these tests are carried out at only a limited number of drinking water treatment plants. Accordingly, chemicals are dosed without knowing the needs. pH adjustment is not done considering the dosages, or not done at all. Acid and base dosages are done without automation. Different dosages are applied at independent treatment lines. Sometimes, coagulant dosage is done at steps different than it was designed in the project. Operators are not changing operation conditions for changing raw water turbidity. Other than issues on chemical usage, it was observed that sometimes the fast-mixers are not employed even if they are available at the plant. Also, flocculation pedals are corroded at many of the plants.

In clarifiers and sedimentations tanks, the belt cleaners were not in operation, or they were broken. Lamella plates were deformed where they were employed. There are dead zones or short circuiting at the basin effluent of some of the plants. The solid concentrations were not analyzed, water is pumped out of the tanks instead of sludge and at some plants rise of upflow sludge blanket were observed due to problems regarding opeation.

There are many problems observed regarding the problems in filtration step. First, backwash frequency is not optimized considering the effluent turbidity levels, but only according to the head losses. Second, minimization of loss of water and energy efficiency during filtration are not emphasised. One of the main concerns of filtration, microbiological removal in terms of Giardia, Cryptosporidium and viruses, are not analyzed at the inflow or outflow of the filtration process. There are automated filtration systems at some plants, however these automation systems are not used and filtration and backwash are done manually. Moreover, at many of the plants, the sand employed in filtration systems has never been changed and in use for over 25 years, causing many problems including microbiological odor. Sometimes backwash is done without using blowers, or the plant do not have any blowers for this job at all. At many of the water treatment plants, wastebackwash water is recycled within the treatment plant (i.e. by directing the flow to the beginning of the treatment plant) which causes the increase in microbiological pollutants.

Moreover, contact time parameter should be taken into consideration when disinfection is done. Disinfection activity should be monitored at plants which do not have a contact tank. Chlorine need of raw water at different temperatures should be determined and dosage should be done considering residual chlorine concentrations. Excess dosing should be avoided. pH during disinfection should be monitored as forms of HOCl and OCl have different chemical features. Pre-chlorination and $FeCl_3$ dosages should be optimized according to water chemistry and arsenic concentrations in water.

Disinfection by-products should be taken into consideration while designing the drinking water treatment plants. Total organic carbon concentrations should be the primary concern while designing chlorination and applying disinfection. Dosage should not be done only according to the microbiological parameters, but also total organic carbon. Chlorine management should be done together with disinfection by-product formation potential.

UV disinfection, ozonation, advanced oxidation or membrane processes should be considered instead of chlorination, where there is high pathogenic potential in raw water resources. If UV disinfection is selected, turbidity should be monitored to have high removal rates. Where ozonation is applied, gas phase ozone measurement should be included in design of off-gas line. Air space in ozone contact tank should be designed considering minimization of off-gas escape. Also, the liquid phase ozone analyzers should be place at the effluent of contact tank.

It was also observed that the treated water storage tanks were not cleaned frequently, causing water quality deterioration after treatment. Some of these tanks lack an appropriate entrance so that it can be cleaned. At some, there is no online chlorine measurement system, so the residual chlorine concentration is not known.

All these problems observed at the treatment plants cause treated water quality to deteriorate and supply of unhealthy drinking water for public use. Out of 193 drinking water treatment plants site-visited, 124 need structural revisions to be able to treat water sufficiently prior to supply. 13 of these plants require a revision at their water intake structures, while 30 of those need a revision at their aeration steps. Conventional treatment units should be revised at 57 drinking water treatment plants. Finally, 84 of those plants site-visited need to have an activated carbon filtration system to be able to treat micropollutants, which possibly will be a concern in the near future as awareness has been raising about these chemicals, harmful for humans at very low concentrations.

Operational refinements at 29 of site-visited drinking water treatment plants will be sufficient enough to meet the drinking water standards. However, 37 plants should be taken out of operation, demolished, and constructed again, as the problems observed at these plants cannot be solved through minor revisions. Revision needs of drinking water treatment plants are summarized in Table 3.

Table 3

Revision Needs in Site-Visited Drinking Water Treatment Plants

Revision need	**Count**
Structural revision	124
Water intake structure	13
Aeration unit	30
Conventional treatment units	57
Activated carbon unit addition	84
Reconstruction	37
Operational revision	29

Conclusions

The study undertaken has shown that there are 489 drinking water treatment plants. Among these, 397 are in operation while the other 92 are out of operation. 158 of those in operation are large scale plants, while the rest are small plants. All the large scale plants in operation are site-visited, while 35 out of the small ones are also included in the work.

This work has revealed the problems observed at especially large scale drinking water treatment plants in Turkey. The quality of surface water resources are regulated by Ministry of Agriculture and Forestry with By-law on quality of surface water to be obtained or planned to be obtained as drinking water (2012), which is under development to include the groundwater resources as well. While these changes are being made, there is high potential that the micropollutants will be included in the standards with limits, as these chemicals are very harmful to human health at very low concentrations. If the regulation on water resources is changed and includes the micropollutants, most of the drinking water treatment plants in Turkey will not be able to treat these chemicals, as many of the existing drinking water treatment plants are constructed as conventional treatment systems, while advanced treatment techniques need to be used for micropollutant removal.

Moreover, the existing drinking water treatment plants need some revisions to be able to meet the current drinking water standards. During site-visits undertaken within this work, it was observed that many of the plants are in need of structural changes, while some other plants need to have operational changes to supply healthy drinking water to the consumers.

Acknowledgement

This study was conducted as a part of the European Union co-financing project "Technical Assistance for Assessment of Drinking Water Resources and Treatment Plants in Turkey, Service Contract No.2007TR16IPO001.3.02/SER/32." (2015-2017) prepeared by MWH, Louis Berger, Tümaş Consortium under the authorization of Ministry of Agriculture and Forestry, General Directorate of Water Management of Turkey (as the Beneficiary).

References

Bauer, C. (2004). Marketing water, marketing reform: lessons from the Chilean experience. Washington D.C: RFF Press.

Benner, J., Helbling, D.E., Kohler, H.P.E., Wittebol, J., Kaiser, E.; Prasse, C., … Boon, N. (2013). Is biological treatment a viable alternative for micropollutant removal in drinking water treatment processes? Water Research, 47 (16), 5955-5976.

Delpla, I., Jung, A.V., Baures, E., Clement, M., & Thomas, O. (2009). Impacts of climate change on surface water quality in relation to drinking water production. Environment International, 35 (8), 1225-1233.

European Union. Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption. Official Journal of the European Community 1998. L330/32 –L330/54.

Ray, C., & Jain, R. (Eds). (2011). Drinking water treatment. New York: Springer.

Schwarzenbach, R.P., Egli, T., Hofstetter, T.B., Gunten, U., & Wehrli, B. (2010). Global water pollution and human health. Annual Review of Environment and Resources, 35, 109-136.

Spellman, F.R., & Drinan, J.E. (2012). The drinking water handbook. Washington D.C: Taylor & Francis. Retrieved from. https://www.routledgehandbooks.com/doi/10.1201/b12305-4

Turkish Republic Official Gazette. (2012). By-law on quality of surface water to be obtained or planned to be obtained as drinking water. Official gazette dated 29/06/2012 and numbered 28338. Retrieved from http://www.resmigazete.gov.tr/eskiler/2012/06/20120629-9.htm

Turkish Republic Official Gazette. (2013). Regulation Concerning Water Intended for Human Consumption. Official gazette dated 07/03/2013 and numbered 28580. Retrieved from http://www.mevzuat.gov.tr/Metin.Aspx?MevzuatKod=7.5.7510&MevzuatIliski=0

United Nations Children Fund. (2008). UNICEF handbook on water quality. New York: UNICEF. Retrieved from http://www.unicef.org/wash/files/WQ_Handbook_final_signed_16_ April_2008.pdf

Extended Turkish Abstract
(Genişletilmiş Türkçe Özet)

Türkiye'deki İçme Suyu Arıtma Tesisleri Envanteri ve Revizyon İhtiyaçlarının Belirlenmesi

Dünyada 1.1 milyar insanın temiz su kaynaklarına erişimi bulunmamaktadır. Günümüzde suyun miktarı kadar kalitesinin de önem taşıdığı anlaşılmıştır. Hem insan eli ile yapılan faaliyetler hem de doğal döngüler sonucunda temiz su kaynaklarının kirliliğinde artış gözlenmektedir. Dolayısı ile insanların su kaynaklarına erişimi de gün geçtikçe kısıtlanmaktadır.

Bu sebeple geçtiğimiz yüzyılda içme suyu arıtımı önem kazanmaya başlamıştır. Tüm içme suyu arıtma tekniklerinin temel amacı, su içinde bulunan patojenlerin ve kimyasal kirleticilerin gideriminin en elverişli ve en ucuz şekilde sağlanmasıdır. Yerüstü içme suyu kaynaklarından su sağlayan tipik bir içme suyu arıtma tesisinde ızgara, havalandırma, koagülasyon, flokülasyon, son çökeltim, filtrasyon, sertlik giderimi ve dezenfeksiyon adımları bulunmaktadır.

Yapılan envanter çalışmasında Türkiye genelinde yerüstü su kaynaklarından su temin eden toplam 489 içme suyu arıtma tesisi tespit edilmiştir. Bu tesislerin her biri için tesis kimlik kartları oluşturulmuştur. Tesislerden 92'sinin mevcut durumda çalıştırılmamakta olduğu belirlenmiştir. 489 tesisten 229'unun büyük kapasiteli tesisler olduğu ve bunlardan 158'sinin mevcut durumda işletilmekte olduğu görülmüştür. Kalan 260 içme suyu arıtma tesisi küçük kapasiteli olup bunların 239'u çalıştırılmaktadır. Büyük kapasiteli ve işletmede olan tüm tesislere ve seçilen 35 küçük kapasiteli tesise saha ziyareti düzenlenmiştir.

Saha ziyaretleri sırasında tesislerin durumları incelenmiş, tesislerde yaşanan problemlerle ilgili tesis operatörlerinden bilgi alınmıştır. Saha ziyaretleri sonrasında tesislerdeki işletme ve yapısal sorunlara odaklanan saha ziyaret raporları düzenlenmiştir. Ziyaret edilen 193 tesiste yapılan gözlemlerde hem işletmede yapılabilecek iyileştirmeler hem de yapıların iyileştirilmesi ile ilgili notlar alınmıştır. Gözlemlere göre, Türkiye'de içme suyu arıtma tesislerinde hem yapısal, hem de işletme odaklı dikkate alınması gereken birçok husus bulunmaktadır.

Yapılan incelemeler sonucunda oluşturulan tesis kimlik kartları ve saha ziyaret raporlarının tamamı, oluşturulan Coğrafi Bilgi Sistemi (CBS) tabanlı İçme Suyu Bilgi Sistemi (İSBİS)'ne yüklenmiştir. Tesis kimlik kartlarındaki bilgileri girdi olarak kullanan İSBİS, kişi başına su tüketimi, kişi başına su üretimi, günlük su üretiminin yıllık üretime oranı, nüfusa göre arıtma tesisi sayıları, su kaynağının kullanılabilir su kapasitesi, su kaynağı kapasitesinin su üretimine oranı ve üretim miktarına göre tesis sayısı olmak üzere yedi farklı rapor üretebilmektedir. Tüm veri harita olarak erişilebilir olup tüm yerüstü su kaynakları ve tesisler koordinatları ile gösterilmektedir.

Bunlardan ilki su sağlanan su alma yapılarının içme suyu temini maksadıyla yapılandırılmamış olmasıdır. İçme suyu temin edilen bazı kaynaklar, aslında tarımsal sulama maksadıyla yapılmış, ancak artan su talebini karşılamak üzere sonradan içme suyu teminine başlamıştır. Bu sebeple su alma yapıları tek seviyeden su alacak şekilde yapılandırılmış olup değişken seviyelerden su alımına müsaade etmemektedir. Bununla ilgili olarak mevcut su alma yapılarının yüzer tipte su alma yapıları ile değiştirilmesi gerektiği belirlenmiştir.

İçme suyu arıtma tesislerinin proses seçimleri kaynaktaki su kalitesi göz önünde bulundurulmadan yapılmıştır. Bunun temel sebebi içme suyu kaynaklarında su kalitesi izleme çalışmalarının çok sınırlı olmasıdır. Bir tesisin projesinin en az 5 yıllık sürekli izleme sonuçlarına dayanılarak yapılması gerekmektedir. Veri eksikliği sebebi ile içme suyu arıtma tesisindeki proses seçimi, çıkışta ihtiyaç duyulan su kalitesinin sağlanması için yetersiz kalabilmektedir.

Saha ziyaretleri sırasında gözlenen bir diğer durum ise suyun tesis içindeki bağımsız hatlara eşit debilerde dağıtılamamasıdır. Tesis içinde meydana gelen çökmeler bu soruna yol açabildiği gibi, tesisin inşaatı sırasında gerçekleşen aksaklıkların da bu tip problemlere sebep olduğu tespit edilmiştir. Tesis operatörleri genellikle bunun yol açtığı sorunların farkında değildir. Bu sebeple her iki hattta giren debiler farklı olmasına rağmen dozlanan kimyasallar ve diğer işletme koşullarının iki hatta aynı olması, iki ayrı hattan çıkan suyun kalitelerinin farklı olmasına yol açmaktadır.

Kimyasal dozlamaları mevcut durumda herhangi bir bilimsel metot kullanılarak yapılmamakta olup tesislerin tamamında Jar-test yapılması önerilmektedir. Dozlanan kimyasalların dozaj ayarının tesise gelen su kalitesine göre ayarlanması, su arıtımı açısından büyük önem teşkil etmektedir. Dozajların manuel olarak değil, pompalarla yapılması önem taşımaktadır.

Dezenfeksiyon uygulamaları genellikle klorlama ile yapılmakta olup klor dozajı tesise gelen suda bulunan organik madde konsantrasyonuna göre ayarlanmamaktadır. Bu da dezenfeksiyon sırasında dezenfeksiyon yan ürünlerinin oluşumuna sebep olup halk sağlığı açısından tehlike arz etmektedir. Dezenfeksiyon yan ürünleri oluştuktan sonra giderimleri için ileri teknikler gerekmekte olup bu yan ürünlerin oluşumunun engellenmesi en iyi çözümdür. Bu sebeple klorla dezenfeksiyon yapılan durumlarda, dozlanan klor konsantrasyonunun doğru şekilde ayarlanması büyük önem taşımaktadır.

Tesisler, mikrokirletici giderimi yapabilecek proses konfigürasyonuna sahip değildir. Mikrokirleticilerle ilgili farkındalık son yıllarda artmış olup, küçük konsantrasyonlarda bile insan sağlığına zararlı olan bu kimyasalların mevzuatlara dahil edilmesi söz konusu olacaktır. Mikrokirletici giderimi konvansiyonel sistemlerle sağlanamamakta olup iyi giderim verimlerinin elde edilebilmesi için ileri arıtma tekniklerinin uygulanması gerekmektedir. Mevzuatlarda mikrokirleticilere yer verildiği takdirde tesislerin birçoğunun uygun arıtma gerçekleştirebilecek proses seçimi bulunmamaktadır. Bu sebeple özellikle su temin ettiği yerüstü su kaynaklarında mikrokirletici tespit edilen birçok tesiste aktif karbon filtrasyonu yapılması önerilmiştir.

Sonuç olarak 29 tesisin işletme koşullarında iyileştirme yapılarak standartlara uygun su arıtılabileceği belirlenmiştir. 37 tesisin ise büyük revizyon ihtiyaçları tespit edilmiş olup bu tesislerin yenisinin yapılması önerilmiştir.

Research Article

The Influences of Arctic & North Atlantic Oscillations on Temperature and Precipitation Data of Eastern and Northern Marmara

Arktik & Kuzey Atlantik Salınımlarının Doğu ve Kuzey Marmara'nın Sıcaklık ve Yağış Verileri Üzerindeki Etkileri

Cenk SEZEN, Turgay PARTAL
Ondokuz Mayıs University, Department of Civil Engineering, Samsun, Turkey
cenk.sezen@omu.edu.tr, turgay.partal@omu.edu.tr
Received Date: 24.07.2018, Accepted Date: 24.12.2018

Abstract

Arctic Oscillation and North Atlantic Oscillation are the two types of the teleconnections which have an influence area particularly at Northern Hemisphere (Russia, Canada, China, United States of America, India, Kazakhstan, Algeria, Saudi Arabia, Mexico and Sudan). To reveal the relation between Arctic Oscillation, North Atlantic Oscillation and temperature, precipitation regime of Eastern and Northern parts of Marmara in Turkey, correlation coefficients were calculated. With our study it was obtained that temperature values under the impact of Arctic Oscillation (-), North Atlantic Oscillation (-) were generally higher than the values under the effect of Arctic Oscillation (+), North Atlantic Oscillation (+). However, it was seemed that the relationship between precipitation data and the phases of atmospheric indices were more complicated. As a result, this study proved that the influence of atmospheric teleconnections on the hydro-meteorological parameters is necessary for the effective management and prediction of water resources.

Keywords: *Arctic Oscillation, North Atlantic Oscillation, Marmara region, precipitation, temperature*

Öz

Arktik Salınım ve Kuzey Atlantik Salınımı özellikle Kuzey Yarımküre'de (Rusya, Kanada, Amerika Birleşik Devletleri, Hindistan, Kazakistan, Cezayir, Suudi Arabistan, Meksika ve Sudan) etki alanına sahip olan tele bağlantılardan iki tanesidir. Arktik Salınım, Kuzey Atlantik Salınımı ve Türkiye'nin Doğu ve Kuzey Marmara kesiminde sıcaklık, yağış rejimi arasındaki ilişkiyi ortaya koymak için korelasyon katsayıları hesaplanmıştır. Çalışmamızda Arktik Salınım (-), Kuzey Atlantik Salınımı (-) etkisi altındaki sıcaklık değerlerinin Arktik Salınım (+),Kuzey Atlantik Salınımı (+) etkisi altındaki sıcaklık değerlerinden genel olarak daha yüksek olduğu elde edilmiştir. Ancak, yağış verisi ve atmosferik indislerin fazları arasındaki ilişkinin daha karmaşık olduğu görülmektedir. Sonuç olarak, bu çalışma atmosferik indislerin hidrometeorolojik parametreler üzerindeki etkisinin su kaynaklarının yönetimi ve tahmini için gerekli olduğunu ortaya koymuştur.

Anahtar kelimeler*: Arktik Salınım, Kuzey Atlantik Salınımı, Marmara bölgesi, yağış, sıcaklık*

Introduction

The impacts of atmospheric events on hydrological cycle are very significant with regard to water resources management and hydrological cycle. In this regard, the influence of atmospheric teleconnections on hydrometeorological variables such as rainfall, temperature or streamflow which need be taken into consideration for design of water structures like dams or prevention of flood or drought risks, is revealed in many studies (Rodo et al, 1997; Givati and Rosenfeld, 2013). All these studies show that atmospheric teleconnections have different effects on hydrometeorological variables with reference to hydrological cycle. Accordingly, the research on Southern Oscillation (SO) and North Atlantic Oscillation (NAO) that are well-recognized atmospheric indices have become widespread not only around the world but also in Turkey (Kahya and Karabörk, 2001; Brönnimann, 2007; Turkes and Erlat, 2009).

In this respect, it is indicated that SO and NAO have various impacts on hydrometeorological variables (eg: decreasing of precipitation, temperature rise) in different parts of the world. Rodo et al. (1997) scrutinize the effects of El Niño Southern Oscillation (ENSO) and NAO on the precipitation regime of Southern Europe. They reveal that ENSO and NAO affect the climate characteristics of different regions of Iberian Peninsula. Kadioglu et al. (1999) investigate the linkage between precipitation and El Niño events in Turkey and they find out that the precipitation pattern of southern Turkey is associated with ENSO. Cullen et al (2002) investigate the relationship between NAO and streamflow data in Tigris-Europhates, Jordan-Yarmouk and Ceyhan rivers. They state that NAO could be influential on the streamflow regime for the winter-spring (DJFM) period. Turkes and Erlat (2003) analyze the relationship between NAO and precipitation regime throughout Turkey. They emphasize that the amount of precipitation during the negative phase of NAO is higher than the precipitation amount during positive phase of NAO. They also point out that the most remarkable link between the NAO and Turkey precipitation data are obtained in winter season in comparison with other seasons. Karabork et al. (2005) research the connections between the NAO/SO indices and climate parameters in Turkey. They state that minimum temperature values are associated with ENSO, whereas NAO has influences on either winter precipitation or winter streamflow pattern. They also add that precipitation and streamflow pattern could be associated with the NAO effect according to lag correlation analysis. Karabork and Kahya (2009) investigate the influence of SO and Multivariate ENSO Index (MEI) on temperature, precipitation and streamflow data in Turkey. They find that precipitation and streamflow data have significant correlations with SO and MEI especially in western Turkey. Kucuk et al. (2009) examine whether NAO affects the water levels of lakes in Turkey or not. They ascertain that NAO has a significant relation with the water levels of Lakes Tuz, Sapanca and Uluabat. Chowdhury and Beecham (2010) study upon the rainfall trends in some locations of Australia and they determine that some of the rainfall trends are connected with the SO index. Burt and Howden (2013) analyze the relationship between the NAO and precipitation/streamflow pattern of upland areas in Britain. They indicate that precipitation regime of upland areas has significant positive correlation with the NAO index particularly in autumn, winter and spring seasons. Furthermore, they also state that in case NAO (+) is influential, flow regime tends to be higher, while even drought conditions occur under the influence of NAO (-). Likewise, impacts of Arctic Oscillation (AO) on climate parameters have been also investigated in recent years (Wang et al., 2005; Tremblay et al., 2011; Wang et al., 2013). Thompson and Wallace (1998) ascertain that although NAO and AO indices are similar to each other, AO is influential on larger part of the Northern Hemisphere as compared with NAO. Turkes and Erlat (2008) investigate the influences of AO on the winter temperature throughout Turkey, and they find the negative correlations between AO index and temperature data during the winter season. Givati and Rosenfeld (2013) research the linkage between the AO and precipitation regime of Eastern Mediterranean basin. They determine that when the AO index rises, the winter precipitation decreases in some parts of Eastern Mediterranean basin.

The main objective of this paper is to determine the possible correlation between AO -NAO and temperature, precipitation data of Eastern and Northern Marmara in Turkey. For this purpose, Pearson correlation coefficients are calculated and used to quantify a relationship between atmospheric indices and aforementioned climate variables. Then, results of correlation analysis are assessed via Student t-test at the significance level of $\alpha=0.10$, $\alpha=0.05$ and $\alpha=0.01$. Furthermore, the temperature and precipitation differences which are based on the negative and positive phases of NAO and AO are addressed. Consequently, the effects of NAO and AO on the temperature and precipitation regime are determined.

Method

Study Area

The relationship between AO, NAO as atmospheric indices and temperature, precipitation data as climate variables were investigated both seasonally and annually in Eastern and Northern Marmara. Temperature and precipitation data in this study were obtained from seven stations of the Turkish State Meteorological Service. Location of the stations used in this study is shown in Figure 1. The stations were selected based on the availability of recorded data for approximately 50 years. The date range for each station is indicated in Table 1.

Figure 1. Stations throughout Marmara region.

Table 1

Date Range for Temperature and Precipitation Data

Location of Stations	Date Range	
	Temperature	Precipitation
Edirne	1960-2015	1960-2015
Kırklareli	1963-2015	1963-2015
Kadıköy Rıhtım	1960-2015	1960-2015
Kocaeli	1961-2015	1961-2015
Yalova	1960-2015	1960-2015
Bursa	1960-2015	1960-2015
Bilecik	1960-2015	1960-2015

The statistical data concerning the temperature and precipitation for winter (December, January, February), spring (March, April, May), summer (June, July, August) and autumn (September, October, November) seasons were given in Tables 2 and 3. In addition, NAO data was obtained via North Atlantic Oscillation Index (2018) and AO data was acquired by means of Arctic Oscillation Index (2018).

Table 2

Statistical Data of Mean Temperature for Each Station

Stations	Winter		Spring		Summer		Autumn		Annual	
	Mean Temp. (°C)	Std.Dev. (°C)	Mean Temp (°C)	Std.Dev .(°C)	Mean Temp. (°C)	Std.Dev. (°C)	Mean Temp. (°C)	Std.Dev. (°C)	Mean Temp. (°C)	Std.Dev. (°C)
Edirne	3.9	1.2	13	1.1	23.9	1.1	14.4	1.0	13.8	0.7
Kırklareli	4.0	1.2	12.1	1.1	22.9	1.0	14.0	1.0	13.3	0.7
Kadıköy Rıh.	6.8	1.1	12.3	1.2	23.1	1.1	15.9	1.0	14.6	0.8
Kocaeli	7.1	1.2	13.1	1.1	23.1	0.9	16.1	1.01	14.9	0.7
Yalova	7.3	1.1	12.6	1.1	22.9	1.0	15.9	0.9	14.7	0.7
Bursa	6.3	1.3	13.0	1.1	23.7	1.0	15.4	0.9	14.6	0.7
Bilecik	3.6	1.5	11.5	1.1	21.4	1.0	13.8	1.1	12.6	0.8

Note. Std. Dev.= Standard Deviation.

Table 3

Statistical Data of Precipitation for Each Station

Stations	**Winter**		**Spring**		**Summer**		**Autumn**		**Annual**	
	Mean Prep. (mm)	Std.Dev. (mm)	Mea n Prep. (mm)	Std.Dev. (mm)	Mean Prep. (mm)	Std.Dev. (mm)	Mean Prep. (mm)	Std.Dev. (mm)	Mean Prep. (mm)	Std.Dev. (mm)
Edirne	186.5	82.8	152.1	51.5	100.6	49.6	159.4	69.8	598.5	131.1
Kırklareli	180.7	82	141.1	48.2	94.7	48.5	153.9	65.4	570.4	134.6
Kadıköy Rıh.	257.6	85.8	139.5	50.9	74.4	47.0	193.7	64.6	665.2	125.6
Kocaeli	274.4	75.9	172.7	53.7	133.7	78.0	227.8	81.0	808.6	131.9
Yalova	277.4	95.9	161.5	50.0	88.9	56.7	219.1	84.0	746.9	143.5
Bursa	267.0	87.1	181.8	57.1	68.1	37.8	190.3	71.1	707.3	138.3
Bilecik	146.3	51.9	137.5	45.3	69.6	38.6	104.8	45.5	458.2	86.1

Sezen (2018) implemented five homogeneity tests, namely Standard Normal Homogeneity Test (SNHT), Buishand Range Test, Pettitt Test, Von Neumann Ratio Test and lastly Kruskal-Wallis Test, to investigate the homogeneity of temperature and precipitation data. It was shown that H_0 hypothesis [it assumes that the distribution of variables is identical and also they are independent (Wijngaard, 2003)] was rejected by all homogeneity tests in almost all stations (Edirne, Kırklareli, Kadıköy Rıh., Kocaeli, Yalova and Bilecik) except Bursa for the temperature data. Inhomogeneity in temperature data could be related with different factors such as spatially increasing or decreasing trends, urbanization and displacement of stations (Turkes et al, 2002; Sahin and Cigizoglu, 2010). On the other hand, H_0 hypothesis was accepted by all homogeneity tests in all stations for the precipitation data. The trend analysis was not carried out in this study because it requires a more comprehensive research which exceeds the scope of this study.

Correlation Analysis

Correlation coefficients are calculated so as to reveal the statistical relation between the variables. High correlations could give a clue about the important relationship between the variables (Bayazıt and Oguz, 2005). In this respect, Pearson correlation coefficients between atmospheric indices and climate variables were calculated described as follows:

$$r_{x,y} = \frac{\Sigma\left(x_i - \bar{x}\right)\left(y_i - \bar{y}\right)}{N s_x s_y} \qquad (1)$$

where x_i stands for the annual or seasonal climate variable belongs to i.th year, $\bar{x}$ for the mean of climate variable, y_i for annual or seasonal NAO or AO index pertains to i.th year, $\bar{y}$ for the mean of NAO or AO index, N for the data length, s_x and s_y for the standard deviations of climate variable and NAO or AO index, respectively (Sezen and Partal, 2017) The statistical importance of correlation coefficients was evaluated by using Student t test at the significance level of α=0.10, α=0.05 and α=0.01. The *t* statistics is calculated as follows:

$$t = \frac{r\sqrt{N-2}}{\sqrt{1-r^2}} \qquad (2)$$

where *r* represents the correlation coefficient and *N* denotes the data length. For example, correlation boundary value is $r \geq 0.34$ at α=0.01, $0.26 \leq r < 0.34$ and α=0.05 and $0.22 \leq r < 0.26$ α=0.10 if the data length is N=56 years.

The Phases of Atmospheric Teleconnections

In addition to correlation analysis, temperature and precipitation differences which derive from the negative and positive phases were calculated as seasonal and annual. This approach is significant in terms of observing the effects of positive and negative phases of NAO and AO. As for the physical phenomena of NAO, Turkes and Erlat (2009) stated that colder weather conditions are dominant over the greater part of Turkey under the effect of the positive phase of NAO. This weather pattern arises from the northeasterly circulation which is based on the low geopotential heights over Iceland low region and high geopotential heights over the Azores high region (Turkes and Erlat, 2009). While the southeasterly circulations lead to warmer weather conditions under the effect of negative phase of NAO throughout Turkey. As for the negative phase of AO circulations 500 hPa height anomalies is high over Northern Africa, Middle East and low over North Atlantic-Europe region, it leads to warmer weather conditions due to warm air movement into Turkey (Turkes and Erlat, 2008). On the other hand, positive phase of AO causes the movement of cold air into Balkans and Turkey because of the northerly circulations (Turkes and Erlat, 2008). In this study, if NAO (AO) index has a value that is greater than or equal to 0.5, it is accepted as NAO (+) [AO (+)]. On the other hand, if NAO (AO) index has a value which is less than or equal to -0.5, it is accepted as NAO (-) [AO (-)]. It is also shown in Table 4. Accordingly, the number of NAO (-) case is 15 for winter; 7 for spring; 15 for summer; 14 for the autumn season for the period of 1960-2015. In addition, the number of NAO (+) case is 17 for winter; 14 for spring; 8 for summer; 11 for the autumn season for the period of 1960-2015. As to the number of AO (-) for the period of 1960-2015, it is 23 for winter; 13 for spring; 6 for summer; 12 for the autumn season. Furthermore, the number of AO (+) case is 14 for winter; 15 for spring; 3 for summer; 10 for the autumn season.

Table 4
The Phases of Atmospheric Indices

Atmospheric Indice Range	Depiction of Atmospheric Indice Phase
NAO≥0.5	NAO (+)
NAO≤-0.5	NAO (-)
AO≥0.5	AO (+)
AO≤-0.5	AO (-)

Results

The Results of Correlation Analysis

The correlations between the NAO and annual and seasonal temperature data are mostly negative. This points out that when NAO index tends to rise, the temperature is inclined to decrease. Besides, as it can be seen in Table 5, the most significant correlations between the NAO and temperature data were obtained in summer season in comparison to other seasons. The summer temperature data of all stations had a negative correlation with NAO index at the significance level of α=0.01. In addition, in the winter season, the significant correlation coefficients were observed in eastern Marmara. This was compatible with the findings of Turkes and Erlat (2009). They also found significant correlations in the eastern and southern Marmara region during the winter season. Similarly, in the spring season the most remarkable correlations were acquired in eastern Marmara, whereas in autumn the season correlations coefficients were not significant at α=0.10, α=0.05 or α=0.01. As annual, there were significant negative correlations, calculated only for Kocaeli and Bilecik stations at α=0.10 and α=0.05, respectively. As to the linkage between the NAO index and precipitation totals, it was seen that substantial negative correlations were obtained in the autumn season and as annual, especially. As indicated in Table 5, annual precipitation data of most stations were correlated with the NAO index at α=0.10, α=0.05 or α=0.01.

Table 5
Correlations between NAO and Temperature, Precipitation Data

Stations	Temperature (°C)					Precipitation (mm)				
	Annual	Winter	Spring	Summer	Autumn	Annual	Winter	Spring	Summer	Autumn
Edirne	-0,16	0,06	-0,22*	-0,46***	-0,14	-0,33**	-0,24*	-0,07	0,08	-0,10
Kırklareli	-0,12	0,06	-0,18	-0,39***	-0,12	-0,32**	-0,31**	-0,12	0,09	-0,15
Kadıköy Rıh.	-0,14	-0,01	-0,18	-0,40***	-0,10	-0,22*	-0,15	-0,12	0,03	-0,15
Kocaeli	-0,24*	-0,23*	-0,30**	-0,45***	-0,12	-0,14	-0,14	-0,22*	0,19	-0,35***
Bilecik	-0,26**	-0,24*	-0,28**	-0,49***	-0,18	-0,22*	-0,21	-0,10	0,03	-0,31**
Bursa	-0,18	-0,31**	-0,25*	-0,39***	-0,14	-0,35***	-0,20	-0,11	0,13	-0,29**
Yalova	-0,12	-0,18	-0,24*	-0,34***	-0,21	-0,40***	-0,31**	-0,26**	0,11	-0,33**

Note. *stands for the significance level at α=0.10, **stands for the significance level at α=0.05, *** stands for the significance level at α=0.01.*

Furthermore, the significant correlations were calculated between the autumn precipitation data and NAO index. On the other hand, in other seasons the number of stations which have significant correlation with NAO is low, even in the summer season there were not observed any remarkable linkage between NAO and precipitation data.

As it can be realized from Table 6, in the winter season correlations between the AO and temperature data are high, particularly in the eastern part of Marmara region. Furthermore, considerable correlations were also observed between the autumn temperature and AO at α=0.10 or α=0.05.

Table 6

Correlations between AO and Temperature, Precipitation Data

Stations	Temperature (°C)					Precipitation (mm)				
	Annual	Winter	Spring	Summer	Autumn	Annual	Winter	Spring	Summer	Autumn
Edirne	-0,05	-0,23*	0,14	-0,18	-0,22*	-0,30**	-0,50***	-0,14	-0,07	-0,21
Kırklareli	-0,03	-0,26*	0,12	-0,12	-0,21	-0,32**	-0,52***	-0,22	-0,03	-0,26*
Kadıköy Rıh.	0,01	-0,34***	0,05	-0,10	-0,17	-0,25*	-0,22*	-0,17	-0,01	-0,06
Kocaeli	-0,17	-0,53***	-0,11	-0,15	-0,25*	-0,02	-0,21	-0,16	0,02	-0,03
Bilecik	-0,19	-0,51***	-0,05	-0,11	-0,32**	-0,16	-0,31**	-0,06	-0,09	-0,16
Bursa	-0,17	-0,60***	-0,04	-0,09	-0,23*	-0,19	-0,34***	-0,06	0,12	-0,20
Yalova	-0,05	-0,51***	-0,05	-0,05	-0,30**	-0,22*	-0,37***	-0,24*	0,24*	-0,08

Note. **stands for the significance level at α=0.10, **stands for the significance level at α=0.05, *** stands for the significance level at α=0.01.*

On the other hand, in other seasons the relationship between the AO and temperature data was weak statistically. Similarly, there were not any strong correlations between annual temperature and AO. In the greater part of the region, the precipitation had strong negative correlations with the AO. However, the correlations between AO and precipitation data were not statistically strong in other seasons. As for the connection between AO and annual precipitation, there were substantial correlations in northwestern Marmara.

The Temperature and Precipitation Differences Based on Phases of Atmospheric Indices

The temperature differences which are based on the NAO (-) and NAO (+) are shown in Table 7. According to Table 7, the temperature values under the impact of NAO (-) are higher than the temperature values under the effect of NAO (+), generally. Moreover, the most significant temperature differences were obtained in the summer and spring seasons as compared with the other seasons. Annual temperature differences also were between 0.5 °C and 1 °C as seen in Table 7.

Table 7

Temperature Differences Based on NAO (-) and NAO (+)

Stations	Temperature (°C)														
	Annual			Winter			Spring			Summer			Autumn		
	NAO (-)	NAO (+)	Dif	NAO (-)	NAO (+)	Dif	NAO (-)	NAO (+)	Dif	NAO (-)	NAO (+)	Dif	NAO (-)	NAO (+)	Dif
Edirne	14.3	13.8	0.5	3.9	4.0	-0.1	14	13	1	24.7	23.6	1.1	14.4	14.1	0.3
Kırklareli	13,8	13.3	0.5	3.9	4.1	-0.2	13.1	12.2	0.9	23.5	22.7	0.8	14	13.7	0.3
Kadıköy Rıh.	15.2	14.4	0.8	6.9	6.9	0	13.3	12.4	0.9	23.9	22.9	1	15.9	15.7	0.2
Kocaeli	15.5	14.6	0.9	7.6	7	0.6	14.1	12.9	1.2	23.7	22.7	1	16.1	15.8	0.3
Bilecik	13.3	12.3	1	4.1	3.5	0.6	12.6	11.4	1.2	22.2	20.9	1.3	13.9	13.3	0.6
Bursa	15.1	14.4	0.7	6.9	6.2	0.7	14.0	13.0	1	24.3	23.3	1	15.5	15.1	0.4
Yalova	15.3	14.6	0.7	7.6	7.3	0.3	13.5	12.6	0.9	23.5	22.6	0.9	16	15.6	0.4

When the relationship between the precipitation regime and NAO (-), NAO (+) was taken into consideration, the annual precipitation differences were significant, in particular. Besides, according Table 8 there are also significant precipitation differences in the winter and autumn seasons, while in the spring and summer seasons precipitation differences are less relatively.

Table 8
Precipitation Differences Based on NAO (-) and NAO (+)

Stations	Precipitation (mm)														
	Annual			Winter			Spring			Summer			Autumn		
	NAO (-)	NAO (+)	Dif.	NAO (-)	NAO (+)	Dif.	NAO (-)	NAO (+)	Dif.	NAO (-)	NAO (+)	Dif.	NAO (-)	NAO (+)	Dif.
Edirne	764	508	256	216	178	38	124	131	-7	92	102	-10	172	146	26
Kırklareli	667	445	222	221	167	54	121	112	9	91	99	-8	176	133	43
Kadıköy Rıh.	759	620	139	282	246	36	131	119	12	73	60	13	208	167	41
Kocaeli	958	794	164	282	271	11	187	152	35	123	147	-24	284	203	81
Bilecik	605	478	127	156	134	22	146	126	20	70	75	-5	125	87	38
Bursa	1015	628	387	289	255	34	173	162	11	65	74	-9	225	172	53
Yalova	1081	688	393	311	256	55	160	135	25	84	91	-7	272	192	80

As inferred from Table 9, in comparison with the NAO, the most remarkable temperature differences between AO (-) and AO (+) were calculated in winter especially in eastern Marmara. In similar to the winter season, in the autumn season there are also remarkable differences in eastern Marmara. On the other hand, the temperature differences are not quite high in the spring season and as annual. In the summer season, temperature values of some stations seem to be influenced by AO (-) and AO (+).

Table 9
Temperature Differences based on AO (-) and AO (+)

Stations	Temperature (°C)														
	Annual			Winter			Spring			Summer			Autumn		
	AO (-)	AO (+)	Dif.	AO (-)	AO (+)	Dif.	AO (-)	AO (+)	Dif.	AO (-)	AO (+)	Dif.	AO (-)	AO (+)	Dif.
Edirne	14.0	14.1	-0.1	4.0	3.5	0.5	13.0	13.2	-0.2	24.0	23.0	1.0	14.8	14.1	0.7
Kırklareli	13.4	13.7	-0.3	4.1	3.6	0.5	12.1	12.3	-0.2	23.1	22.4	0.7	14.4	13.8	0.6
Kadıköy Rıh.	14.6	15.0	-0.4	7.0	6.4	0.6	12.3	12.5	-0.2	23.1	22.7	0.4	16.3	15.8	0.5
Kocaeli	15.2	15.1	0.1	7.6	6.4	1.2	13.4	13	0.4	23.3	22.6	0.7	16.5	15.8	0.7
Bilecik	12.8	12.8	0	4.2	2.6	1.6	11.6	11.5	0.1	21.4	20.9	0.5	14.3	13.3	1.0
Bursa	14.8	14.9	-0.1	7.0	5.3	1.7	13.1	13	0.1	23.7	23.4	0.3	15.8	15.2	0.6
Yalova	14.8	15	-0.2	7.7	6.7	1.0	12.6	12.6	0	22.8	22.6	0.2	16.3	15.6	0.7

In Table 10, precipitation differences that are depending upon the AO (-) and AO (+) were demonstrated. In this regard, significant annual precipitation differences were observed in northwestern Marmara. It can be noticed that the annual precipitation under the effect of AO (-) is less than the annual precipitation values under the impact of AO (+) particularly in eastern Marmara. As for the winter season, there were remarkable precipitation differences between the AO (-) and AO (+) in the greater part of the region. The other point was that the quantity of summer precipitation under the influence of AO (-) was less than the amount of the precipitation under the effect of AO (+). In other seasons, the precipitation values which were based on AO (-) and AO (-) were close to each other in the majority of region.

Table 10
Precipitation Differences Based on AO (-) and AO (+)

Stations	Precipitation (mm)														
	Annual			Winter			Spring			Summer			Autumn		
	AO (-)	AO (+)	Dif.	AO (-)	AO (+)	Dif.	AO (-)	AO (+)	Dif.	AO (-)	AO (+)	Dif.	AO (-)	AO (+)	Dif.
Edirne	638	579	59	219	146	73	147	146	1	116	122	-6	176	163	13
Kırklareli	638	503	135	217	139	78	139	121	18	94	114	-20	176	144	32
Kadıköy Rıh.	678	590	88	274	219	55	137	123	14	65	63	2	184	168	16
Kocaeli	758	797	-39	286	258	28	177	152	25	113	151	-38	218	239	-21
Bilecik	476	489	-13	163	136	27	134	123	11	62	88	-26	113	101	12
Bursa	725	761	-36	289	239	50	182	170	12	55	92	-37	221	189	32
Yalova	763	738	25	293	233	60	173	138	35	57	126	-69	230	206	24

Conclusion and Discussion

In this study, it is aimed to determine the relationship between temperature, precipitation and NAO, AO in Eastern and Northern Marmara in Turkey.

In this context, the most significant linkage between the NAO and temperature was observed in the summer season. On the other hand, for the relation between AO and temperature regime, the remarkable results were obtained in the winter and partly autumn seasons. This shows that if the AO index has an increasing trend, the winter temperature values have a decreasing inclination. Especially, the results which were obtained for AO and temperature regime are consistent with the results of Turkes and Erlat (2008). They also found that AO index is negatively correlated with winter temperature. According to Turkes and Erlat (2008), this could be related with the influences by AO (-) and AO (+) which lead to westerly, southwesterly flows and northerly flows over Turkey, respectively.

Correlations between the NAO and summer temperature are significant compared with the AO. Accordingly, further analysis should be carried out whether or not NAO really affects the summer seasonal characteristics. Turkes and Erlat (2009) find the negative correlations between NAO and temperature data in Eastern Marmara during the winter season. In this study, significant negative relationship between NAO and winter temperature were also obtained especially in Eastern Marmara. Accordingly, findings of this study comply with the findings of study of Turkes and Erlat (2009). Correlation analysis and precipitation differences indicate that NAO has a relationship with the annual and autumn precipitation particularly in Eastern Marmara. During the winter season, significant correlations between NAO and precipitation were not observed in majority of Eastern Marmara. This is compatible with the findings of study which was carried out by Karabork et al (2005). They do not also find significant correlations between winter precipitation and NAO particularly in northeastern Marmara. On the other hand, winter precipitation and AO has a strong relationship in Marmara region when correlations and precipitation differences are taken into account. In addition, significant annual precipitation differences were also acquired especially in northwestern Marmara.

This study demonstrates that not only NAO but also AO could have a relationship with the temperature and precipitation regime of Eastern and Northern Marmara. When considered from this point of view, the role of atmospheric teleconnections could be substantial on the hydrological cycle and water resources management. In other words, atmospheric teleconnection can lead to decrease or increase in precipitation, temperature or other hydrometeorological variables. Thus, the relationship between atmospheric teleconnections and hydrometeorological variables should be taken into account for the planning of water structures such as dams or weirs and taking measures against extreme events like flood or drought. Further comprehensive studies need be carried out so as to determine to what extent atmospheric indices could affect the hydrometeorological variables and thereby water cycle in the nature.

Acknowledgment

The results of this study are part of the Master’s thesis of Cenk Sezen, namely “Effects of global atmospherıc indexes on temperature and precipitation data in Turkey”.

References

Bayazıt, M., & Oguz, Y. B. E. (2005).*Mühendislik için istatistik.* İstanbul:Birsen Yayınevi

Brönnimann, S. (2007). Impact of El Niño–Southern oscillation on European climate. *Reviews of Geophysics, 45,* RG3003.

Burt, T., & Howden, N. (2013). North Atlantic oscillation amplifies orographic precipitation and river flow in upland Britain. *Water Resources Research*, *49(6)*, 3504-3515.

Chowdhury, R., & Beecham, S. (2010). Australian rainfall trends and their relation to the Southern oscillation index. *Hydrological Processes*, *24(4)*, 504-514.

Climate Prediction Center, National Weather Service, NOAA, North Atlantic Oscillation (NAO) Index (2018). Retrieved January 2, 2018, from http://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/ norm.nao.monthly.b5001.current.ascii.table

Climate Prediction Center, National Weather Service, NOAA, Arctic Oscillation (AO) Index (2018). Retrieved January 2, 2018, from http://www.cpc.ncep.noaa.gov/products/precip/CWlink/ daily_ao_index/ao.shtml,

Cullen, H. M., Kaplan, A. &Arkin, P. A. 2002. Impact of the North Atlantic Oscillation on Middle Eastern climate and streamflow. *Climatic Change, 55(3)*, 315-338.

Givati, A., & Rosenfeld, D. (2013). The Arctic oscillation, climate change and the effects on precipitation in Israel. *Atmospheric Research*, *132*, 114-124.

Kadioglu, M., Tulunay, Y. & Borhan, Y. (1999). Variability of Turkish precipitation compared to El Nino events. *Geophysical Research Letters*, *26(11)*, 1597-1600.

Kahya, E., & Karabork, M. C. (2001). The analysis of El Nino and La Nina signals in streamflows of Turkey. *International Journal of Climatology*, *21(10)*, 1231-1250.

Karabork, M. C., Kahya, E. & Karaca, M. (2005). The influences of the Southern and North Atlantic oscillations on climatic surface variables in Turkey. *Hydrological Processes*, *19(6)*, 1185-1211.

Karabork, M. C., & Kahya, E. (2009). The links between the categorised Southern Oscillation indicators and climate and hydrologic variables in Turkey. *Hydrological Processes, 23(13)*, 1927-1936.

Kucuk, M., Kahya, E., Cengiz, T. M. & Karaca, M. (2009). North Atlantic oscillation influences on Turkish lake levels. *Hydrological Processes*, *23(6)*, 893-906.

Rodo, X., Baert, E., & Comin F. (1997). Variations in seasonal rainfall in Southern Europe during the present century: relationships with the North Atlantic oscillation and the El Niño-Southern oscillation. *Climate Dynamics*, *13(4)*, 275-284.

Sahin, S., & Cigizoglu, H. K. (2010). Homogeneity analysis of Turkish meteorological data set. *Hydrological Processes*, *24(8),* 981-992.

Sezen, C., & Partal, T. (2017). The relation of North Atlantic oscillation (NAO) and North Sea Caspian pattern (NCP) with climate variables in Mediterranean region of Turkey. *The Eurasia Proceedings of Science, Technology, Engineering & Mathematics, 1*, 366-371.

Sezen, C. (2018). Effects of global atmospherıc indexes on temperature and precipitation data in Turkey. (Master's thesis).

Thompson, D. W., & Wallace, J. M. (1998). The Arctic oscillation signature in the wintertime geopotential height and temperature fields. *Geophysical Research Letters*, *25(9)*, 1297-1300.

Tremblay, L., Larocque, M., Anctil, F. & Rivard, C. (2011). Teleconnections and interannual variability in Canadian groundwater levels. *Journal of Hydrology*, *410(3)*, 178-188.

Turkes, M., Sumer, U. M. & Demir, Ġ. I. (2002). Reevaluation of trends and changes in mean, maximum and minimum temperatures of Turkey for the period 1929–1999. *International Journal of Climatology, 22(8),* 947-977.

Turkes, M., & Erlat, E. (2003). Precipitation changes and variability in Turkey linked to the North Atlantic Oscillation during the period 1930–2000. *International Journal of Climatology*, *23*(14), 1771-1796.

Turkes, M. & Erlat, E. (2008). Influence of the arctic oscillation on the variability of winter mean temperatures in Turkey. *Theoretical and Applied Climatology*, *92(1),* 75-85.

Turkes, M. & Erlat, E. (2009). Winter mean temperature variability in Turkey associated with the North Atlantic oscillation. *Meteorology and Atmospheric Physics*, *105(3-4)*, 211-225.

Wang, D., Wang, C., Yang, X. & Lu, J. (2005). Winter Northern hemisphere surface air temperature variability associated with the Arctic oscillation and North Atlantic oscillation. *Geophysical Research Letters*, *32(16)*.

Wang, S., Zhang, M., Sun, M., Wang, B. & Li, X. (2013). Changes in precipitation extremes in alpine areas of theChinese Tianshanmountains. Central Asia, 1961–2011, *Quaternary International*, (*311)*, 97-107.

Wijngaard, J., Klein, T. A. & Können, G. (2003). Homogeneity of 20th century European daily temperature and precipitation series. *International Journal of Climatology, 23(6),* 679-692.

Extended Turkish Abstract
(Genişletilmiş Türkçe Özet)

Arktik & Kuzey Atlantik Salınımlarının Doğu ve Kuzey Marmara'nın Sıcaklık ve Yağış Verileri Üzerindeki Etkileri

Atmosferik olayların, hidrolojik döngü ve su kaynaklarının planlanması üzerindeki etkilerinin belirlenmesi büyük önem arz etmektedir. Atmosferik salınımlar ile hidrometeorolojik değişkenlerin arasındaki ilişkiyi belirlemeye yönelik gerçekleştirilen çalışmalar da bu alanda yapılanlar arasında yer almaktadır. Buna göre, Kuzey Atlantik Salınımı (NAO) ve Arktik Salınım (AO) gibi küresel atmosferik indislerin yağış, sıcaklık ve akış gibi hidrolojik değişkenler üzerindeki etkilerinin ortaya çıkarılması su kaynaklarının yönetimi açısından önemlidir. Bu amaçla çalışmamızda NAO, AO atmosferik indisleri ile Türkiye'nin kuzeybatısında yer alan Marmara Bölgesi'nin doğusu ve kuzeyinde sıcaklık ve yağış rejimi arasında herhangi bir etkileşim olup olmadığı araştırılmıştır.

Bu çalışmada, Marmara Bölgesi'nde yer alan 7 istasyona (Edirne, Kırklareli, Kadıköy Rıh, Kocaeli, Yalova, Bursa ve Bilecik) ait sıcaklık ve yağış verileri kullanılmıştır. Söz konusu veriler genel itibariyle 1960 -2015 dönemini kapsamaktadır. Atmosferik indisler (NAO, AO) ve hidrometeorolojik parametreler arasındaki ilişki, kış (Aralık, Ocak, Şubat), ilkbahar (Mart, Nisan, Mayıs), yaz (Haziran, Temmuz, Ağustos) ve sonbahar (Eylül, Ekim, Kasım) mevsimleri için ve yıllık olarak araştırılmıştır. Buna göre, ilk olarak AO, NAO indisleri ile sıcaklık ve yağış verileri arasındaki korelasyon katsayıları hesaplanmıştır. Korelasyon katsayılarının istatistiksel olarak değerlendirilmesi ise Student t testine göre gerçekleştirilmiştir. Daha sonra, AO ve NAO indislerinin negatif [AO (-), NAO (-)] ve pozitif [AO (+) ve NAO (+)] fazları nedeniyle oluşan sıcaklık ve yağış farkları hesaplanmıştır.

NAO ile sıcaklık verisi arasında genel olarak negatif korelasyonlar elde edilmiştir. Bu durum, NAO indeksinin değerinin düşmesi ile birlikte sıcaklık değerinin arttığına işaret etmektedir. Bununla birlikte, NAO ile sıcaklık verisi arasında en önemli korelasyonlar özellikle yaz mevsiminde elde edilmiştir. Kış ve ilkbahar mevsimlerinde ise bölgenin doğusunda önemli negatif korelasyonlar tespit edilmiştir. NAO ile yağış verisi arasında ise birçok istasyonda yıllık olarak önemli korelasyonlar görülmüştür. Bunun dışında, özellikle sonbahar mevsiminde bölgenin doğusunda da önemli negatif korelasyonlar görülmüştür. AO ile kış sıcaklık verisi arasında ise bilhassa Marmara Bölgesi'nin doğusunda yüksek negatif korelasyonlar gözlenmiştir. Ayrıca, sonbahar mevsiminde de AO ve sıcaklık verisi arasında istatistiksel olarak önemli bir ilişki tespit edilirken, diğer mevsimlerde ise AO ile sıcaklık arasındaki ilişkinin daha az olduğu görülmüştür. AO ile yağış arasında da kış mevsiminde ve kısmen yıllık olarak önemli bir ilişki olduğu elde edilmiştir.

Korelasyon analizinin tamamlanmasının ardından, yıllık ve mevsimsel sıcaklık değerlerinin, NAO ve AO indekslerinin negatif ve pozitif fazlarından etkilenip etkilenmediği araştırılmıştır. NAO (-), AO (-), NAO (+), AO (+) etkisi altında ortalama sıcaklık ve toplam yağış değerleri hesaplanmıştır. Buna bağlı olarak, mevsimsel ve yıllık sıcaklık, yağış farkları elde edilmiştir. İlk olarak NAO indeksinin negatif ve pozitif fazlarının etkileri analiz edildiğinde, genel itibariyle NAO (-) etkisi altındaki sıcaklık değerlerinin, NAO (+) etkisi altındaki sıcaklık değerlerinden daha fazla olduğu görülmüştür. Bununla birlikte, sıcaklık farklarının bilhassa ilkbahar (0.9-1.2 °C) ve yaz (0.8-1.3 °C) mevsimlerinde diğer mevsimlere nazaran daha fazla olduğu tespit edilmiştir. NAO indeksinin negatif ve pozitif fazları ile yağış rejimi arasındaki ilişki irdelendiğinde ise, yaz mevsimi haricinde diğer mevsimlerde ve yıllık olarak NAO (-) etkisi altındaki yağış miktarının, NAO (+) etkisi altındaki yağış miktarından genellikle daha fazla olduğu görülmüştür. Buna göre, özellikle sonbahar ve kış mevsimlerinde diğer mevsimlere oranla yağış farklarının daha fazla olduğu tespit edilmiştir. Ayrıca yıllık olarak da önemli yağış farkları hesaplanmıştır. AO (-) ve AO (+) etkisi nedeniyle oluşan sıcaklık farkları özellikle kış mevsiminde (0.5-1.7 °C) daha fazla olup, sonbahar mevsiminde (0.5-1 °C) ve yaz mevsiminde (0.2-1 °C) de sıcaklık farkları elde edilmiştir. İlkbahar mevsiminde ve yıllık olarak ise önemli sıcaklık farkları gözlenmemiştir. AO indeksinin negatif ve pozitif fazı etkisiyle oluşan yağış farkları incelendiğinde ise, AO (-) etkisi altında yağış miktarının kış, ilkbahar ve sonbahar mevsimlerinde AO (+) etkisi altındaki yağış değerlerinden daha fazla olduğu görülmüştür. NAO indeksine benzer şekilde, yaz mevsiminde AO (+) etkisi altında yağış miktarının AO (-) etkisi altındaki yağış miktarından fazla olduğu tespit edilirken, aynı şekilde yıllık olarak özellikle Marmara Bölgesi'nin doğusunda AO (+) etkisi altındaki yağış miktarının, AO (-) etkisi altındaki yağış miktarından daha fazla olduğu görülmüştür.

Bu çalışmada, NAO ve AO indeksleri ile Türkiye'nin Marmara Bölgesi'nin doğusunda ve kuzeyinde sıcaklık ve yağış verileri arasında mevsimsel ve yıllık olarak bir ilişki olup olmadığı gösterilmeye çalışılmıştır. Buna göre, sıcaklık verisinin NAO indeksi ile etkileşiminin özellikle yaz mevsiminde, AO indeksi ile ise kış mevsiminde kuvvetli olduğu ifade edilebilir. Bununla birlikte, sıcaklık verisi ile atmosferik indisler arasında gerçekleştirilen korelasyon analizi ve sıcaklık fark analizi sonuçlarının genel olarak birbirleriyle uyumlu olduğu söylenebilir. Yağış verisinin NAO indeksi ile ilişkisinin kış, sonbahar mevsimlerinde ve yıllık olarak, AO indeksi ile ilişkisinin ise bilhassa kış mevsiminde ve yıllık olarak güçlü olduğu gözlenmiştir. Fakat yağış verisi ile atmosferik indisler arasında gerçekleştirilen analizler göz önüne alındığında, aralarındaki ilişkinin sıcaklık verisine göre daha karmaşık olduğu ifade edilebilir. Elde edilen sonuçlar, atmosferik indisler ile hidrometeorolojik değişkenler arasında önemli bir ilişki olabileceğini göstermekte, bu durumun hidrolojik döngü, su kaynakları planlaması ve yönetimi açısından önem arz ettiğini ortaya koymaktadır. Daha sonraki çalışmalarda atmosferik salınımlar ile hidrometeorolojik değişkenler arasında herhangi bir ilişki olup olmadığını belirlemek amacıyla farklı analiz yöntemleri araştırılacaktır.

Kiss, K. T., Klee, R., Ector, L. & Ács, É. (2012). Centric diatoms of large rivers and tributaries in Hungary. Morphology and biogeographic distribution. *Acta Bot Croat* 71: 311 - 363.

Krammer, K. (2002). *Diatoms of Europe, Diatoms of the European Inland waters and comparable habitats*. Cymbella. In: H. Lange-Bertalot (ed.).A.R.G. Gantner Verlag K.G., 584.

Krammer, K. (1997). Die cymbelloiden Diatomeen. Eine Monographie der weltweit bekannten Taxa. Teil 1. Allgemeines und *Encyonema* part. Bibliotheca Diatomologica Vol. 36. 382 pp.

Krammer, K., & Lange-Bertalot, H. (1986). Bacillariophyceae. *1*. Teil: Naviculaceae In: Ettl, H., J. Gerloff, H. Heynig and D. Mollenhauer (eds.). *Süßwasserflora von Mitteleuropa*, 2 (1), 1 – 876.

Krammer, K. & Lange-Bertalot, H. (1991). Bacillariophyceae, 2. Teil: Bacillariaceae, Epithemiaceae, Surirellaceae. *Süßwasserfora von Mitteleuropa* 2 (2), 1 – 596.

Krammer, K., & Lange-Bertalot, H. (1991). Bacillariophyceae 3.Teil: Centrales, Fragilariaceae, Eunotiaceae. *Süßwasserflora von Mitteleuropa,* 2(3), 1 – 576.

Lange-Bertalot, H., Hofmann, G., Werum, M., & Cantonati, M. (2017). Freshwater Benthic Diatoms of Central Europe: Over 800 Common Species Used in Ecological Assessment.. *Koeltz Botanical Books, 942.*

Levkov Z. (2009). *Amphora* sensu lato. In: H. Lange-Bertalot (ed.), *Diatoms of Europe* 5: 1 – 916.

Patrıck R. & Reımer C. W. (1966). The Diatoms of the United States, exclusive of Alaska and Hawaii. 1. Fragilariaceae, Eunotiaceae, Achnanthaceae, Naviculaceae. *Acad. Nat. Sci. Philadelphia Monogr.* 13 (1): 1 – 688.

Patrıck R. & Reımer C. W. (1975). The Diatoms of the United States, States, Exclusive of Alaska and Hawaii. 2 (1). Entomoneidaceae, Cymbellaceae, Gomphonemaceae, Epithemaceae. *Acad. Nat. Sci. Philadelphia Monogr*. 13 (2): 1 – 213.

Solak, C.N., Wojtal, A.Z. (2012). The diatoms in springs and streams of the Türkmen Mountain (Sakarya River Basin), commonly reported from Turkish inland waters. *Polish Botanical Journal 57(2)*, 375-425.

Solak C.N., Kulikovskiy M.S., Kaleli, A., & Gönülol, A. (2016). Rare and new records of diatoms in Turkey from Kütahya flowing waters, *Oceanological and Hydrobiological Studies* 45(4): 564-587.

Solak, C.N., Çetin, T., & Kaleli, A. (2018a). Distribution of benthic diatom (phytobenthos) composition in Küçük Menderes river basin. *Turkish Journal of Water Science and Management*, *1(2)*, 2-35.

Solak, C.N., Kulikovskiy, M., Kiss, T.K., Kaleli, A., Kociolek, J.P., & Ács, É. (2018b). The distribution of centric diatoms in different river catchments in the Anatolian Peninsula, Turkey. *Turkish Journal of Botany 42 (1)*, 100-122.

Swift, E. (1967). Cleaning diatom frustules with ultraviolet radiation and peroxide. *Phycologia 6*: 161-163.

Tarım ve Orman Bakanlığı, Su Yönetimi Genel Müdürlüğü. (2018). *Gediz Nehir Havza Yönetim Planı Hazırlanması Projesi Nihai Raporu*. Ankara.

Wojtal, A. Z. (2009). The diatoms of Kobylanka stream near Kraków (Wyżyna Krakowsko-Częstochowska, S Poland). *Polish Botanical Journal* 54: 129 - 330.

Wojtal, A. Z. & Kwandrans, J. (2006). Diatoms of the Wyżyna Krakowsko Częstochowska Upland (S Poland) – Coscinodiscophyceae (Thalassiosirophycidae). *Polish Botanical Journal* 51: 177 - 207.

Yurterin, N., & Öztürk, M. (2001). Gürle Deresi ve yakın çevresi fitoplanktonları üzerine bir çalışma. *IV. Ulusal Ekoloji ve Çevre Kongresi Kitabı.* Bodrum.

Case Study

Investigating the Suitability of Drainage Channels Water for Irrigation in Bafra Plain

Bafra Ovasındaki Drenaj Kanallarındaki Suyun Sulamaya Uygunluğunun İncelenmesi

Bilal CEMEK, Erdem KÜÇÜKTOPCU, Kadir GÜLER
University of Ondokuz Mayıs, Department of Agricultural Structures and Irrigation, Samsun
bcemek@omu.edu.tr, erdem.kucuktopcu@omu.edu.tr, kguler@hotmail.com
Received Date: 20.07.2018, Accepted Date: 24.12.2018

Abstract

In this study, drainage effluent water quality parameters of Muamlı and Bedeş drainage canals, to which there are not any intrusion from other places, were monitored all year-long. Water samples were taken from 9 different locations of Muamlı and Bedeş canals in July and September. Soil samples were taken from paddy fields irrigated with the effluents of these drainage canals after harvest. Water and soil samples were analyzed for different quality parameters. Present findings revealed that water samples did not have any problems with regard to residual sodium carbonate (RSC), sodium, sulphate and chlorine and can be used safely. For salinity of water samples taken from Muamlı drainage canal varied between 2.79-2.97 dS/m and the salinity values of Bedeş drainage canal varied between 1.01-4.95 dS/m. It was concluded that drainage canal effluents created serious salinity problems and ultimately resulted in significant yield losses. To reduce the effect of salinity problem caused by irrigation with drainage waters, it was recommended to apply extra water to leach salts below the rootzone.
Keywords: *Drainage channels, Bafra Plain, paddy, salinity*

Öz

Bu çalışmada, Bafra ovasında herhangi bir şekilde dışarıdan drenaj kanallarına su karışımı söz konusu olmayan Muamlı ve Bedeş drenaj kanallarındaki suların kimyasal değerlerinin yıl içerisindeki değişimleri incelenmiştir. Muamlı ve Bedeş kanallarının 9 farklı noktasından Temmuz ve Eylül aylarında su örnekleri alınmıştır. Bu kanallarla sulama yapılan çeltik alanlarından da hasat sonunda toprak örnekleri alınmıştır. Alınan su ve toprak örnekleri farklı kalite parametreleri kullanılarak analiz edilmiştir. Analiz sonuçlarına göre suların kalıcı sodyum karbonat (RSC), sodyum, sülfat ve klor açısından herhangi bir sorun teşkil etmemekle birlikte, yüksek tuz içeriklerinin bitki gelişimine zarar verecek seviyede olduğu belirlenmiştir. Muamlı drenaj kanalındaki suyun tuzluluk değerleri 2.79-2.97 dS/m arasında, Bedeş drenaj kanalındaki suyun ise tuzluluk değerlerinin 1.01-4.95 dS/m aralığında olduğu belirlenmiştir. Sonuç olarak bu suların tuzluluk açısından sorun teşkil ettiği ve bu kanallarla sulanan çeltik alanlarında önemli verim kaybı oluşturduğu ve topraktaki tuz içeriğini de daha fazla artırabileceği tespit edilmiştir. Drenaj sularının neden olduğu tuzluluk probleminin etkisini azaltmak için, kök bölgesi altında bulunan tuzların ekstra sulama uygulayarak yıkanması tavsiye edilmiştir.
Anahtar kelimeler: *Drenaj kanalları, Bafra Ovası, çeltik, tuzluluk*

Introduction

Water is one of the main input providing higher yields in agricultural practices. In order to efficient agronomic practices, it should be used at optimum quantities. In this context, irrigation facilities should be properly operated, general irrigation programs should definitely be created and water management should be well-performed for better control of water in agricultural practices. In addition to this, in areas where irrigation water is scarce, reusing of drainage effluents is an important part of water management.

Agricultural drainage is an indispensable component of irrigated agriculture, which is an engineering practice to reduce water table levels beneath the harmful levels for plant growth and development and to prevent salt accumulation within root zone. In humid regions, drainage practices provide a proper soil-water-air balance within the root zone. Such practices in arid and semi-arid regions with intensive irrigation practices prevent accumulation of salt within the root zone, provide salt balance and prevent agricultural lands from aridity (Çiftçi et al., 1995).

Regardless of the climate zone, irrigation and drainage practices are the primary factors providing continuity in agricultural practices. Drainage effluents is normally of lower quality compared with the original irrigation water. Chemical composition of drainage effluents is influenced by several factors such as drainage system, agricultural practices, soil structure, soil infiltration rates, initial soil salinity, irrigation methods and climate conditions. These factors also affect irrigation water quality and designate potentiality of reuse of drainage effluents in irrigation practices (Erözel & Çakmak, 1993). State Hydraulic Works (DSI) identified improper irrigation practices as the primary reason of drainage and salinity problems over agricultural lands of Harran plain. Smoot topography of the project site, outlet problems, heavy soil textures and lack of land leveling practices aggravated already existing problems (Özer & Demirel, 2003).

Leaching is one of a significant practice used in soil reclamation. The amount of leaching water to be used for a full reclamation is primarily depend on concentration and type of salt in soil and groundwater, quality of leaching water, soil permeability, drainage system efficiency and depth of soil profile to be leached (Singh & Dahiya, 1979).

Bahçeci et al. (2007) carried out a study to investigate the potential environmental impacts of drainage effluents and salt leaching through sub-surface drainage system in Konya plain and indicated that current sub-surface drainage system was able to provide sustainability of agricultural practices. Cemek et al. (2006) in a study carried out in Bafra plain reported excessive water use because of recent paddy culture in the plain and indicated that such excessive uses may result in salinity problems over the agricultural lands. In this study, drainage effluent water quality parameters were monitored year-long and the effects of drainage canals on salt leaching from plain soils were assessed.

Material and Method

Geographical Location and Climate Characteristics

The research site is located in Middle Black Sea region between 41° 10’-41° 45’ North latitudes and 35° 30’ - 36° 15’ East longitudes. Mild climate conditions of Black Sea Region are dominant in the research site. Meteorological data were supplied from Bafra Meteorological Station. Long-term annual average precipitation of the research site is 722.5 mm. July is the driest and December is the wettest month. July is the hottest and January the coldest month of the year (Table 1).

Table 1
Long-Term (1993-2013) Averages for Climate Parameters and 2013 Precipitations of the Research Site

Months	*Temperature °C*	*Relative Humidity %*	*Precipitation mm*	*2013 Precipitation mm*
January	5.7	70.0	91.2	62.8
February	6.9	71.0	48.9	14.0
March	7.8	77.0	54.9	82.8
April	11.2	77.0	55.6	43.0
May	15.6	78.0	38.1	28.8
June	20.2	72.0	33.4	43.6
July	22.7	70.0	26.3	48.0
August	22.3	73.0	52.5	66.8
September	19.0	77.0	71.8	37.2
October	15.1	77.0	79.6	8.4
November	12.0	70.0	79.9	21.8
December	8.4	69.0	100.4	38.0
Annual	13.9	73.0	722.5	435.2

Soil Characteristics

Soils of the research site are composed of young alluvial deposits, brought by Kızılırmak. Research Site which is located close to Alaçam border of Bafra along Samsun-Sinop motorway and covers the drainage canals of Muamlı and Bedeş (Figure 1).

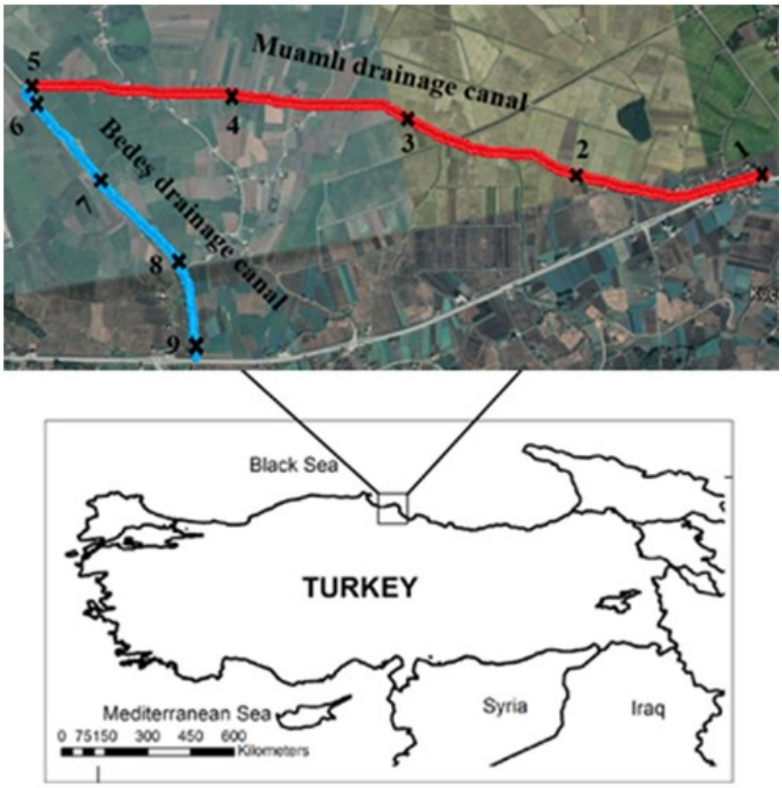

Figure 1. General view of Muamlı and Bedeş drainage canals.

Water and Soil Sampling from Drainage Canals

Physical, chemical and bacteriological characteristics of irrigation water should not include any risks on soil quality and plant development (Ayers & Westcot, 1985; Fipps, 1994). Therefore, irrigation water (surface or groundwater) quality should definitely be analyzed before irrigation. Irrigation water quality generally assessed with physico-chemical quality parameters such as total salt concentration, sodium absorption ratio, chlorine content, toxic ions, water temperature and pH. Analyses are performed in accordance with national and international standards (EPA, 1994; Anonymous, 2004). In this study, irrigation water samples were analyzed in accordance with the principles specified in Tüzüner (1990).

Water samples were taken twice in July and September from the locations with 1 km distance from each other as shown in Figure 1. Soil samples were taken from 9 different locations in paddy fields irrigated with pumping from specified drainage canals after the harvest. Water and soil samples were taken by qualified technical staff. Specifications provided in Ayyıldız (1990) were used in water samplings. Water samples were taken into 2-liter glass bottles with a rubber plugs and samples were numbered from 1 to 9 based on sampling locations over the canals. Water samples were analyzed in accordance with Standard Methals 3000 method. Samples were subjected to EC, pH, Na, Ca, K, Mg, CO_3, HCO_3 and Cl analyses. Water samples were also subjected to hardness, nitrate, nitrite, sodium adsorption ratio (SAR), sulphate, phosphate, and ammonium and pesticide analyses. Results were expressed as ppm. The equation developed by US Salinity Lab. was used to calculate SAR values (Kanber et al., 1999). In this equation, Na, Ca and Mg, K, carbonate, bicarbonate, chloride and sulphate values were expressed both in ppm and me/l. With these values, total anion and cation values were calculated. Soil samples were extracted and resultant extract was subjected to Na, Ca and Mg, K, carbonate, bicarbonate, chloride, and sulphate analyses and then total anions and cations were calculated. Electrical conductivity, pH, SAR, hardness analyses were also performed in laboratory.

Results and Discussion

In this study, chemical characteristics of effluent waters of Muamlı and Bedeş drainage canals of Bafra plain, to which there is no intrusion of water from anywhere around, and soil of paddy fields which were irrigated with these effluent waters were investigated.

Chemical Characteristics of Irrigation Waters of Muamlı and Bedeş Drainage Canals

To assess the irrigation water quality of Muamlı and Bedeş drainage canals, EC, SAR, RSC and other ions (Ca, Mg, K, Na, and Cl) and heavy metals were analyzed. Descriptive statistics for the samples taken from Muamlı drainage canal are provided in Table 2 and 3. Sodium, carbonate, SAR and pH values increased and the other parameters decreased in September. Coefficient of variation (CV) was used to assess the changes in irrigation water quality parameters. Wilding (1985) classified CV values as follows: low variability, ≤ 15%; moderate variability, 16–35%; and high variability, ≥36%. According to this assessment, in Muamlı drainage canal, the greatest variability was observed in potassium in July and in sulphate and carbonate in September. Descriptive statistics for the samples taken from Bedeş drainage canal are provided in Table 4 and 5. Only the carbonate values increased and the other parameters decreased in September. The greatest variability was observed in sulphate, carbonate, sodium and SAR in July and in sulphate, sodium, chloride and SAR in September.

Table 2

Descriptive Statistics for Water Quality Parameters of Muamlı Drainage Canal in July

Parameter	*Unit*	*Min*	*Max*	*Mean*	*SE*	*SD*	*Kurt*	*Skew*	*CV(%)*
Sodium(Na)	meq/l	209.68	222.53	214.66	2.39	5.34	-0.35	0.72	2.49
Potassium(K)	meq/l	6.30	18.50	11.90	2.49	5.56	-2.59	0.06	46.72
Calcium (Ca)	meq/l	118.53	130.47	124.42	2.15	4.81	-1.54	0.13	3.87
Magnesium(Mg)	meq/l	73.67	85.04	80.34	2.26	5.05	-2.35	-0.66	6.29
Carbonate(CO_3)	meq/l	5.39	9.70	7.33	0.86	1.93	-2.32	0.06	26.33
Bicarbonate(HCO_3)	meq/l	278.22	309.95	293.11	5.49	12.28	-0.64	0.35	4.19
Chloride(Cl)	meq/l	454.0.7	518.94	481.46	10.85	24.26	1.26	0.88	5.04
Sulphate (SO_4)	meq/l	139.27	241.22	189.50	20.92	46.79	-2.85	0.26	24.69
EC	dS/m	1.79	1.90	1.83	0.02	0.05	0.51	0.90	2.73
pH	---	7.44	7.59	7.52	0.03	0.06	-0.48	-0.52	0.80
Sodium percentage	%	40.07	42.88	41.78	0.47	1.05	2.49	-1.30	2.51
SAR	---	3.64	3.81	3.73	0.03	0.07	-0.39	-0.27	1.88
Water Hardness	°dH	33.54	37.53	35.90	0.74	1.66	-1.23	-0.76	4.62

Note. *Min* = minimum, *Max* = maximum, *SE* = standard error of mean, *SD* = standard deviation, *Kurt* = kurtosis, *Skew* = skewness, *CV* = coefficient of variation

Table 3

Descriptive Statistics for Water Quality Parameters of Muamlı Drainage Canal in September

Parameter	*Unit*	*Min*	*Max*	*Mean*	*SE*	*SD*	*Kurt*	*Skew*	*CV(%)*
Sodium(Na)	meq/l	126.34	284.66	229.09	28.76	64.31	1.44	-1.19	28.07
Potassium(K)	meq/l	6.10	8.10	6.84	0.39	0.87	-1.29	0.89	12.72
Calcium (Ca)	meq/l	78.30	110.64	96.43	7.11	15.90	-3.20	-0.55	16.49
Magnesium(Mg)	meq/l	46.57	73.73	55.93	4.64	10.38	3.64	1.76	18.56
Carbonate(CO_3)	meq/l	7.54	60.34	40.08	8.90	19.90	2.37	-1.32	49.65
Bicarbonate(HCO_3)	meq/l	250.15	369.74	293.35	20.68	46.23	2.36	1.47	15.76
Chloride(Cl)	meq/l	234.24	486.51	339.47	45.39	101.50	-0.45	0.59	29.90
Sulphate (SO_4)	meq/l	60.24	311.77	181.54	41.64	93.12	0.45	0.24	51.29
EC	dS/m	1.28	1.90	1.69	0.12	0.28	-0.77	-1.01	16.57
pH	---	8.11	8.35	8.23	0.04	0.09	1.85	-0.23	1.09
Sodium percentage	%	34.96	55.82	50.16	3.96	8.87	3.26	-1.84	17.68
SAR	---	2.45	5.62	4.61	0.58	1.30	2.37	-1.54	28.20
Water Hardness	°dH	21.69	28.18	26.38	1.19	2.67	4.32	-2.05	10.12

Note. *Min* = minimum, *Max* = maximum, *SE* = standard error of mean, *SD* = standard deviation, *Kurt* = kurtosis, *Skew* = skewness, *CV* = coefficient of variation.

Table 4

Descriptive Statistics for Water Quality Parameters of Bedeş Drainage Canal in July

Parameter	*Unit*	*Min*	*Max*	*Mean*	*SE*	*SD*	*Kurt*	*Skew*	*CV(%)*
Sodium(Na)	meq/l	53.75	484.19	366.29	104.30	208.59	3.96	-1.99	56.95
Potassium(K)	meq/l	5.10	11.90	10.08	1.66	3.32	3.97	-1.99	32.94
Calcium (Ca)	meq/l	90.82	176.52	135.16	17.55	35.10	1.41	-0.25	25.97
Magnesium(Mg)	meq/l	39.55	117.10	83.24	16.12	32.23	1.82	-0.88	38.72
Carbonate(CO_3)	meq/l	0.00	10.77	6.47	2.45	4.90	-0.74	-0.90	75.73
Bicarbonate(HCO_3)	meq/l	297.74	339.23	319.71	9.85	19.70	-4.10	-0.18	6.16
Chloride(Cl)	meq/l	216.23	900.94	723.46	169.18	338.36	3.97	-1.99	46.77
Sulphate (SO_4)	meq/l	-48.89	338.71	197.57	91.45	182.90	-0.28	-1.05	92.57
EC	dS/m	0.65	3.17	2.53	0.63	1.29	4.00	-2.00	50.99
pH	---	7.55	7.74	7.65	0.04	0.09	-2.99	0.00	1.18
Sodium percentage	%	23.00	58.66	48.29	8.46	16.92	3.86	-1.96	35.04
SAR	---	1.20	7.67	5.88	1.56	3.13	3.92	-1.98	53.23
Water Hardness	°dH	21.80	45.69	38.07	5.63	11.26	2.38	-1.60	29.58

Note. *Min* = minimum, *Max* = maximum, *SE* = standard error of mean, *SD* = standard deviation, *Kurt* = kurtosis, *Skew* = skewness, *CV* = coefficient of variation.

Table 5

Descriptive Statistics for Water Quality Parameters of Bedeş Drainage Canal In September

Parameter	*Unit*	*Min*	*Max*	*Mean*	*SE*	*SD*	*Kurt*	*Skew*	*CV(%)*
Sodium(Na)	meq/l	52.67	466.17	170.92	99.14	198.29	3.69	1.92	116.01
Potassium(K)	meq/l	5.40	7.90	6.55	0.53	1.07	-0.30	0.48	16.34
Calcium (Ca)	meq/l	45.96	104.68	84.26	13.27	26.55	2.43	-1.58	31.51
Magnesium(Mg)	meq/l	18.89	52.52	29.82	7.88	15.76	2.26	1.58	52.85
Carbonate(CO_3)	meq/l	21.55	35.55	29.09	2.95	5.90	0.25	-0.49	20.28
Bicarbonate(HCO_3)	meq/l	215.99	286.76	251.99	16.05	32.09	-3.09	-0.07	12.73
Chloride(Cl)	meq/l	57.66	544.17	209.22	113.73	227.45	3.13	1.77	108.71
Sulphate (SO_4)	meq/l	27.87	419.91	156.00	89.93	179.87	3.10	1.75	115.30
EC	dS/m	0.75	2.49	1.22	0.43	0.85	3.98	1.99	69.67
pH	---	8.22	8.31	8.26	0.02	0.04	1.59	0.40	0.48
Sodium percentage	%	25.51	69.61	42.73	10.47	20.93	-1.75	0.76	48.98
SAR	---	1.27	9.73	3.86	2.00	4.00	3.11	1.77	103.63
Water Hardness	°dH	12.99	24.31	18.66	2.31	4.63	1.40	-0.02	24.81

Note. *Min* = minimum, *Max* = maximum, *SE* = standard error of mean, *SD* = standard deviation, *Kurt* = kurtosis, *Skew* = skewness, *CV* = coefficient of variation.

There were not significant differences in EC values of Muamlı drainage canal in July and September. EC values of Muamlı drainage canal varied between 1.79-1.90 dS/m in July and between 1.28-1.90 dS/m in September. There were significant differences in EC values of Bedeş drainage canal in July and September. EC values of Bedeş drainage canal varied between 0.75-2.49 dS/m in July and between 0.65-3.17 dS/m in September. Sensitivity of all plants to salinity may differ and, less yield loss occurs in some plants at much greater salinity than others (Abrol et al., 1988). For example, if Muamlı drainage canal is used for irrigation purposes in paddy fields, there will nearly a full yield. If Bedeş drainage canal is used, it will cause 15-20% losses in yields. Instead of paddy, if wheat is grown by using these drainage canals, there will not almost a yield loss. With regard to SAR values, waters of both drainage canals were classified as “low sodium waters” and hazardous Na accumulation was not identified. Since RSC values of both drainage canals were lower than zero, it was thought that such levels would not have significant effects on plant growth and development. Sodium levels of irrigation waters should not exceed 50-60 ppm. Only the water sample taken from 6th sampling location of Bedeş canal in September had sodium level over 60 ppm. Except for this sample, the other waters did not exert any problems with regard to sodium. The pH values of drainage canals were between 7.50-8.30 and did not pose a significant effect on plants.

Wilcox’s graphic (USSL diagram, 1954) was used in classifying Maumlı and Bedeş drainage channels water for irrigation (Figure 2 and 3). With regard to irrigation water quality class, the water samples taken from the 1st, 2nd, and 3rd locations in July and September were classified as “C3S1” (high saline and low sodium waters). The waters taken from 4th and 5th locations in July were placed in “C3S1” and “C3S2” (high saline and medium sodium waters) class in September. The samples taken from the 6th location in July was classified as “C4S2” (very high saline and medium sodium waters), while in September the water was placed in “C4S3” class indicating very high salinity and high sodicity risk. The waters taken from 7th and 8thlocations in July were classified as “C4S2” and as “C3S1” class in September. The water samples taken from the 9thlocation were classified as “C2S1” (medium saline – low sodium waters) in July and as “C3S1” class in September. In this case, high saline waters should not be used as irrigation water and water should be supplied from the other canals. In this way, possible yield losses could be prevented.

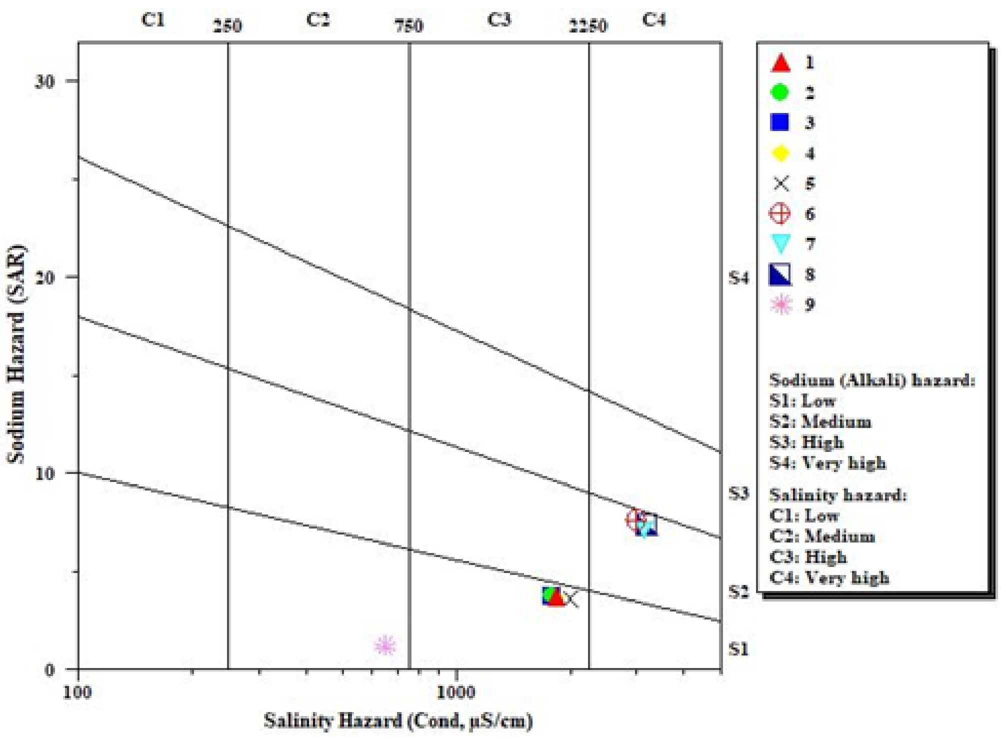

Figure 2. Classification of irrigation water quality in different locations of Muamlı and Bedeş canals in July.

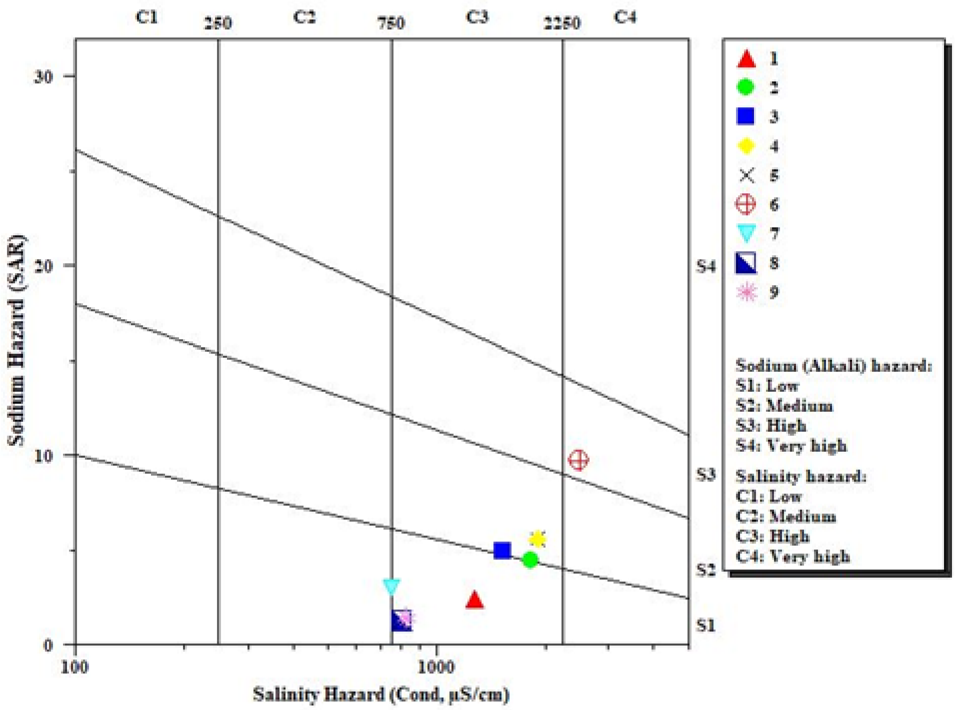

Figure 3. Classification of irrigation water quality in different locations of Muamlı and Bedeş canals in September.

The variations in the before and after irrigation season (July to September) on both canals in EC, pH, Na%, SAR and hardness values based on sampling locations are presented in Figure 4. In the 1st sampling location, all parameters, except for pH, increased. In the 2nd sampling location, maximum 20% decrease was observed in all parameters, except for hardness. In the 3rd sampling location, EC and hardness increased by 30-40% and the other parameters decreased. In the 4th sampling location, increase was observed only in hardness and decreases were observed in all the other parameters. In the 5th sampling location, about 30% increase was observed in hardness and a slight increase was observed in EC values and large decreases were observed in the other parameters. In the 6th sampling location, a distinctive increase was observed in hardness and EC values and sharp decreases were observed in the other parameters. Especially in the 7th and 8th sampling locations, a sharp increase was observed in all parameters, except for pH with slight decreases. In the 9th sampling location, about 10% increase was observed in hardness and decreases were observed in all the other parameters. All of these changes on Muamlı (sample 1-5) and Bedeş (sample 6-9) canals were probably due to seasonal rainfall and cultural applications such as, fertilization.

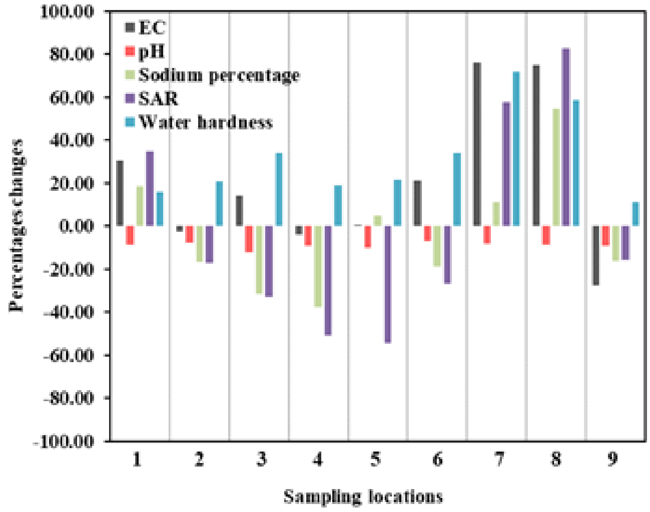

Figure 4. Percentage changes in the various water quality parameters.

Assessment of Soil Samples

Variations in soil salinity values of the samples taken from the lands irrigated with pumping from drainage canals are presented in Figure 5.

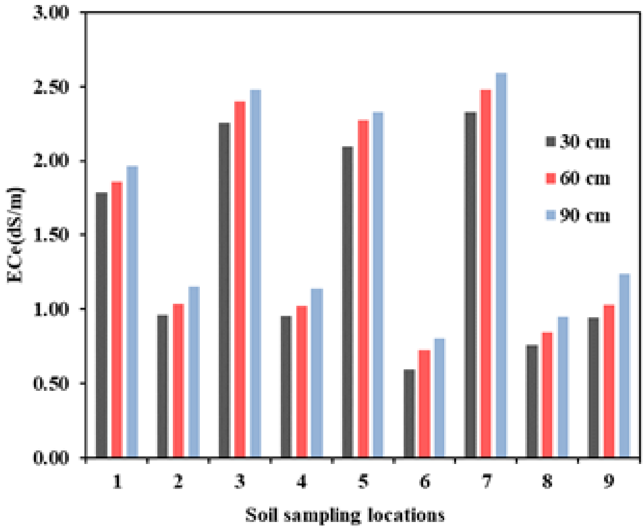

Figure 5. Variations in soil salinity.

According to USSL (1954), a saline soil has an EC_e of the saturated paste extract of more than 4 dS/m. Soils did not have an important problem with regard to salinity. However, especially in 3rd, 5th and 7th sampling locations, soil salinity levels at 30, 60 and 90 cm soil profile reached to 2.50 dS/m. Such a value indicated slightly salinity levels for these samples. In the other location, salinity at all depths was around 1.00-2.00 dS/m.

A soil SAR value below 2.00 is most desirable. A soil SAR level above 13.00 is considered very high, and the soil is classified as sodic (McKenzie & Woods, 2010). Soil SAR values at 30, 60 and 90 cm soil profile varied between 0.20-3.00 (Figure 6).

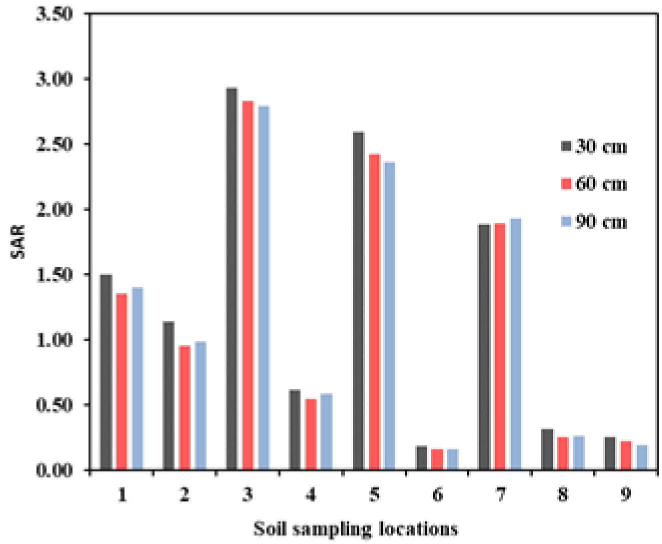

Figure 6. Variations in soil SAR values.

The SAR value at 3rd sampling location was higher than the SAR values of other locations. The SAR value of the 7th and 8th sampling locations varied between 2.00-2.50. The SAR value of the 1st and 2nd locations varied between 1.00-1.50 and the SAR values of the other sampling locations at 30, 60 and 90 cm soil profile varied between 0.20-0.60.

The pH value of the saturated soil paste is generally less than 8.2 and more often near neutrality (Abrol et al., 1980). Soil pH values at 30, 60 and 90 cm soil profile of 9 sampling locations varied between 7.15-7.42 (Figure 7). Soil pH values were within the desired values.

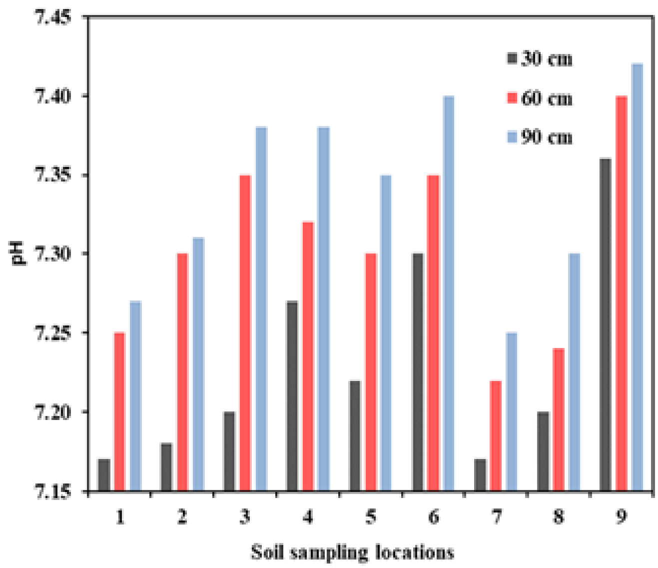

Figure 7. Variations in soil pH values.

Conclusion

The water samples taken from Muamlı and Bedeş drainage canals varied between 2.79-2.97 dS/m and 1.01-4.95 dS/m, respectively. It was concluded that drainage canal effluents created serious salinity problems and ultimately resulted in significant yield losses.

The water samples taken from 6^{th}, 7^{th} and 8^{th} locations in July were found to be unsuitable for irrigation with regard to chlorine contents. On the other hand, in September, these water samples were suitable for use in irrigation because of precipitations. In this case, these waters should not be used in July and water should be supplied from other canals. There were not any problems with regard to chlorine contents in other sampling locations.

Drainage effluents did not pose any problems for irrigation with regard to sodium and sulphate contents. Drainage effluents did not have any problems also with regard to residual sodium carbonate (RSC) and can be used safely. Soil salinity values determined for 9 sampling locations at 30, 60 and 90 cm soil profile revealed that soil salinity was a serious problem for present irrigated lands. The greatest reason of soil salinity was identified as the high salt contents of drainage effluents since these effluents were used in irrigations.

Since paddy was cultivated over irrigated lands of plain, excessive water was used in irrigation and thus high salt content of drainage effluents resulted in 15-25% losses in yields. Precipitations were not sufficient to leach excess salt in soil profile. Low-saline waters should be used for leaching purposes. If there is a chance, farmers are recommended not to use drainage effluents in irrigation. They should search for other quality water resources for irrigation rather than using highly saline drainage effluents.

References

Abrol, I.P., Chhabra, R. & Gupta, R.K. (1980). A fresh look at the diagnostic criteria for sodic soils. In: Int. Symp. on Salt Affected Soils, 142-147.

Abrol, I.P., Yadav, J.S.P., & Massoud, F.I. (1988). *Salt-affected soils and their management* (No. 39). Food & Agriculture Org.

Anonymous. (2004). Turkish environmental legislation. Water pollution control regulation. Retrieved from http://www.resmigazete.gov.tr.

Ayers, R.S. & Westcot, D.W. (1985). *Water quality for agriculture*. FAO irrigation and drainage paper 29 Rev. 1. Rome: Food and Agricultural Organization.

Ayyıldız, M. (1990). *Sulama suyu kalitesi ve tuzluluk problemleri*. Ankara Üniversitesi Ziraat Fakültesi Yayınları, 1196.

Bahçeci, İ., Tarı, A.F. & Dinç, N. (2007). Konya ovası yüzey altı drenaj sistemlerinde taban suyu ve drenaj sularının sulamada kullanılma olanakları. *Selçuk Üniversitesi Ziraat Fakültesi Dergisi*, *21*(3), 7-13.

Cemek, B., Güler, M. & Arslan, H. (2006). Bafra ovası sağ sahil sulama alanındaki tuzluluk dağılımının coğrafi bilgi sistemleri (CBS) kullanılarak belirlenmesi. *Atatürk Üniversitesi Ziraat Fakültesi Dergisi*, *37* (1), 63-72.

Çiftçi, N., Yilmaz, M.A. & Kara, M. (1995). *Konya ovası drenaj şebekelerinde su kalitesinin yıllık değişimi ve sulamada kullanılabilirliği*. V. Kültürteknik (Sulama) Kongresi, Kemer, Antalya.

Eaton, F.M. (1950). Significance of carbonates in irrigation waters. *Soil Science*, 69, 123-133.

Erözel, Z. & Çakmak. B. (1993). Drenaj suyunun sulamada kullanılması. *Topraksu Dergisi*, 2, 2-6.

Fipps, G. (1994). Irrigation water quality standarts and salinity management.

Kanber, R. (1999). *Sulama ders kitabı*. Adana.

McKenzie, R.H. & Woods S.A. (2010). Management of sodic soils in Alberta. Irrigation and farm water division Alberta agriculture and rural development lethbridge.

Özer, N., & Demirel, F.A. (2003). *Şanlıurfa ve Harran ovalarında işletme aşamasında taban suyu ve tuzluluk problemleri*. II. Ulusal Sulama Kongresi Bildirimleri, Aydın, 193-199.

Singh, M. & Dahiya, I.S. (1979). Simultaneous transport of surface salt and water through unsatured soils during infiltration and redistribution. *Soil Science Plant Analysis,* 10, 591-611.

Tüzüner, A. (1990). Toprak ve su analiz laboratuvarı el kitabı.

USA EPA (1994). Water quality standards handbook.

USSL, (1954). US Salinity Laboratory Staff. Diagnosis and improvement of saline and alkali soils. USDA Agricultural Handbook No. 60. Washington, DC: U.S. Government Printing Office.

Wilding, L.P. (1985). Spatial variability: its documentation, accommodation and implication to soil surveys. In: D.R. Nielsen & J. Bouma (Eds.), *Soil spatial variability,* 166-194.

Extended Turkish Abstract
(Genişletilmiş Türkçe Özet)

Bafra Ovasındaki Drenaj Kanallarındaki Suyun Sulamaya Uygunluğunun İncelenmesi

Su, tarımsal üretim artışında en etkili bileşenlerden birisidir. Bu girdinin verimli olabilmesi ihtiyaç oranında kullanılmasıyla mümkündür. Bu nedenle suyun kontrolünün sağlanması için sulama tesislerinin iyi işletilmesi, genel sulama planlarının mutlaka yapılması ve planlı su dağıtımının diğer bir anlatımla su yönetiminin çok iyi uygulaması gerekmektedir. Tarımsal drenaj, taban suyunu bitki gelişimini engellemeyecek düzeye düşürmek ve kök bölgesinde tuz birikimini önlemek için yapılan mühendislik çalışmalarıdır. Sulu tarım uygulamalarında tarımsal drenaj, sulamanın ayrılmaz bir parçası olarak kabul edilmektedir.

Sulama ve drenaj hangi iklim kuşağında olursa olsun üretimde sürekliliği sağlayan ve diğer faktörlerin değerlendirilmesine imkân tanıyan temel uygulamalardır. Drenaj suyunun kimyasal bileşimi, drenaj sistemi, tarımsal faaliyetler, toprağın yapısı, toprağın infiltrasyon hızı, başlangıçtaki toprak tuzluluğu, sulama yöntemleri ve iklim gibi çok sayıda faktöre bağlı olarak değişmektedir. Aynı zamanda sulama suyu kalitesini kontrol eden bu faktörler yardımıyla drenaj suyunun sulamada kullanım olanağı belirlenebilir.

Bu çalışma ile Bafra Ovasında drenaj kanallarındaki suların kalite özelliklerinin yıl içerisindeki değişimlerinin incelemesi, drenaj kanallarının ovadaki tuzluluğun yıkanması üzerine olan etkilerinin belirlenmesi ve değerlendirilmesi amaçlanmıştır.

Çalışma alanı, Samsun Sinop Yolu üzeri Bafra'nın Alaçam sınırına yakın bir kısmında yer alan Muamlı ve Bedeş drenaj kanalları ve civarında gerçekleştirilmiştir. Çalışma alanı olarak belirlenen bu alandan Temmuz ve Eylül aylarında iki sefer olmak üzere ortalama birer km aralıklarla su örnekleri alınmıştır. Toprak örnekleri ise belirtilen drenaj kanallarından pompajla sulanan 9 farklı noktadan alınmıştır. Çalışma alanına ait suların özelliklerinin belirlenmesi amacıyla örnekler üzerinde Elektriksel iletkenlik (EC), pH, Na, Ca, K, Mg, CO_3, HCO_3 ve Cl analizleri yapılmıştır. Toprak örnekleri ise laboratuvar koşullarında gerekli işlemler uygulanıp, toprak suyu süzülerek Na, Ca ve Mg, K, CO_3, HCO_3, SO_4 ve Cl gibi değerler hesaplanarak toplam anyonlar ve katyonlar bulunmuştur. EC, pH, SAR, Sertlik (Alman) gibi değerlerde laboratuvar koşullarında analiz edilmiştir. Toprak örnekleri ise bu drenaj sularının pompajla araziye verildiği ve çeltik yetiştiriciliği yapılan alanlardan, hasat sonrası alınabilmiştir.

Muamlı ve Bedeş drenaj kanallarının sulama suyu olarak kullanımı açısından değerlendirmede EC, SAR, RSC ve diğer iyonların (Ca, Mg, K, Na, Cl vb.) etkileri ile birlikte ağır metallerde incelenmiştir. Muamlı drenaj kanalında temmuz ayında en fazla değişim gösteren parametre potasyum, eylül ayında ise sülfat ve karbonat olmuştur. Bedeş drenaj kanalında ise temmuz ayında en fazla değişim gösteren parametreler sülfat, karbonat, sodyum ve SAR, eylül ayında ise sülfat, sodyum, klor ve SAR olarak tespit edilmiştir.

Temmuz ve eylül aylarındaki Muamlı drenaj kanalları sularının EC değerleri incelendiğinde dönemler arası çok büyük farklılıkların olmadığı görülmektedir. Muamlı drenaj kanalı suyu EC değeri temmuz ayı için 1.79-1.90 dS/m arasında değişmekte iken, eylül ayı için 1.28-1.90 dS/m arasında değişmiştir. Bedeş kanalından alınan su örneklerinde ise dönemler arasında farklılıklar oluştuğu belirlenmiştir. Drenaj kanalı EC değeri temmuz ayı için 0.75-2.49 dS/m, eylül ayı içinse 0.65-3.17 dS/m olarak belirlenmiştir.

SAR değeri açısından her iki drenaj kanalından alınan su örneklerinin az sodyumlu sular sınıfına girdiği ve toprakta zararlı miktarda sodyum birikmeyeceği tespit edilmiştir.

RSC değeri her iki drenaj kanalında da sıfırın altında olduğundan dolayı, arazide bitki yetiştirmeye önemli bir etkisinin olmadığı görülmüştür.

Sodyum değerinin sulama sularında 50-60 ppm değerini geçmemesi istenmektedir. Alınan örneklerden sadece Bedeş kanalında eylül ayında 6. noktada 60 ppm değerini geçtiği görülmüştür. Bunun dışında drenaj suları sodyum açısından bir sorun teşkil etmemektedir.

9 noktada ve 30-60-90 cm derinliklerden alınan toprak numunelerinde tuzluluğun önemli bir sorun olduğu belirlenmiştir. Bunun en önemli sebebi ise pompajla alınarak araziye verilen drenaj kanallarındaki araziyi sulamak için kullanılan sulardaki tuz miktarlarının yüksek olmasından dolayıdır.

Arazilerde çeltik yetiştiriciliği yapıldığından dolayı sulama suyundaki tuz miktarının toprağa olan etkisinden dolayı çeltikteki verim kayıplarının %15-30 arasında olduğu belirlenmiştir. Bu durumda yağmurların toprak yıkama işleminde etkisinin yeterli olmadığı saptanmıştır. Drenaj suları ile yapılan sulamadan kaynaklanan tuzluluk sorununu topraklarda uzaklaştırmak için arazideki drenaj sisteminin varlığını göz önünde bulundurarak, toprağa tuzluluk açısından sorun teşkil etmeyen sulama suları ile tarla kapasitesi üzerinde su verilip toprak yıkaması yapılmalıdır. Eğer drenaj kanalındaki suları kullanmayarak sulama yapma imkânı varsa drenaj sularının kullanımından vazgeçilerek tuzluluk açısından sorun teşkil etmeyen sulama suları ile topraklar sulanmalıdır.

Case Study

Common Diatoms of Phytobenthos in Gediz River Basin

Gediz Nehir Havzasındaki Fitobentozun Yaygın Diyatomeleri

Cüneyt Nadir SOLAK[1], Tolga ÇETİN[2], Yakup KARAASLAN[2], Aydın KALELİ[1], Elif YILMAZ[1], Mustafa DURAN[3], Gürçay KIVANÇ[3], Taner KİMENÇE[2], Şebnem AYNUR KOYUNLUOĞLU[4], Burhan Fuat ÇANKAYA[2], Deniz YILMAZ AŞIK[2]

[1]*Dumlupınar University, Faculty of Arts and Sciences, Department of Biology, Kütahya, Republic of Turkey*
cnsolak@gmail.com, aydinkaleli84@gmail.com, elfyilmaz38@gmail.com
[2]*Ministry of Agriculture and Forestry, General Directorate of Water Management, Ankara, Republic of Turkey*
tolga.cetin@tarimorman.gov.tr, yakup.karaaslan@tarimorman.gov.tr, taner.kimence@tarimorman.gov.tr
burhanfuat.cankaya@tarimorman.gov.tr, yilmazasik.deniz@tarimorman.gov.tr
[3]*Pamukkale University, Faculty of Arts and Sciences, Hydrobiology Laboratory, Kinikli Campus, 20070 Denizli, Republic of Turkey*
mduran@pau.edu.tr, gkakyildiz@pau.edu.tr
[4]*TÜBİTAK MAM, Environment and Cleaner Production Institute, Gebze/KOCAELİ, Republic of Turkey*
sebnem.aynur@tubitak.gov.tr
Received Date: 4.12.2018, Accepted Date: 24.12.2018

Abstract

Diatoms (important representatives of phytobenthos) are ecologically significant quality elements for rivers and lakes according to the EU Water Framework Directive (2000/60/EC). We aimed to investigate common diatoms of Gediz River Basin within the scope of the studies for preparation of Gediz River Basin Management Plan. Samples were collected from epilithon and epipelon substrates of 17 rivers, 2 lakes (Gölcük and Marmara) and 4 dams (Demirköprü, Küçükler, Buldan, Afşar) from November 2017 to April 2018. The samples were boiled with H_2O_2 and HCl for removing the organic matter from frustules. Permanent slides were mounted with Naphrax solution. As a result, 28 taxa were found as common diatoms of Gediz River Basin. Many of the taxa were commonly found also in Turkish rivers and lakes. *Amphora pediculus* (Kützing) Grunow, *Navicula reichardtiana* Lange-Bertalot, *Navicula veneta* Kützing, *Nitzschia dissipata* (Kützing) Rabenhorst and *Nitzschia inconspicua* Grunow were most common diatoms in sampling points. On the other hand, *Navicula erifuga* Lange-Bertalot, *Navicula reichardtiana* Lange-Bertalot and *Nitzschia archibaldii* Lange-Bertalot were rarely found in Turkish rivers and lakes.
Keywords: *Common diatoms, Gediz River Basin, phytobenthos*

Öz

AB Su Çerçeve Direktifine (2000/60/EC) göre; fitobentozun önemli temsilcilerinden olan diatomlar, nehir ve göller için önemli ekolojik kalite göstergelerindendir Gediz Havzası Yönetim Planı hazırlanması çalışmaları kapsamında Gediz Nehir Havzası için yaygın diyatomelerin araştırılmasını amaçladık. Örnekler 17 nehir, 2 göl (Gölcük ve Marmara) ve 4 barajdan (Demirköprü, Küçükler, Buldan, Afşar) Kasım 2017 ve Nisan 2018'de epiliton ve epipelon substratlardan toplanmıştır. Organik maddenin frustullerden uzaklaştırılması için örnekler H_2O_2 ve HCl ile kaynatılmıştır. Daimi preparatlar Naphrax solüsyonu ile hazırlanmıştır. Sonuç olarak, Gediz Nehir Havzasında 28 diyatome taksonu yaygın olarak bulunmuştur. Taksonların pek çoğu Türkiye nehir ve göllerinde yaygın olarak bulunan taksonlardır. *Amphora pediculus* (Kützing) Grunow, *Nitzschia dissipata* (Kützing) Rabenhorst ve *Nitzschia inconspicua* Grunow örnekleme noktalarında tespit edilen en yaygın türler olmuştur. Ancak, *Navicula erifuga* Lange-Bertalot, *Navicula reichardtiana* Lange-Bertalot ve *Nitzschia archibaldii* Lange-Bertalot Türkiye nehir ve gölleri için nadir bulunan türlerdendir.
Anahtar kelimeler: *Yaygın diyatomeler, Gediz Nehir Havzası, fitobentoz*

Introduction

Water Framework Directive (2000/60/EC) (Anonymous, 2000) aims to establish a framework for the protection of rivers, lakes, transitional waters, coastal waters and groundwater. Member States shall ensure that a river basin management plan is produced for each river basin. Establishment of river basin management plans has been accelerated last years in Turkey. Turkey has 25 river basins and for 11 river basins (Konya, Susurluk, Meriç-Ergene, Büyük Menderes, Gediz, Yeşilırmak, Akarçay, Batı Akdeniz, Burdur, Küçük Menderes, Kuzey Ege) preparation of river basin management plans are still on-going.

A river basin management plan shall cover the surface waters ecological status. Ecological status is an expression of the quality of the structure and functioning of aquatic ecosystems associated with surface waters. Phytoplankton, macrophyte and phytobenthos, benthic invertebrates and fish are the biological quality elements for the classification of ecological status (Anonymous, 2000). There are some studies (Demir et al., 2017; Çelekli et al., 2018; Solak et al., 2018a) for identifying the ecological status of water bodies in Turkey within the scope of the river basin based monitoring studies.

Regarding the diatom studies of Gediz River Basin, some works were done in the basin. Karagöl was one of the pioneer works for Turkish inland waters by Güner (1969). Then, Marmara Lake was investigated by Cirik (1983, 1994) and Demirköprü Reservoir was worked by GezerlerŞipal et al. (1999) in the basin. Also, Gürle River was examined by Yurterin & Öztürk (2001) as lotic system. This study aims to investigate the distribution of common benthic diatoms in the Gediz River Basin.

Method

Study Site

Gediz River Basin is located between 38° 04'-39°-13' northern latitudes with 26° 42'-29° 45' eastern longitudes. The main water source of the basin is Gediz River. The Gediz River is 275 km. long and is fed by 17220 km^2 of precipitation area in Western Anatolia. There are very few natural lakes in the basin. The most important natural lake is Marmara. The minimum and maximum elevation of the lake is 73.2-79.2 m and the minimum and maximum volume is 8.5-320 hm^3. There is Gölcük Lake as a natural lake in the basin except Lake Marmara. This lake is a crater lake, 80 ha wide and 10 m deep.

There are 5 dams in the river basin. The larger dam in the basin is Demirköprü Dam with a storage capacity of 1.022 million m^3. A hydroelectric power plant was established to produce energy on the dam. Küçükler Dams are also used for drinking water supply. The other dams are used for irrigation, flood protection and energy production. Demirköprü, Afşar and Buldan Dams are located in Manisa and Küçükler Dam is located in Uşak (Tarım ve Orman Bakanlığı, Su Yönetimi Genel Müdürlüğü, 2018).

Sampling

Samples were collected from 17 rivers, 2 lakes (Gölcük and Marmara) and 4 dams (Demirköprü, Küçükler, Buldan, Afşar) (Table 1) in Gediz River Basin (Figure 1) in November 2017 and April 2018 from 23 sampling points. Epilithic samples were taken by brushing the submerged stones and epipelic samples were taken by using a pipette aspirator from the sediment.

Table 1
The Coordinates of the Sampling Points of the Water Bodies in Gediz River Basin

Stations	Water Bodies	Coordinates	
		X	Y
1	G1-Buldan Reservoir	38° 09' 25.235"	28° 50' 41.002"
2	G2-Demirköprü Reservoir	38° 39' 56.785"	28° 22' 14.717"
3	G3-Marmara Lake	38° 36' 54.525"	28° 00' 47.469"
4	G4-Gölcük Lake	38° 19' 02.038"	28° 01' 30.273"
5	G5-Küçükler Reservoir	38° 52' 21.664"	29° 37' 08.719"
6	G6-Afşar 2 Reservoir	38° 13' 59.251"	28° 35' 50.661"
7	N1-Demirci Stream	38° 47' 51.690"	28° 29' 54.949"
8	N2-Gürdük Stream	39° 03' 13.752"	27° 55' 21.694"
9	N3-Gediz River	38° 40' 55.351"	27° 21' 44.960"
10	N4-Gediz River	38° 36' 06.540"	28° 48' 46.854"
11	N5-Gürlevik Stream	38° 28' 58.543"	27° 49' 59.015"
12	N6-Bahçeler Stream	38° 58' 32.408"	29° 23' 31.106"
13	N7-Diken Stream	38° 45' 12.438"	29° 11' 36.873"
14	N8-Derbent Stream	38° 10' 55.692"	28° 32' 35.872"
15	N9-Selendi Stream	38° 44' 27.451"	28° 51' 59.706"
16	N10-Alaşehir Stream	38° 30' 27.337"	28° 08' 55.644"
17	N11-Gediz River	38° 36' 55.182"	27° 33' 15.366"
18	N12-Nif Stream	38° 34' 15.362"	27° 34' 11.112"
19	N13-Sarıkız Springs	38° 46' 16.611"	27° 39' 49.604"
20	N14-Canburt Stream	38° 39' 07.524"	27° 01' 44.680"
21	N15-Murat Stream	38° 58' 12.143"	29° 42' 53.063"
22	N16-Ağıl Stream	39° 04' 27.436"	28° 40' 20.049"
23	N17-Gürdük Stream	39° 08' 13.548"	28° 00' 24.678"

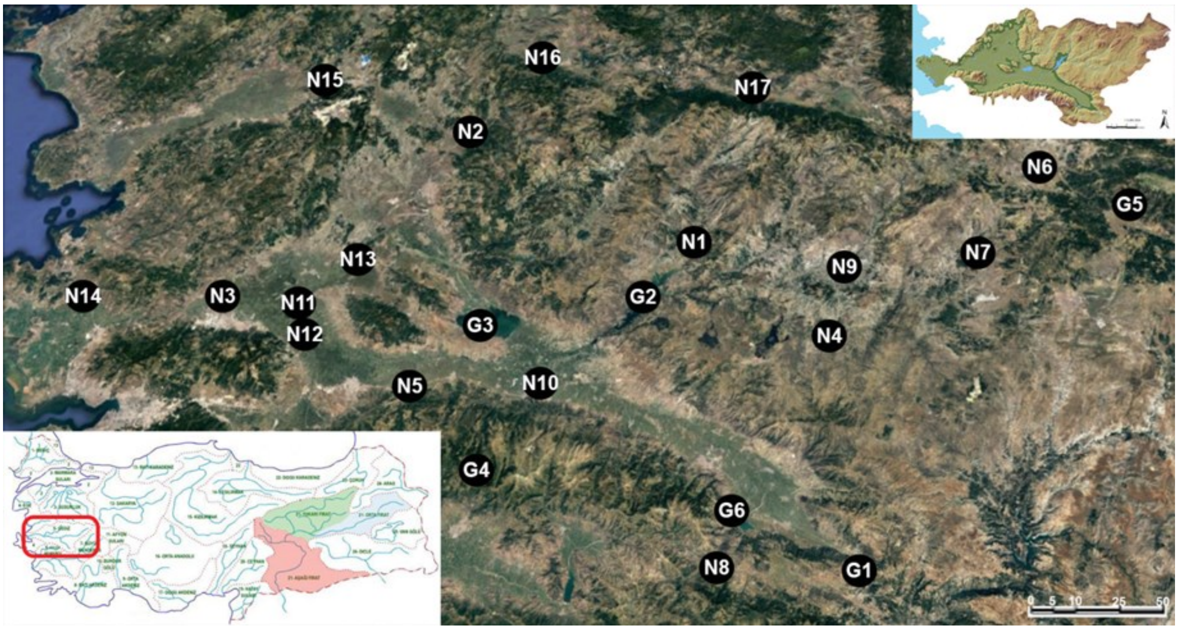

Figure 1. Distribution of sampling points in Gediz River Basin.

Sample Processing, Observation and Identification

Samples were boiled with H_2O_2 and HCl to remove the organic matter from frustules (Swift 1967). After washing three times of diatoms with distilled water, the material was air-dried on cover glasses and mounted with Naphrax solution. Diatoms were observed with a Nikon Ci Light Microscope (LM) in Dumlupınar University, Turkey. The literature used for identification and dimensions (Krammer 2002, Krammer & Lange-Bertalot 1986, 1991, Lange-Bertalot et al. 2017).

Diatom Distribution

Description of the distribution of Turkish diatom flora was made according to Gönülol (2018). The taxa reported from Turkey by Gönülol (2018) which cover 10% of the literature are categorized as "*common*" diatoms, the ones cover less than 10% are noted as "*rare*" diatoms. If a taxon exists in more than 10 stations, it was named as "*common*" in this study.

Results

In this work, common diatoms of Gediz River Basin was evaluated and as a result, totally 28 taxa were commonly found in the sampling stations (Table 2, Figure 2).

***Amphora pediculus* (Kützing) Grunow**
Ref. Hustedt 1930 (p. 343, Fig. 629); Patrick & Reimer 1975 (p. 253, Fig. 16: 9 – 10); Krammer & Lange-Bertalot 1986 (p. 346, Fig. 150: 8 – 13); Levkov 2009 (p. 101, Figs. 55: 31 – 34; 78: 40 – 47); Hofmann *et al.* 2011 (p. 98, Fig. 91: 29 – 33).

***Cocconeis pediculus* Ehrenberg**
Ref. Hustedt 1930 (p. 188, Fig. 259); Patrick & Reimer 1966 (p. 240, Fig. 15: 3 – 4); Krammer & Lange-Bertalot 1991 (p. 88, Fig. 57: 1 – 4); Hofmann *et al.* 2011 (p. 132, Fig. 19: 17 – 19).

***Cyclotella meneghiniana* Kützing**
Ref. Krammer and Lange-Bertalot, 1991 (p. 44, fig. 44: 1 – 10); Håkansson, 2002 (p. 79, figs. 263 – 268); Wojtal and Kwandrans, 2006 (p. 186, fig. 4: 18 – 21, 7: 1 – 13, 9: 1 – 8, 10: 1 – 5); Kiss et al., 2012 (p. 337, fig. 14: A – C); Bey and Ector, 2013 (Vol. 1, p. 30); Cavalcante et al., 2013 (p. 243, fig. 8: A – O); Houk et al., 2010 (p. 16, fig. 143: 1 – 15).

***Cymbella excisa* Kützing**
Ref. Krammer 2002 (p. 26, pl. 8: 1 - 26); Hofmann *et al*. 2011 (p. 150, pl. 77: 23 - 28); Bąk *et al*. 2012 (p. 81, pl. 54).

***Diatoma moniliformis* (Kützing) D.M.Williams**
Ref. Hofmann *et al*. 2011 (p. 174, pl. 2: 11 - 15); Bąk *et al*. 2012 (p. 99, pl. 4).

***Encyonema minutum* (Hilse) D.G.Mann**
Ref. Krammer 1997 (p.53-pl.25:1-19); Hofmann *et al*. 2011 (p. 188, pl. 87: 33 - 40); Bąk *et al*. 2012 (p. 111, pl. 61).

***Epithemia sorex* Kützing**
Ref. Hustedt 1930 (p. 388, Fig. 736); Patrick & Reimer 1975 (p. 188, Fig. 27: 4); Krammer & Lange-Bertalot 1988 (p. 154, Fig. 106: 1 – 13); Hofmann *et al.* 2011 (p. 206, Fig. 121: 1 – 7)

***Gomphonema olivaceum* (Hornemann) Brébisson**
Ref. Hustedt 1930 (p. 378, Fig. 719); Patrick & Reimer 1975 (p. 139, Fig. 8: 13 – 14); Krammer & Lange-Bertalot 1986 (p. 374, Fig. 165: 1 – 8); Hofmann *et al.* 2011 (p. 310, Fig. 95: 1 – 6).

***Gomphonema parvulum* (Kützing) Kützing**
Ref. Hustedt 1930 (p. 372, Fig. 713a); Patrick & Reimer 1975 (p. 122, Fig. 17: 7 – 12); Krammer & Lange-Bertalot 1986 (p. 358, Fig. 154: 1 – 25); Hofmann *et al.* 2011 (p. 312, Fig. 99: 1 – 10).

***Melosira varians* C.Agardh**
Ref. Krammer and Lange-Bertalot, 1991 (p. 7, fig. 4: 1 – 8); Wojtal, 2009 (p. 238, fig. 1: 1 – 4); Bey and Ector, 2013 (Vol. 1, p. 48); Cavalcante et al., 2013 (p. 246, fig. 11: A).

***Navicula capitatoradiata* H.Germain**
Ref. Hofmann *et al*. 2011 (p. 374, pl. 36: 28 - 34); Bąk *et al*. 2012 (p. 215, pl. 31).

***Navicula cryptotenella* Lange-Bertalot**
Ref. Hofmann *et al*. 2011 (p. 378, pl. 32: 1 - 5); Bąk *et al*. 2012 (p. 217, pl. 29).

***Navicula tripunctata* (O.F.Müller) Bory**
Ref. Hustedt 1930 (p. 299, Fig. 514); Patrick & Reimer 1966 (p. 513, Fig. 49: 3); Krammer & Lange-Bertalot 1986 (p. 95, Fig. 27: 1 – 3); Lange-Bertalot 2001 (p. 73, Fig. 1: 1 – 8); Hofmann *et al.* 2011 (p. 403, Fig. 35: 11 – 16).

***Navicula veneta* Kützing**
Ref. Hustedt 1930 (p. 295, Fig. 497a); Patrick & Reimer 1966 (p. 504, Fig. 48: 5); Krammer & Lange-Bertalot 1986 (p. 104, Fig. 32: 1 – 4); Lange-Bertalot 2001 (p. 74, Fig. 14: 23 – 30); Hofmann *et al.* 2011 (p. 406, Fig. 9: 8 – 12).

***Nitzschia archibaldii* Lange-Bertalot**
Ref. Krammer & Lange-Bertalot 1991 (p. 115, pl. 81: 10 – 12), Hofmann et al. 2011 (p. 435, pl. 111: 30 – 34).

***Nitzschia capitellata* Hustedt**
Ref. Krammer & Lange-Bertalot 1991 (p. 88, pl. 62: 1 – 12), Hofmann et al. 2011 (p. 438, pl. 113: 11 – 16).

***Nitzschia dissipata* (Kützing) Rabenhorst**
Ref. Hustedt 1930 (p. 412, Fig. 789); Krammer & Lange-Bertalot 1988 (p. 19, Fig. 11: 1–7); Hofmann *et al.* 2011 (p. 441, Fig. 109: 8–18).

***Nitzschia fonticola* (Grunow) Grunow**
Ref. Hustedt 1930 (p. 415, Fig. 800); Krammer & Lange-Bertalot 1988 (p. 103, Fig. 75: 1–22); Hofmann *et al.* 2011 (p. 259, Fig. 9: 8–12).

***Nitzschia inconspicua* Grunow**
Ref. Krammer & Lange-Bertalot 1991 (p. 95 - pl. 69: 1–13); Hofmann et al. 2011 (p. 446 - pl. 112: 35–40).

***Nitzschia intermedia* Hantzsch**
Ref. Hofmann *et al*. 2011 (p. 449, pl. 107: 1-6); Bąk *et al*. 2012 (p. 251, pl. 72).

***Nitzschia linearis* W.Smith**
Ref. Hustedt 1930 (p. 409, Fig. 784); Krammer & Lange-Bertalot 1988 (p. 69, Fig. 55: 1 – 4); Hofmann *et al.* 2011 (p. 452, Fig. 106: 1 – 3).

***Nitzschia media* Hantzsch**
Ref. Krammer & Lange-Bertalot 1991 (p. 19, pl. 11: 8 – 14), Hofmann *et al.* 2011 (p. 441: 14 – 18).

***Nitzschia palea* (Kützing) W.Smith**
Ref. Hustedt 1930 (p. 416, Fig. 801); Krammer & Lange-Bertalot 1988 (p. 85, Figs 59: 1 – 24; 60: 1 – 6); Hofmann *et al.* 2011 (p. 454, Fig. 111: 1 – 20).

***Tryblionella apiculata* W.Gregory**
Ref. Krammer & Lange-Bertalot 1991 (p. 43, pl. 35: 1 – 6); Hofmann *et al*. 2011 (p. 439, pl. 104: 18 - 22); Bąk *et al*. 2012 (p. 246, pl. 71).

Table 2
Common and Rare Diatoms in Turkey (Gönülol, 2018) and in This Study

		In this study	
	Status in Turkey	Status	Station(s)
Amphora pediculus (Kützing) Grunow	C	C	G2, G3, G4, G5, G6, N1, N2, N4, N5, N7, N8, N9, N10, N11, N12, N15, N16, N17
Cocconeis pediculus Ehrenberg	C	C	N3, N4, N5, N6, N7, N8, N9, N10, N11, N12, N15, N16, N17
Cyclotella meneghiniana Kützing	C	C	G3, G4, G6, N3, N4, N6, N8, N9, N11, N14
Cymbella excisa Kützing	C	C	G1, G2, G3, N2, N3, N5, N7, N8, N9, N11, N12, N15, N17
Diatoma moniliformis (Kützing) D.M.Williams	C	C	N1, N2, N3, N4, N5, N6, N7, N9, N11, N12, N15, N16, N17
Encyonema minutum (Hilse) D.G.Mann	C	C	G1, G3, G6, N3, N5, N6, N8, N9, N10, N11, N15
Epithemia sorex Kützing	C	C	G1, G2, G3, G4, G5, N5, N12, N15, N16, N17
Gomphonema olivaceum (Hornemann) Brébisson	C	C	G1, N1, N2, N3, N4, N5, N6, N7, N8, N9, N11, N12, N15, N16, N17
Gomphonema parvulum (Kützing) Kützing	C	C	G6, N1, N4, N6, N7, N8, N9, N10, N11, N12, N14, N16
Melosira varians C.Agardh	C	C	G2, G5, G6, N1, N3, N4, N6, N8, N9, N11, N14
Navicula capitatoradiata H.Germain	C	C	G1, G2, G3, G5, G6, N2, N4, N5, N7, N8, N9, N11, N12, N16, N17
Navicula cryptotenella Lange-Bertalot	C	C	G4, G5, G6, N1, N2, N4, N5, N7, N9, N10
Navicula erifuga Lange-Bertalot	R	C	G1, G6, N1, N2, N4, N8, N9, N11, N12, N14
Navicula gregaria Donkin	C	C	G6, N1, N2, N3, N4, N5, N7, N8, N9, N10, N11, N12, N16
Navicula novaesiberica Lange-Bertalot	C	C	G1, G2, G6, N2, N3, N4, N5, N8, N9, N10, N11, N12, N15
Navicula reichardtiana Lange-Bertalot	R	C	G1, G2, G3, G6, N1, N2, N4, N5, N7, N8, N9, N10, N11, N15, N16, N17
Navicula tripunctata (O.F.Müller) Bory	C	C	G4, N2, N4, N5, N9, N10, N11, N12, N15, N16, N17
Navicula veneta Kützing	C	C	G1, G2, G3, G6, N1, N2, N3, N4, N6, N8, N9, N10, N11, N12, N15, N16
Nitzschia archibaldii Lange-Bertalot	R	C	G1, G2, G3, G4, N2, N3, N5, N7, N12, N16
Nitzschia capitellata Hustedt	C	C	G6, N1, N2, N3, N4, N6, N8, N9, N10, N11, N12, N13, N14
Nitzschia dissipata (Kützing) Rabenhorst	C	C	G1, G2, G3, N1, N2, N4, N5, N6, N7, N9, N10, N11, N12, N15, N16, N17
Nitzschia fonticola (Grunow) Grunow	C	C	G1, G2, G6, N1, N2, N9, N11, N12, N15, N16, N17
Nitzschia inconspicua Grunow	C	C	G1, G2, G3, G4, G6, N1, N2, N4, N6, N8, N9, N10, N11, N12, N15, N16
Nitzschia intermedia Hantzsch	C	C	G3, G6, N1, N2, N3, N4, N8, N9, N11, N12, N14
Nitzschia linearis W.Smith	C	C	G3, G6, N1, N2, N6, N7, N8, N9, N10, N11, N15, N16
Nitzschia media Hantzsch	C	C	G1, G2, G3, G6, N1, N2, N4, N5, N15, N16, N17
Nitzschia palea (Kützing) W.Smith	C	C	G1, G2, G3, G6, N1, N2, N3, N4, N6, N7, N8, N9, N10, N11, N12, N13, N14, N16
Tryblionella apiculata W.Gregory	C	C	G3, N1, N2, N3, N4, N6, N7, N9, N10, N11, N14, N16, N17

Note. C: common ; R: rare

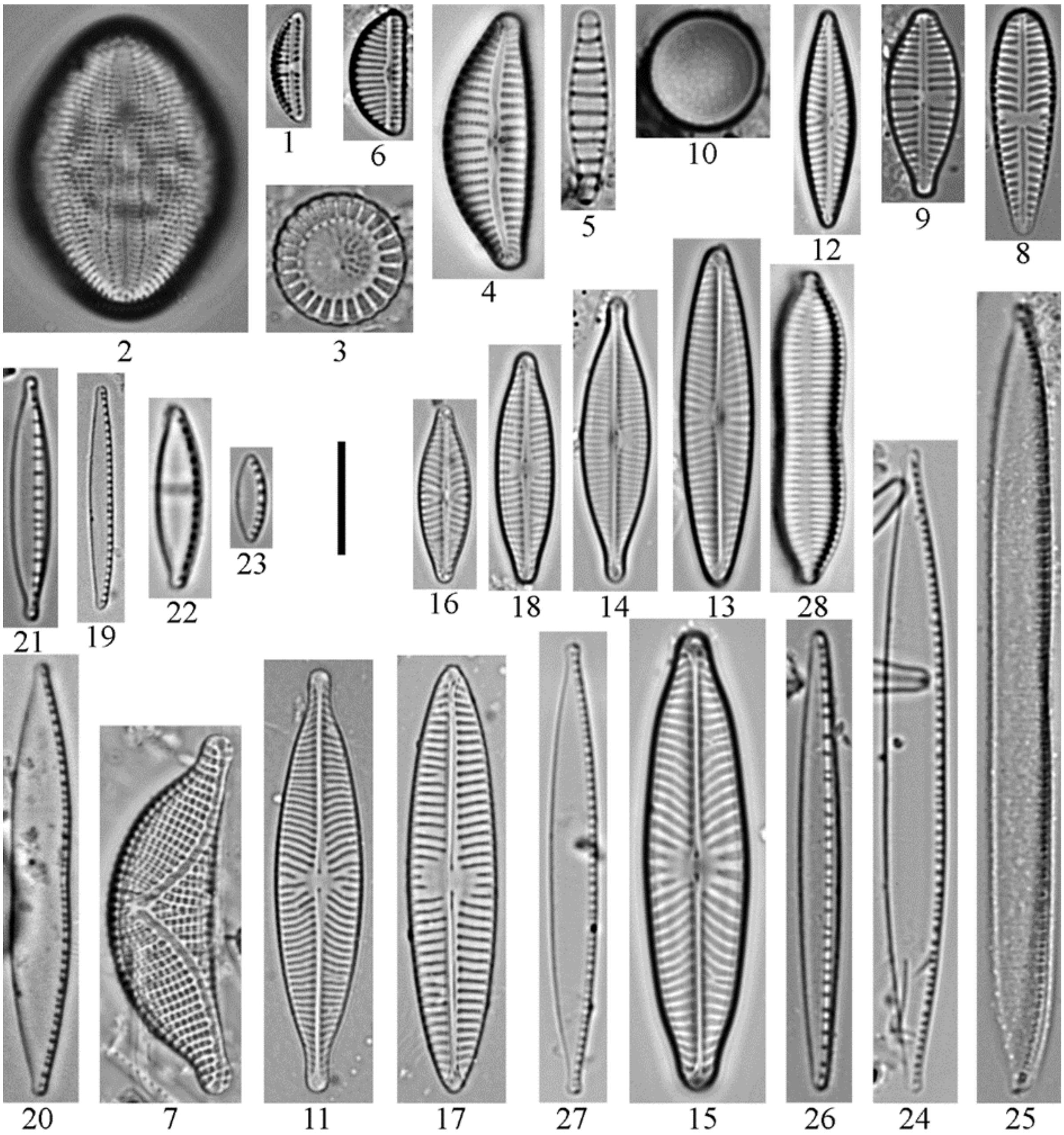

Figure 2. Common Diatoms of Gediz River Basin **1-** *Amphora pediculus;* **2-** *Cocconeis pediculus;* **3-** *Cyclotella meneghiniana;* **4-** *Cymbella excisa;* **5-** *Diatoma moniliformis;* **6-** *Encyonema minutum;* **7-** *Epithemia sorex;* **8-** *Gomphonema olivaceum;* **9-** *G. parvulum;* **10-** *Melosira varians;* **11-** *Navicula capitatoradiata;* **12-** *N. cryptotenella;* **13-** *N. erifuga;* **14-** *N. gregaria;* **15-** *N. novaesiberica;* **16-** *N. reichardtiana;* **17-** *N. tripunctata;* **18-** *N. veneta;* **19-** *Nitzschia archibaldii;* **20-** *N. capitellata*; **21-** *N. dissipata;* **22-** *N. fonticola;* **23-** *N. inconspicua;* **24-** *N. intermedia;* **25-** *N. linearis;* **26-** *N. media;* **27-** *N. palea;* **28-** *Tryblionella apiculata*. Scale bar: 10 µm.

Discussion and Conclusion

Regarding to distribution of the taxa, many of them were also common diatoms in Turkish inland waters (e.g. *Amphora ovalis, C. placentula, C. placentula var. euglypta, Craticula accomoda, Cyclostephanos dubius, Cymbella neocistula* etc.) (Solak and Wojtal, 2012, Solak et al. 2018b). However, *Navicula erifuga, N. reichardtiana,* and *Nitzschia archibaldii* were rarely found in the Turkish waters. Taxonomically, *Navicula erifuga* close to *N.simulata* Manguin. However, the latter is radiate striae. The taxon was found in Uluabat Lake (Karacaoğlu et al. 2004; Dalkıran et al. 2017) and Küçük Menderes river basin (Solak et al. 2018a). *N. reichardtiana* similar to *N. moskalii* Metzeltin et al. and *N. caterva* Hohn & Hellerman. *N. moskalii* is wider outline while, *N. caterva* has a higher stria density. The taxon was found in Asartepe reservoir (Atıcı et al. 2010), Küçük Menderes river basin (Solak et al. 2018a) and Kütahya flowing waters (Solak et al. 2016). *Nitzschia archibaldii* similar to *N. pumila* Hustedt but *N. pumila* is characterised by long protracted ends (Lange-Bertalot et al., 2017). The taxon was found in Küçük Menderes river basin (Solak et al. 2018a). *Cocconeis pediculus* is close to *C. placentula* sensu lato. However, *C. pediculus* has typical striation and structure on RLV. *Cymbella excisa* was described by Lange-Bertalot (2002). The taxa is very common in the inland waters (identified as *C. affinis* according to Krammer & Lange-Bertalot (1986). Generally, *Nitzschia dissipata* is often found together with *N. media.* The latter is longer while, the former has typical axial area.

Ecologically, *A. pediculus* exists in oligo- and β-mesosaprobic habitats. However, its ecology needs to be revised because the taxon is not easy to identify under LM. *C. pediculus* are characteristics of alkaline, lentic and lotic systems with medium to high trophic levels. *C. excisa* is cosmopolitan and abundant in the mountains. *D. moniliformis* tolerates brackish conditions. *E. minutum* is in anthropogenically little affected habitats. *E. sorex* exists in medium to high trophic levels. *G. olivaceum* is in mostly eutrophic and moderately electrolyte-rich and, *G. parvulum* is in oligosaprobic and mesosaprobic habitats. *Navicula capitatoradiata* is in eutrophic to polytrophic running waters and lakes with in weakly brackish waters. *N. cryptotenella* is indicator of β-mesosaprobic and better conditions. *N. erifuga* is in brackish waters. *N. gregaria* is tolerates up to the α-mesosaprobic level. *N. veneta* is dominant in industrial waste water. *Nitzschia amphibia* is tolerant to the α-mesosaprobic zone while, *N. capitellata* is tolerant to polysaprobic level (Lange-Bertalot et al., 2017; Krammer, 2002).

Acknowledgement

This study was supported by the Ministry of Agriculture and Forestry, General Directorate of Water Management. We would like to thank to the Directors and the staff of TÜBİTAK MAM Environment and Cleaner Production Institute, who executed Project on Preparation of Gediz River Basin Management Plan.

References

Anonymous (2000). Directive 2000/60/EC of the European Parliament and the council of 23 October 2000 establishing a framework for community action in the field of water policy. *Official Journal of the European Communities, L327,* 1-72.

Atıcı, T., & Obalı, O. (2010). The diatoms of Asartepe Dam Lake (Ankara), with environmental and some physicochemical properties. *Turk J Bot* 34: 541-548.

Bey, M. Y. & Ector, L. (2013). Atlas des diatomées des cours d'eau de la région Rhône-Alpes. Tome 1. Vincennes, France: Agence Française pour la Biodiversité (in French).

Cavalcante, K. P., Tremarin, P. I. & Ludwig, T. A. V. (2013). Taxonomic studies of centric diatoms (Diatomeae): unusual nanoplanktonic forms and new records for Brazil. Acta Bot Bras 27: 237 - 251.

Çelekli, A., Toudjani, A.A., Lekesiz, H.Ö., Kayhan, & S., Çetin, T. (2018). Bioassessment of ecological status of three Aegean reservoirs based on phytoplankton metrics. *Turkish Journal of Water Science and Management*, *1(2)*, 76-99.

Dalkıran, N., Zünbülgil, B., Karacaoğlu, D & Dere, Ş. (2016). Uluabat gölü epifitik diyatomelerinin uzun dönemdeki değişimleri. *LimnoFish* 2(3): 153-163.

Demir, N., Çetin, T., Gök, C., & Şanal, M. (2017). First biological monitoring in the Akarçay basin according to the Water Framework Directive: phytoplankton and phytobenthos. *Turkish Journal of Water Science and Management*, *1*, 90-107.

Güner, H. (1969). Karagöl'ün makro ve mikro vejetasyonu hakkında ön çalısmalar. – *E. Ü. Fen Fakültesi İlmi Raporlar Serisi No. 66.* İzmir.

Cirik, S. (1983). Marmara Gölü'ndeki (Manisa) Alg Gruplarının Mevsimsel Belirişleri Üzerinde Bir Araştırma. *E.Ü. Fen Fakültesi Dergisi B(I),* 574-587.

Cirik, S. (1994). Marmara Gölü Fitoplanktonu IV. Bacillariophyceae. – *XII. Ulusal Biyoloji Kongre Kitabı,* 315-322. Edirne.

Gezerler-Şipal, U., Balık, S., & Ustaoğlu, M.R. (1999). Demirköprü Baraj Gölünün (Salihli-Manisa) Fitoplanktonu. *II. International Symposium on Aquatic Products,* 199-207. İstanbul-Turkey.

Gönülol, A. (2018). Turkish algae electronic publication. Retrieved from http://turkiyealgleri.omu.edu.tr

Håkansson H. (2002). A compilation and evaluation of species in the general *Stephanodiscus, Cyclostephanos* and *Cyclotella* with a new genus in the family Stephanodiscaceae. *Diatom Res.* 17 (1): 1 – 139.

Hofmann G., Werum M. & Lange-Bertalot H. (2011). Diatomeen im Suβwasser-Benthos von Mitteleuropa. A.R.G. Gantner Verlag K.G., Ruggell.

Hustedt F. (1930). Bacillariophyceae. In: A. Pascher (ed.), Die Susswasser-Flora Mitteleuropas*,* pp. 1 – 669. Fischer, Jena.

Houk, V., Klee, R., & Tanaka, H. (2010). Atlas of freshwater centric diatoms with a brief key and descriptions. Part III. Stephanodiscaceae A: *Cyclotella*, *Tertiarius*, *Discostella*. *Fottea* 10: 1 - 498.

Karacaoğlu, D., Dere Ş., & Dalkıran N. (2004). A taxonomic study on the phytoplankton of Lake Ulubat (Bursa). *Turk J Bot* 28: 473-485.

Kiss, K. T., Klee, R., Ector, L. & Ács, É. (2012). Centric diatoms of large rivers and tributaries in Hungary. Morphology and biogeographic distribution. *Acta Bot Croat* 71: 311 - 363.

Krammer, K. (2002). *Diatoms of Europe, Diatoms of the European Inland waters and comparable habitats*. Cymbella. In: H. Lange-Bertalot (ed.).A.R.G. Gantner Verlag K.G., 584.

Krammer, K. (1997). Die cymbelloiden Diatomeen. Eine Monographie der weltweit bekannten Taxa. Teil 1. Allgemeines und *Encyonema* part. Bibliotheca Diatomologica Vol. 36. 382 pp.

Krammer, K., & Lange-Bertalot, H. (1986). Bacillariophyceae. *1*. Teil: Naviculaceae In: Ettl, H., J. Gerloff, H. Heynig and D. Mollenhauer (eds.). *Süßwasserflora von Mitteleuropa*, 2 (1), 1 – 876.

Krammer, K. & Lange-Bertalot, H. (1991). Bacillariophyceae, 2. Teil: Bacillariaceae, Epithemiaceae, Surirellaceae. *Süßwasserfora von Mitteleuropa* 2 (2), 1 – 596.

Krammer, K., & Lange-Bertalot, H. (1991). Bacillariophyceae 3.Teil: Centrales, Fragilariaceae, Eunotiaceae. *Süßwasserflora von Mitteleuropa,* 2(3), 1 – 576.

Lange-Bertalot, H., Hofmann, G., Werum, M., & Cantonati, M. (2017). Freshwater Benthic Diatoms of Central Europe: Over 800 Common Species Used in Ecological Assessment.. *Koeltz Botanical Books, 942.*

Levkov Z. (2009). *Amphora* sensu lato. In: H. Lange-Bertalot (ed.), *Diatoms of Europe* 5: 1 – 916.

Patrıck R. & Reımer C. W. (1966). The Diatoms of the United States, exclusive of Alaska and Hawaii. 1. Fragilariaceae, Eunotiaceae, Achnanthaceae, Naviculaceae. *Acad. Nat. Sci. Philadelphia Monogr*. 13 (1): 1 – 688.

Patrıck R. & Reımer C. W. (1975). The Diatoms of the United States, States, Exclusive of Alaska and Hawaii. 2 (1). Entomoneidaceae, Cymbellaceae, Gomphonemaceae, Epithemaceae. *Acad. Nat. Sci. Philadelphia Monogr*. 13 (2): 1 – 213.

Solak, C.N., Wojtal, A.Z. (2012). The diatoms in springs and streams of the Türkmen Mountain (Sakarya River Basin), commonly reported from Turkish inland waters. *Polish Botanical Journal 57(2)*, 375-425.

Solak C.N., Kulikovskiy M.S., Kaleli, A., & Gönülol, A. (2016). Rare and new records of diatoms in Turkey from Kütahya flowing waters, *Oceanological and Hydrobiological Studies* 45(4): 564-587.

Solak, C.N., Çetin, T., & Kaleli, A. (2018a). Distribution of benthic diatom (phytobenthos) composition in Küçük Menderes river basin. *Turkish Journal of Water Science and Management*, *1(2)*, 2-35.

Solak, C.N., Kulikovskiy, M., Kiss, T.K., Kaleli, A., Kociolek, J.P., & Ács, É. (2018b). The distribution of centric diatoms in different river catchments in the Anatolian Peninsula, Turkey. *Turkish Journal of Botany 42 (1)*, 100-122.

Swift, E. (1967). Cleaning diatom frustules with ultraviolet radiation and peroxide. *Phycologia 6*: 161-163.

Tarım ve Orman Bakanlığı, Su Yönetimi Genel Müdürlüğü. (2018). *Gediz Nehir Havza Yönetim Planı Hazırlanması Projesi Nihai Raporu*. Ankara.

Wojtal, A. Z. (2009). The diatoms of Kobylanka stream near Kraków (Wyżyna Krakowsko-Częstochowska, S Poland). *Polish Botanical Journal* 54: 129 - 330.

Wojtal, A. Z. & Kwandrans, J. (2006). Diatoms of the Wyżyna Krakowsko Częstochowska Upland (S Poland) – Coscinodiscophyceae (Thalassiosirophycidae). *Polish Botanical Journal* 51: 177 - 207.

Yurterin, N., & Öztürk, M. (2001). Gürle Deresi ve yakın çevresi fitoplanktonları üzerine bir çalışma. *IV. Ulusal Ekoloji ve Çevre Kongresi Kitabı.* Bodrum.

Extended Turkish Abstract
(Genişletilmiş Türkçe Özet)

Gediz Nehir Havzasındaki Fitobentozun Yaygın Diyatomeleri

Avrupa Birliği Su Çerçeve Direktifi; su kaynaklarının korunması, geliştirilmesi ve kalitedeki kötüye gidişin engellenmesi amacıyla yürürlüğe konmuştur. Direktifin ana hedefi su kütlelerinde ekolojik iyi duruma ulaşılabilmesidir. Direktifin uygulanabilmesi için her bir havza için nehir havzası yönetim planlarının oluşturulması gerekmektedir. Türkiye'de bulunan 25 nehir havzasından 11 havza (Konya, Susurluk, Meriç-Ergene, Büyük Menderes, Gediz, Yeşilırmak, Akarçay, Batı Akdeniz, Burdur, Küçük Menderes ve Kuzey Ege) için yönetim planı hazırlanması çalışmaları devam etmektedir. Nehir havzası yönetim planlarının hazırlanması sürecinde havzada bulunan su kütlelerinin ekolojik durumunun ortaya konulması gerekmektedir. Ekolojik durumun ortaya konulması için fitoplankton, makrofit, fitobentoz, bentik makroomurgasızlar ve balık gibi biyolojik kalite bileşenleri nehir havzalarında izlenmektedir.

Gediz Havzası coğrafi bakımdan 38°04'-39°-13' kuzey enlemleri ile 26°42'-29°45' doğu boylamları arasında yer almaktadır. Havzanın temel su kaynağı olan Gediz Nehrine birçok yan dere katıldıktan sonra Manisa ve Menemen Ovalarını sulayarak denize dökülmektedir. 275 km uzunluğunda olan Gediz Nehri Batı Anadolu'da 17.220 km^2'lik bir yağış alanından beslenmektedir. Gediz Havzası'nda doğal göl sayısı yok denecek kadar azdır. Havzada yer alan en önemli doğal göl, Akhisar'ın Marmara beldesi yakınlarındaki Marmara Gölü'dür. Marmara Gölünün minimum ve maksimum kotu 73.2–79.2 m, hacmi 8,5–320 hm^3'tür. Havzada Marmara Gölü'nün dışında doğal göl olarak Gölcük Gölü vardır. Bir krater gölü olan Gölcük Gölü, 80 ha genişliğinde ve 10 m derinliğindedir. Havzada 5 baraj bulunmaktadır. Havzadaki en büyük baraj 1.022 milyon m^3 depolama kapasitesiyle Demirköprü Barajı'dır. Barajın üzerine enerji üretmek üzere HES kurulmuştur. Küçükler Barajları içmesuyu temini için, diğer barajlar sulama, taşkın koruma ve enerji üretimi amaçlı kullanılmaktadır. Demirköprü, Afşar ve Buldan Barajları Manisa'da, Küçükler Barajı ise Uşak'ta yer almaktadır.

AB Su Çerçeve Direktifi kapsamında diyatomeler, fitobentoz biyolojik kalite bileşeninin nehir ve göllerde temsil eden en önemli organizma gruplarındandır. Nehir havzası yönetim planlarının hazırlanması sürecinde yerüstü su kütlelerinde ekolojik durumun ortaya konulması maksadıyla diyatomeler birçok nehir havzasında izlenmektedir. Diyatome örnekleri havzada bulunan 17 nehir (Demirci, Gürdük, Gediz, Gürlevik, Bahçeler, Diken, Derbent, Selendi, Alaşehir, Nif, Sarıkız, Canburt, Murat, Ağıl ve Gürdük akarsuları), 2 göl (Gölcük ve Marmara) ve 4 barajdan (Demirköprü, Küçükler, Buldan, Afşar) Kasım 2017 ve Nisan 2018'de epiliton ve epipelon substratlardan toplanmıştır. Epilitik örnekler nehir yatağında yer alan taşların fırçalanmasıyla, epipelik örnekler ise pipet yardımıyla sedimentten toplanmıştır. Organik maddenin frustullerden uzaklaştırılması maksadıyla örnekler H_2O_2 ve HCl ile kaynatılmıştır. Daimi preparatlar Naphrax solüsyonu ile hazırlanmıştır. Diyatomeler mikroskop yardımıyla incelenmiş ve taksonomik literatüre göre teşhis edilmiştir. Havzada yaygın olarak bulunan taksonların görsel katalogları hazırlanmış ve Türkiye florasındaki durumu ile karşılaştırılmıştır. Tür, literatürde %10 dan fazla yer alıyorsa "*yaygın*", % 10 dan daha azında yer alıyorsa "*az rastlanır*" olarak sınıflandırılmıştır.

Sonuç olarak, Gediz Nehir Havzasında 28 diyatome taksonu yaygın olarak bulunmuştur. Çalışmada tespit edilen taksonların pek çoğu Türkiye nehir ve göllerinde yaygın olarak bulunan taksonlardır. *Amphora pediculus* (Kützing) Grunow, *Nitzschia dissipata* (Kützing) Rabenhorst ve *Nitzschia inconspicua* Grunow örnekleme noktalarında en yaygın tespit edilen türler olmuştur. Ancak, *Navicula erifuga* Lange-Bertalot, *Navicula reichardtiana* Lange-Bertalot ve *Nitzschia archibaldii* Lange-Bertalot Türkiye nehir ve gölleri için nadir bulunan türlerdendir. *Navicula erifuga* ülkemizde Marmara ve Küçük Menderes nehir havzalarında rastlanmıştır. Diğer bir baskın takson *N. reichardtiana* ise Sakarya ve Küçük Menderes nehir havlalarında tespit edilmiştir. Türlerin taksonomik özellikleri dikkate alındığında, *Cocconeis pediculus* ile *C. placentula* birbirine oldukça benzer durumda olup, raphe içermeyen kabuk yapısı (stria yapısı) farklılık göstermektedir. *Cymbella excisa* ise yine yaygın diyatomelerden biridir. Bu tür ilk olarak *C. affinis* olarak tanımlanmıştır. Türlerin ekolojik özellikleri gözönüne alındığında, *Amphora pediculus* temiz sularda bulunur. *Cymbella excisa* az kirli alkalinsularda bulunur. *Diatoma moniliformis* hafif tuzlu suların karakteristik türlerinden birisidir.

*Gomphonema olivaceum*daha ziyade ötrofik ve orta derecede iletkenlik seviyesine sahip sularda bulunur. Diğer yaygın bir tür olan G. parvulum ise ekolojik toleransı geniş türlerden biridir. *Navicula capitatoradiata* daha ziyade kirli sularda yayılış gösterir. *Navicula gregaria* ve *Nitzschia amphibia* kirliliğe nispeten toleranslı türlerden biridir. *Nitschia capitellata* ise çok kirli sulara toleranslı türler arasındadır.

http://waterjournal.tarimorman.gov.tr
e-mail: waterjournal@tarimorman.gov.tr

Beştepe District Alparslan Türkeş Street No: 71 Yenimahalle/ANKARA
+90 (312) 207 50 00 • Fax: +90 (312) 207 51 87